OMEGA OPTICAL

OPTICAL INTERFERENCE FILTERS

For Life Sciences, Machine Vision, Astronomy, Aerospace

CATALOG 2012

www.omegafilters.com

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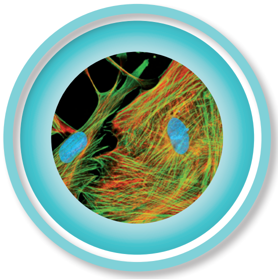

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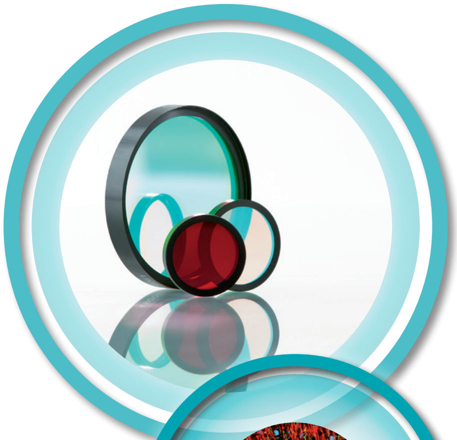
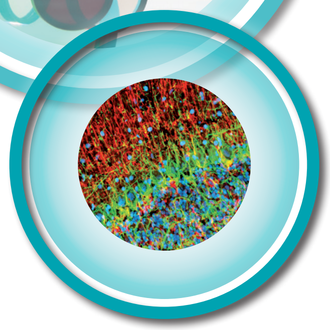




INTRODUCTION

Founded in 1969 by Robert Johnson D. Sc., President and Technical Director, Omega Optical is a leader in photonics, exploring new areas with fresh ideas, an eager team, and the latest technology to produce the best in optical interference filters.

Our products encompass many markets including; Industrial, Commercial, Life Science, Clinical, Astronomy (amateur and professional), as well as Defense and Aerospace. We design and produce the most diverse offering of interference filters in the industry. With over 40 years of experience partnering with researchers and instrument designers to meet their requirements, we have the experience you need. Along with our experience, we bring a corporate commitment to cooperatively explore, understand and ultimately refine solutions. This support originates with our team of Scientists, Engineers, and Industry experts from various scientific fields. We want to be your partner on every project... challenging or simple. Our guiding philosophy has always been to find solutions. If you need us, call. We will be happy to assist. Toll free within the U.S. 866-488-1064 or +1-802-254-2690, sales@omegafilters.com

Our headquarters resides on the Delta Campus in Brattleboro Vermont USA. We encourage you to visit! Our location is in the heart of the New England business community, conveniently located off Interstate 91; a two-hour drive from Albany New York, Boston Massachusetts and Hartford Connecticut.

If you are currently a customer of Omega Optical, thank you!

If you are new to Omega Optical, we look forward to working with you.

This catalog is representative of only a small portion of products we have to offer. The filters within are **stock** (off-the-shelf) or **standard** (common specifications that are typical of industry standards). What's unique, and not represented in this catalog, is our ability to provide custom solutions in a reasonable time frame at typical catalog prices from our component inventory. Contact your sales representative, or use our online tool, buildafilter for your filter solution.

Original Equipment Developers and Manufacturers

Our expertise not only lies in the design and manufacturing of optical coatings, but in the support we can offer you in the development phase of your project. Based on your input, our engineering team will design a cost effective solution for the life cycle of your instrument. We urge you to contact us in the early development stage of your project. Our goal is to assist you in finding a solution that will achieve maximum system efficiency at the lowest cost. We will work closely with you through all steps, proof-of-concept, bread-boarding and prototyping to ensure the development of an optical solution that is consistent with your expectations.

We regard our relationship with you as a long-term partnership. Our support will continue into the production phase of your project.

Research Scientists and Engineers

Whether your lab or research project requires one or several interference filters we invite you to contact our technical sales team. We will assist in finding the right solution whether it is an off-the-shelf product, a semi-custom solution, or a filter custom manufactured to your requirements.

Stock interference filters are available off the shelf at competitive prices.

Semi-custom solutions from our extensive inventory of overstock filters or plate stock configured to your requirements can be processed and shipped to you in 5 business days.

Custom solutions are specifically produced to your requirements. Our sales team will work with you to develop the most cost effective solution for your application.

ABOUT US

Collaboration

In any instrument development project, collaboration is key. Involving Omega early in the system design process results in optimized filter design before the system specifications become fixed. The result is reduced costs and improved performance. For these reasons, free flow of information is critical. To protect trade secrets, we ensure confidentiality throughout the life of the project. As the process unfolds, crucial performance features are identified, proof-of-concept filters are supplied for breadboarding needs, and beta parts are produced meeting the established requirements. With the completion of the development phase, we have demonstrated and provided a manufacturing plan that can be repeatedly executed for your specified production requirements.

System/Instrument Development

From many years of partnership experience with the world's leading OEMs, we have developed a comprehensive understanding of the needs of instrument developers and one of the largest ranges of capabilities and product lines in the thin-film industry. A collaborative engineering approach results in high signal-to-noise, application optimization, responsive prototyping, and rapid time-to-market cycles.

Throughout the design process our engineering and sales staff works with your development team to optimize total system performance within time and budgetary guidelines.

Following "proof-of-concept," breadboarding, and prototyping, a developed design is translated into an optimized manufacturing plan for production. An effective plan takes into account performance specifications, as well as yield maximization, product uniformity, and cost targets. Projections are then used to create delivery schedules to address critical inventory requirements. Review of manufacturing plans on a regular basis results in the integration of continuous improvements for your project.

Partnership

For more than 40 years we have been the filter supplier of choice to hundreds of system manufacturers. This stands as testament to our high technical standards, the ability to produce thousands of parts to identical specifications, and timely delivery. Throughout these long-term partnerships we build your confidence to become your sole supplier. A relationship is based on intimate knowledge of your instrument, and team that leads to increased efficiencies and instrument performance over time.

Custom Solutions

Standard catalog products can provide a high velocity filter solution with reasonable performance and, as a result, can be used for R&D, proof-of-concept, and breadboarding. For optimum system performance and significantly reduced cost we strongly recommend collaborative engineering and customized filter solutions for your specific instrument and application.

Custom Filters Overview

Custom filters are available in wavelengths from 185nm in the UV to 2500nm in the IR. There are a variety of filter types including bandpass, narrowband, wideband, longpass, shortpass, edge, rejection band, beamsplitters, mirrors, and absorption glass. Filters can be manufactured to almost any physical configuration up to 200mm round.

Omega has developed a number of programs to service the custom filter needs and requirements of OEM instrumentation customers and researchers.

Engineering Services Overview

Omega Optical's engineering services are founded on years of technical experience, proprietary software, and custom modified optical measurement instruments. Our engineers play a collaborative role in design teams, assembled to develop prototype instruments, and are experienced at optimizing system performance. For sub-assembly engineering and manufacturing, our design and manufacturing services include interference filters; optical components; and customized rings, holders, and mounting hardware. Further, the R&D group develops both new coatings, and novel applications of optical filters. These applications include biomedical scanning, pathogen detection, and photovoltaic stacks.

ABOUT US

MARKETS & APPLICATIONS

Life Science

Omega Optical is a leading supplier worldwide of custom filters for research, clinical, and point-of-care fluorescence based instruments and applications. We service the world's leading system manufacturers and have developed one of the largest ranges of capabilities and product lines in the industry. Our filters are used extensively in research and clinical applications in the biomedical, biotech, and drug discovery markets, with filters being engineered into the next generation of life science instruments.

Representative Markets include:

- Microplate and MicroArray Readers and Scanners
- DNA Sequencers and Analyzers
- Lab-on-a-Chip and Gene Chip Readers
- Flow Cytometers and Cell Sorters
- Real-time PCR Analyzers
- Gel Documentation Readers
- Scanners and Imaging Systems
- High-Throughput and High-Content Systems
- Genomics and Proteomics Systems
- Fluorescence and Raman Spectroscopes
- Confocal and Multiphoton Microscopes

Fluorescence Microscopy

We have played a pioneering role in the developments of filter technology for fluorescence microscopy and are one of the world's leading suppliers in this market. We offer an extensive product line of dye-specific filter sets for single and multi-label fluorescence microscopy applications and work collaboratively with researchers, labs, and microscope manufacturers on the development of sets for new cutting-edge applications. Filter sets, individual filters, and holders are available for all major microscope manufacturers and models, including Leica, Nikon, Olympus, and Zeiss.

Representative Applications:

- Confocal
- Multiphoton
- Fluorescent Proteins
- Quantum Dots
- M-FISH
- FRET
- Ratio Imaging
- Caged Compounds

Astronomy/Aerospace

We are one of the most respected suppliers of optical filters in the world for space-based and observational astronomy and aerospace projects. We work in collaboration with NASA, JPL, AURA, ESO as well as a variety of international consortia, government agencies, and researchers. We have years of experience designing and manufacturing custom and standard prescription filters to the highest imaging quality standards. Our capabilities include solar observation, photometric sets encompassing Bessel, SDSS, Stromgren, and other filters.

Our filters have helped probe deep space as part of the Hubble Space Telescope's Widefield Planetary Camera and served as the eyes of the Mars Exploration Rovers. See pages 45-47.

Photolithography

Our i-line filters for semiconductor lithographic tools, such as LSI and LCD Steppers, surpass the performance of standard OEM filters. These high performance and environmentally stable bandpass filters resolve monochromatic wavelengths from the high power Metal Halide/Mercury lamps reaching the photomask substrate, so that optimum resolution is achievable. We also supply superior mask-aligner filters for the lithographic process. See page 64.

Color Imaging

Color imaging systems benefit from the use of precision optical filters which control the spectral properties of light and color separation to exacting tolerances. Image capture and reproduction are enhanced when the prime colors of light are precisely separated or trimmed on capture and then recombined before reaching the detector. Image quality and performance improves when system optics deliver precise color separation, high color signal-to-noise, and a wide dynamic range. Omega offers a variety of products to this market, including a patented color enhancement filter, as well as color separation, color correction, and color temperature filters. See pages 16-18. For detailed product specifications, please visit our website.

Raman Spectroscopy

Raman spectroscopy is employed in many applications, including mineralogy, pharmacology, corrosion studies, analysis of semiconductors and catalysts, in situ measurements on biological systems, and single molecule detection. While this technique provides positive material identification of unknown specimens to a degree that is unmatched by other spectroscopies, it also requires rigorous filter specifications for the detection and resolution of narrow bands of light with very low intensity and minimal frequency shift relative to the source. To meet these requirements Omega supplies a variety of products, including laser line filters for "cleaning up" laser signals and high performance edge filters that out-perform holographic notch filters.

Industrial Instrumentation

Industrial instrumentation requires precision filters for control, analysis, and detection. We provide a wide variety of filter solutions for various industrial applications that includes some of the following: Process Control and Monitoring; End Point Determination; Closed Loop and Real-time Instruments; Materials Analysis; and others.

Capabilities

Design

- Thin Film DesignSoftware
- TF CALC
- Optilayer (Leybold)
- FilmStar
- The Essential Macleod
- Optical Raytrace Software
- Mechanical CAD Packages
- Instrumentation Interface Tools such as LabView and Python
- Chemical modeling with Hyperchem

Optical Testing

- Spectrally Resolved Measurements of Transmission, Reflectance, and Absorption:

- Multiple Spectrophotometers
- A Spectrophotometric Mapping System for large substrates
- Attachments for off-axis R&T Measurements including Polarization Effects

- Optical Density Measurements:

- Visible Laser Radiometers
- NIR Laser Radiometers

- Surface Quality (total wavelength distortion, flatness, wedge, roughness, and pinhole density):

- Broadband Achromatic Twyman-Green Interferometer
- Shack-Hartmann Wavefront Tester
- Autocollimator
- Integrating Sphere
- Angle Resolved Scatter Test Set
- Differential Interference Contrast (DIC) Microscopy

- Fiber Optic Testing at Visible and Near Infrared Wavelengths

- Fluorescence and Autofluorescence:

- Spectrofluorimeters
- Multispectral Fluorescence Imaging

- Environmental Testing:

- Low and High Temperature Testing
- Humidity Testing

- Photovoltaic Testing:

- IV/CV Profiles
- Kelvin Probe

Coating Systems

Of our numerous vacuum coating systems, we have the capability for coating a full range of dielectric metal and insulation materials. We achieve physical vapor deposition (PVD) (evaporated coatings) with or without ion assist (IAD) of refractory oxides, as well as thermal evaporation of metal salts and metal alloys. All of our coating systems have been designed to enhance our proprietary coating processes.

Optical Fabrication

- CNC Metal Machining
- Scribe & Break
- Laser Scribing, Welding, and Ablation

Our glass fabrication shop is equipped with a Speedfam grind and polish machine, along with diamond-tooled machines, including CNC drills, shapers, and saws.

Scribe and break

For the best competitive price and reduced lead times, our scribe and break capabilities make use of a unique diamond wheel cutting technology. Scribe and break is a clean process that does not require oils, blocking waxes, or exposure to heat. Additionally there is significantly less handling of the optical coated plate. Fundamentally, we scribe the exact shape of the finished product penetrating through the optical coating on the substrate material. Scribes may be generated with a depth up to 90% of the material thickness greatly reducing a required breaking force. This technology is useful over a wide range of substrate material thicknesses from .05 mm to upwards of 3 mm.

The end results of this capability include consistent outcome, higher yield, increased edge strength, rapid dicing, and a reduction of potential edge chipping and cracks. Cutting accuracy is very high enabling the production of very small finished product. Additionally, the ability to hold very tight tolerances as well as produce more unusual, irregular, or non-standard shapes becomes available.

Optical Assembly

Our fully equipped machine shop has the capability of producing jigs and fixtures along with a variety of custom filter rings, wheels, and holders.

Filter components are cleaned ultrasonically and assembled under laminar flow hoods.

Glass Substrates

We stock nearly all scientific glasses, fused silica, and specialty glass substrates.

ABOUT US

Quality Assurance, Testing, and Certification

The Quality Management System of Omega Optical is modeled on the foundations of the ISO 9001:2000 quality management standards.

The overall company goal is to enhance product quality with standardized and systematic methods.

Filters are tested and evaluated at every stage of production. Spectrometers and optical measuring instruments are tested, controlled, calibrated, and maintained to meet the requirements of our quality system.

- Filter surface durability and quality is in accordance with MIL-C-48497A.
- Environmental durability, testing documentation and certification can be provided at the customer's request.
- When appropriate, we follow sampling procedures defined by MIL-STD-105E.
- REACH, PFOS and RoHS statements can be found on our website.

We have an in-house capability for making automated spatially-resolved spectral measurements of coated plates up to 200 mm in diameter. These high-resolution spatial-spectral measurements quantify in-spec regions of each plate; the result is fed directly to downstream part configuring operations. Plate regions that do not meet spec are inventoried for future sale requiring no additional spectral measurements. This one-stop measurement of the entire plate eliminates redundant measurement and drastically increases efficiency both in plate utilization to meet immediate orders and future data mining operations to locate surplus stock.

"Omega Optical will deliver quality product on time, which meets or exceeds customer expectations, through continual improvement and effective partnerships with suppliers and customers."

Personnel

A technical staff of engineers, industry specialists, scientists, PhDs, and technicians combine years of experience, a broad knowledge base, and a command of the craft involved in producing precision interference filters.

INTELLECTUAL PROPERTY

3RD Millennium filters are available as high-performance commodity filters for OEM instrumentation or for research and lab applications. ▶ **Patent #6,918,673**

SpectraPlus™ for accurate hue, enhanced saturation, increased color signal-to-noise, and a resulting improved Modulation Transfer Function (MTF). SpectraPLUS coating technology is the deposition of multiple layers of thin film coatings on glass and acrylic lenses for the enhancement of viewing color images to address two primary areas. This technology benefits color imaging systems as well as applications where the eye is the detector. The coating allows transmission of the three bands of pure color—red, green, and blue—while blocking those intermediate wavelengths that distort the perception or recording of color. It also eliminates wavelengths in the ultraviolet and near infrared which are detrimental to an accurate color rendering and visual record. ▶ **Patent #5,646,781**

Multispectral stereographic display system ▶ Patent pending

Multispectral stereographic display system with additive and subtractive techniques ▶ Patent pending

ALPHA™ coating technology

Omega Optical's proprietary **ALPHA™ coating technology** for extremely steep slopes resulting in precise edge location, the ability to place transmission and rejection regions exceptionally close together, and high attenuation between the passband and the rejection band. ALPHA coating technology pushes the limits of fluorescence and Raman signal detection, producing extremely high signal-to-noise and brighter images for demanding imaging applications.

Multi-band Technology

Omega Optical holds the 1992 patent on all filters with multiple passband and rejection bands, including dual-band, triple-band, and quad-band filters. These filter types have usefulness in a variety of life science applications for visualizing multiple fluorophores simultaneously, as well as in a range of other applications. ▶ **Patent #5,173,808**

Multispectral Imaging

Omega Optical licenses and owns IP related to high speed systems for multispectral imaging of tissue. Our filters are used within a device, which has many applications in the biomedical optics field.

Organic Photovoltaics

Omega Optical owns IP related to organic photovoltaic devices. Our thin film expertise is leveraged to fabricate these devices, which have significant potential in the alternative energy field.

RESEARCH & DEVELOPMENT

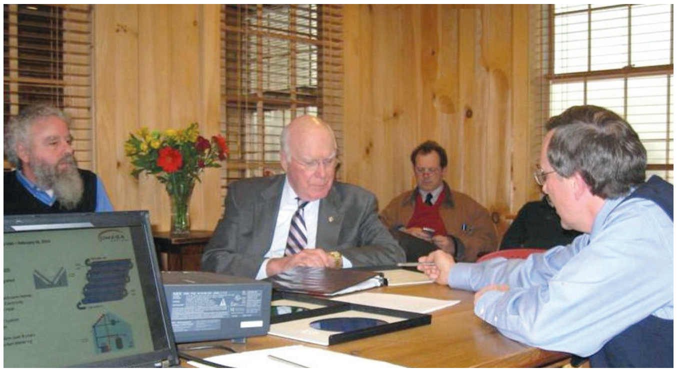
We embrace a vision that goes beyond designing and fabricating state-of-the-art interference filters. Most bandpass, longpass and shortpass interference filters are based on the real component of the refractive index of dielectric materials. At Omega Optical, our R&D team is developing novel thin films where the refractive index has both a real and a complex component.

Examples include semiconductors (such as p-type organics, & n-type organics), and transparent conductive oxides (such as indium-tin-oxide, & aluminum-zinc-oxide). The complex component of the index of these materials can lead to absorption and/or reflectance in specific spectral bands. In addition, we are depositing dielectric stacks on unusual substrates, such as the tips of optical fibers. Our team includes expertise in optical sciences, physics, chemistry, materials science, electrical engineering, mechanical engineering, bioengineering, and software (3 PhDs, 1 MS, and 3 undergraduate degrees). We focus on leveraging our expertise to create products that rely on advanced thin films. Currently, we are addressing two key areas: solar conversion and multispectral scanning.

Omega Optical's Solar Conversion program employs organic thin film absorbers, and electrodes composed of transparent conductive oxides. Our solar goal centers on creating a solar cell prototype enabling significant reductions in module cost and significant increases in module efficiency, leading to acceptable payback times. This objective will be addressed by integrating photovoltaic (PV) and/or photothermal (PT) collection mechanisms while avoiding both scarce and toxic materials. The potential of low cost organic PV materials has not been widely realized because of low efficiency relating to electronic mobility and excitonic diffusion lengths. We believe that organic thin film deposition parameters can be adjusted to optimize these parameters and maximize PV efficiency. Further, organic materials can be configured to harvest multiple spectral bands. We plan to separate these bands via cost-effective spectral splitting for efficient collection by the appropriate material. Ultimately, we plan to integrate our designs with residential and commercial building materials. Targeted products include semitransparent solar windows.

This effort has been co-funded by Omega Optical Inc. and the United States Department of Energy.

Omega's Multispectral scanning program project integrates interference filters, fiber Bragg gratings, and optical fibers. This fiber based design enables high speed spectral management, providing medical diagnoses in real-time. Our biomedical goal centers on developing a high-speed fiber optic based optical spectrum analyzer (OSA) that can enable real time multispectral imaging of cancer at the cellular level. Existing technologies have not combined sufficient spatial, spectral, and temporal resolution in one instrument. Standard spectrometer acquisition speeds are not fast enough to generate multispectral data at rates that avoid spatial impairments due to the movements of living biological samples. The central innovation in this effort is that spectra can be acquired for each pixel in a confocal spatial scan by using our



Left to Right: Dr. Robert Johnson – President and Technical Director - Omega Optical; Patrick Leahy - United States Senator, Vermont; Dr. Gary Carver - Director of R&D - Omega Optical.

fast fiber based spectrometer. This project leverages several of our interference filter designs deployed in the fluorescence market since the last 1980's.

Ultimately, biomedical researchers will use this new technology to catalog extensive libraries of multispectral images showing tumor angiogenesis and subsequent metastases. These enhanced libraries will lead to several applications in pathology labs, oncology labs, and clinics. Clinicians will use the technology to take optical biopsies, perform treatments, and monitor long-term results. Patients will have access to real-time diagnosis and treatment. Surgeons will be able to optimize surgical margins, extending the lives of many cancer victims. Targeted products include disease-specific fiber cassettes for use in customized confocal scanning systems.

This project is funded by a Phase II SBIR grant from the National Cancer Institute within the National Institutes of Health in Bethesda Maryland USA.

Technical Outgrowths

The above projects are generating results that are finding additional applications including customized transparent conductive oxides, and thin film spectral blocking layers with low wavefront distortion. We also see potential in applications in such as food & water testing, pharmaceutical product screening, multispectral microscopy, and flow cytometry. Further, we have developed a suite of optical testing capabilities that are available on a consulting basis.

Optical solutions can be employed in a multitude of applications from creating alternative energy solutions to new methods for treating cancer. We encourage you to inquire regarding other novel optical methods that will improve the quality of life throughout the world.

- Involved in the design, fabrication, or production of optics or optical devices?
- Teaching or learning about photonics?
- Learn principles of photonics and how the interaction of light with matter plays a role in our everyday lives.
- Get a head-start on the exciting careers of tomorrow.
- Hands-on labs examine a wide variety of topics within photonics.
- One Photonics Kit accommodates 6 small groups.

Photonics now and in the future begins with the educational systems of our society.

THE OMEGA OPTICAL PHOTONICS KIT – TEACH PHOTONICS!

- **For Science Educators –** Help students to explore the environment around them, discovering the principles on the interactions of light and matter and how to manipulate these interactions.
- **For Professionals –** Finding workers with a fundamental understanding of optical principles is a challenge. The need for cost-effective employee training and education that delivers real-time benefits is a priority as organizations continuously adapt to changing marketplaces, and external competition.

Our Photonics Teaching kit includes 12 lab activities based on various topics within the field of photonics including solar cells, reflection, refraction, wave interference, LEDs, light detection, complementary colors, fluorescence, and phosphorescence.

The comprehensive labs are organized and supported with all required hardware for the following:

- wave/particle duality of light
- interactions of light and matter including scattering, reflection, refraction, fluorescence and phosphorescence
- relationship between the electronic structure of an atom or molecule and its emission and absorption spectra
- how light can be used to encode information by changing intensity, spectral characteristics or polarization
- how information about the structure of a molecule can be elucidated using spectroscopy
- principles behind optical computing
- human and animal perception of color
- principles behind the operation of LEDs, solar cells, and fiber optic cables are explored

DESCRIPTIONS & NOMENCLATURE

Bandpass Filters

555XX30

CWL (center wavelength) Filter Design FWHM/Bandwidth

3RD550-580

Cut-on Cut-off

Note: Full Width Half Max (FWHM) is defined by the region of the passband where the transmission of the filter is 50% of the maximum transmission.

Filter Design – Our nomenclature and descriptors define the performance characteristics of filter designs.

- **BP – Bandpass filter**: Bandpass filters transmit light within a defined spectral band. Coating designs range from 2 to 6 cavities.
- **QM – QuantaMAX™**: Surface coated, single substrate designs provide steep edges, very high transmission and minimal registration shift.
- **3RD – 3RD Millennium**: Filters are manufactured using proprietary ALPHA coating technology and Omega's patented, hermetic assembly, and defined by the critical cut-on and cut-off requirement.
- **AF – ALPHA Filter**: Alpha filter designs are manufactured using Omega's proprietary technology resulting in extremely steep edges, precise edge placement, and theoretical attenuation >OD10. Defined by the critical cut-on and cut-off requirement.
- **DF – Discriminating Filter**: These filter designs have 6 or more interfering cavities, resulting in a rectangular bandpass shape, very steep edges, and very deep blocking up to optical density (OD) 6 outside the passband.
- **WB – Wideband Filter**: Wideband filters are 4 & 5 cavity designs with FWHM greater than 30nm, up to several hundred nanometers.
- **NB – Narrowband**: Narrowband filters are 2-cavity designs with FWHM typically between 0.2 and 8nm.

Dichroic Filters

505DRLP

Cut-on Filter Design

675DCSPXR

Cut-off Filter Design

Note: Cut-on or cut-off wavelength is defined as the wavelength at which the dichroic is at 50% of its maximum transmission.

Filter Design – Dichroics are filters that highly reflect one specified spectral region while optimally transmitting another. These filters are often used at non-normal angles of incidence, typically 45 degrees.

- **DC – Dichroic**: These filters provide wide regions of both transmission and reflection, exhibiting a high degree of polarization along with a somewhat shallow transition slope.
- **DR – Dichroic Reflector**: These designs provide a steeper slope than typical DC filters, low polarization, a wide range of transmission and a limited region of reflection.
- **DCXR – Dichroic Extended Reflector**: A design that provides extended reflection regions.
- **DCSP / DCLP / DRSP / DRLP**: These designations dictate those portions of the spectrum that will be transmitted and reflected. The "SP" (shortpass) nomenclature means the filter will be transmitting wavelengths below the defined cut-off region. The "LP" (longpass) nomenclature defines the region of transmission as wavelengths above the defined cut-on region.

Longpass & Shortpass Filters

515ALP

Cut-on Filter Design

680ASP

Cut-off Filter Design

3RD650LP

Filter Design Cut-on

Note: Cut-on or cut-off wavelength is defined as the wavelength at which the filter is at 50% of its maximum transmission.

- **LP – Longpass**: These filters transmit wavelengths longer than the cut-on and reflect a range of wavelengths shorter than the cut-on.
- **SP – Shortpass**: These filters transmit wavelengths shorter than the cut-off and reflect a range of wavelengths longer than the cut-off.

Multi-band Filters

- **DB – Dual Band**: Filters are designed to have two passbands and two rejection bands.
- **TB – Triple Band**: Filters are designed to have three passbands and three rejection bands.
- **QB – Quad Band**: Filters are designed to have four passbands and four rejection bands.

Filter Product Line Codes

XA – Analytical Filters
XB – Bandpass Filters
XC – Microscope Filter Holders
XCC – Clinical Chemistry
XCY – Flow Cytometry Filters
XF – Fluorescence Filters
XL – Laser Line Filters (not blocked)
XLD – Laser Diode Clean-up
XLK – Laser Line Filters (fully blocked)
XLL – Laser Line Filters
XMV – Machine Vision
XND – Neutral Density Filters
XRLP – Raman Longpass Filters
XUV – UV Filters

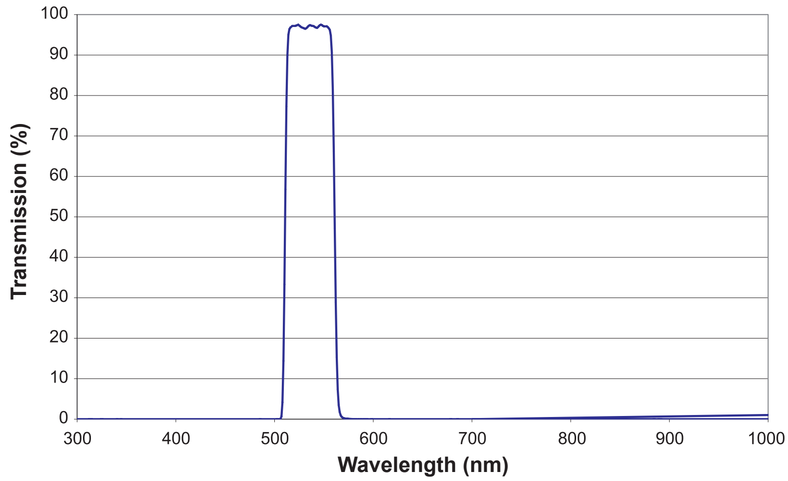
QuantaMAX™ – for high performance interference filters

Outstanding spectral characteristics on a wide variety of substrate materials utilizing our state-of-the-art deposition technology, *Dual Magnetron Reactive Sputtering (DMRS).*

Transmission

For today's most sensitive instruments, **QuantaMAX™ optical coatings** provide exceptional throughput. As seen in Figure 1, a standard 510-560 interference filter achieves transmission in excess of 97%. Combined with deep out of band attenuation, **QuantaMAX™ optical coatings** make every photon count.

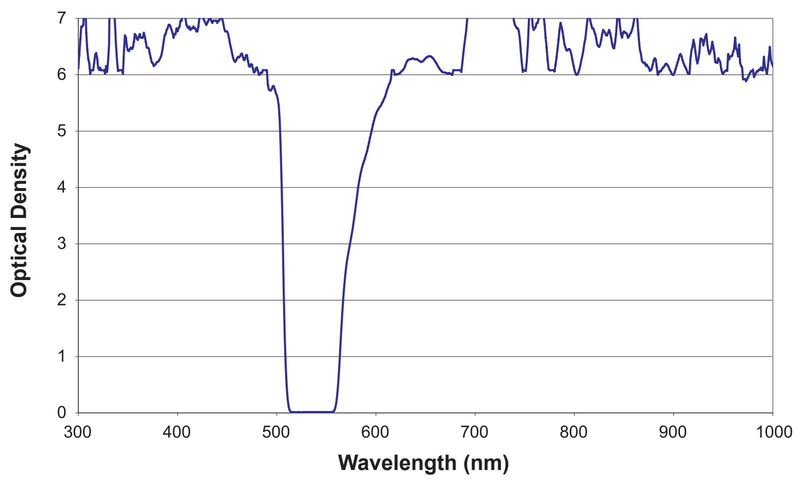
Figure 1 – *actual performance* **Transmission of a standard 510-560 interference filter**



Optical Density

For many applications, the out of band blocking at the detector is as important as the overall transmission. Figure 2 shows the out of band blocking from 300-1000nm and the optical density average of > 6.0. A filter with these characteristics operating in a system with an ideal light source and detector could be expected to have a signal/noise ratio of exceeding 10,000:1, while collecting all available signal.

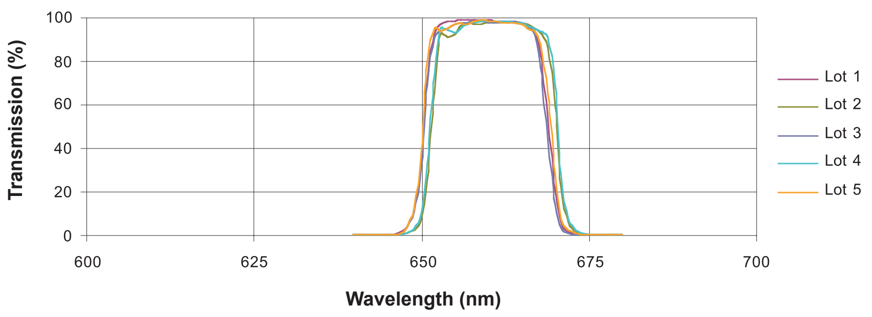
Figure 2 – *actual performance* **Optical Density of a standard 510-560 interference filter**



Lot to Lot Reproducibility

With the *Dual Magnetron Reactive Sputtering* (DMRS) process, **QuantaMAX™ optical coatings** employ the latest methods in optical thin-film design and deposition control. Utilizing the DMRS technology we achieve very precise individual layer thickness, along with forward and backward "proof-reading" of layer execution, leading to a high degree of predictability and reproducibility lot-to-lot. As depicted in Figure 3, the edge of the 650-670 bandpass filter varies only 1 nm in either the cut-on or cut-off edges across a sampling of 5 individual deposition lots.

Figure 3 – *actual performance* **Lot to Lot Reproducibility**



Minimized Transmission Band Distortion

The ability to precisely deposit a layer of coating material of optimized optical thicknesses in a stable and highly reproducible manner throughout the deposition cycle provides excellent transmission characteristics with minimal pass-band rippling. Figure 4 and 5 show the typical performance of long-pass and short-pass interference filters.

Figure 4 – *actual performance* **Long Pass Interference Filter**

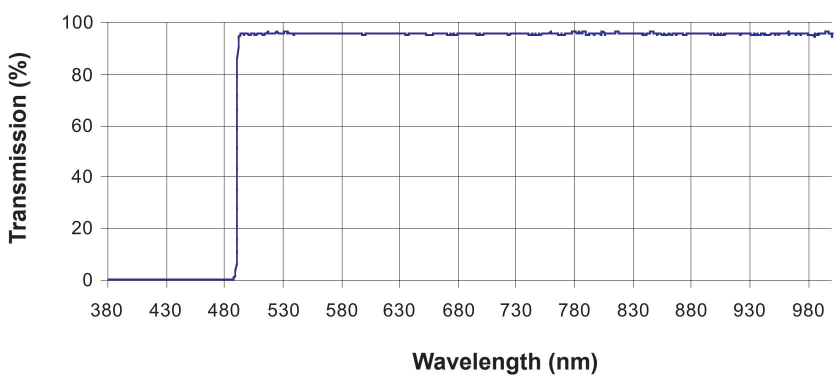
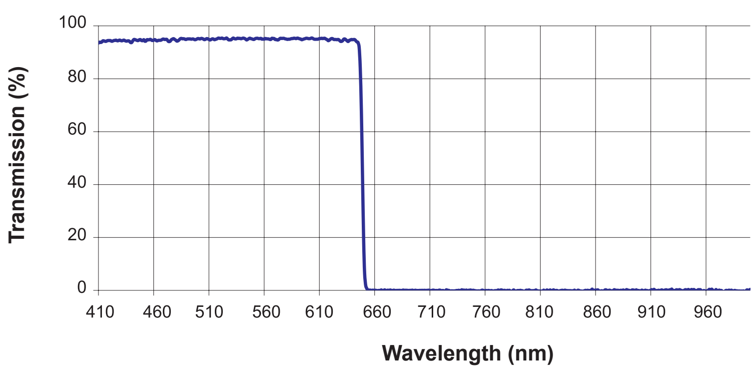


Figure 5 – *actual performance* **Short Pass IR Filter**



COATING TECHNOLOGY

Viewing Enhancement Coatings

◗ **SpectraPlus™** for accurate hue, enhanced saturation, increased color signal-to-noise, and a resulting improved Modulation Transfer Function (MTF). SpectraPLUS coating technology is the deposition of multiple layers of thin film coatings on glass and acrylic lenses for the enhancement of viewing color images to address two primary areas. This technology benefits color imaging systems as well as applications where the eye is the detector. The coating allows transmission of the three bands of pure color—red, green, and blue—while blocking those intermediate wavelengths that distort the perception or recording of color. It also eliminates wavelengths in the ultraviolet and near infrared which are detrimental to an accurate color rendering and visual record.

Two of the more recent and unique technical capabilities developed at Omega have been employed in developing these products. They offer the ability to deposit complex coatings on curved surfaces with control of the thickness distribution over the full usable aperture of the curved optic that makes these features possible. The control of thickness can be either to create uniform thickness where the normal distribution is thinner away from the center, or it can be applied and adjusted to create a thickening coating profile toward the edge to compensate for viewed angular effects that would cause band shifting.

Both of these product developments open many possibilities for new areas of optical device improvement and development.

Photo courtesy of Leybold Optics. Syrus Pro 1510 LION Assisted Electron Beam Custom Opthalmic Coater. Our engineers have worked closely with Leybold Optics of Germany to refine the performance of this large coating tool for the precise deposition of complex multi-layers for Image Enhancement coatings under the SpectraPlus brand.

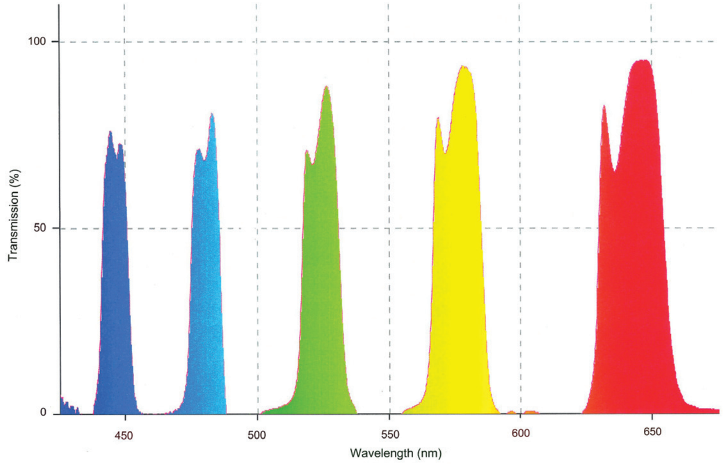
Other enhancements can be integrated into viewing systems. Coatings such as photochromics, or anti-scratch, or hydophobic can be added to produce the highest technology, and performing eyewear world-wide. Applications where these coatings can make the difference between success and failure exist everywhere that excellent vision is a benefit. Typical of these would be dentistry, surgery, sports, high speed maneuvering and viewing in poorly lite situation.

Omega Optical is prepared and anxious to work closely to refine this product line to bring your offer to be the last considered.

SpectraPLUS is protected by U.S. patent #5,646,781.

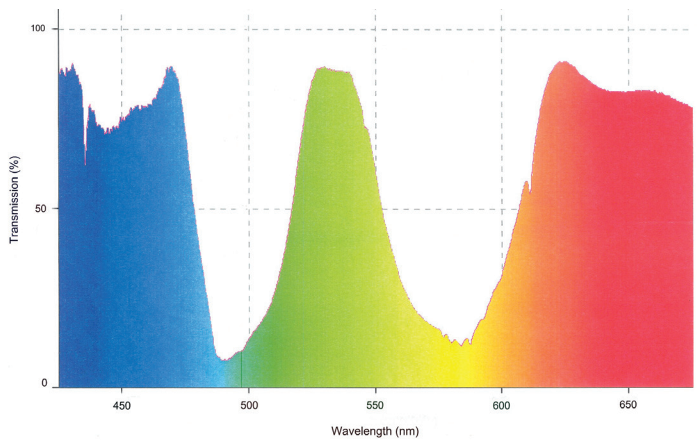
◗ **Depth Defining®** series is a totally new approach to displaying and viewing an image with an X and Y impression as well as a clear Z element. The ultra-complex spectral function divides the visible into two visually identical white mixtures which are mutually exclusive.

The left and right viewing eye see distinct images that have been projected spatially or temporally independent. The result is an image with depth that the viewer can experience with clarity.



◗ **ColorMAX™** series is intended for spectral refinement with the intended purpose of improving color rendition through saturation and hue. Curved lenses are coated with a complex multi-layer coating that removes harmful UV rays, as well as IR. These coatings further eliminate the colors of light that stimulate multiple cones that result in color confusion. The final product is eyewear that forces all colors to explode from their background.

We offer two ColorMAX filters with SpectraPLUS coatings; XB29 is optimized for digital imaging sensors and XB30 is optimized for the human eye and film. All filters are finished to the highest imaging quality standards and are available in stock and custom sizes.



◗ **XB29 for Digital Imaging Systems and CCD based cameras** blocks the crossover regions between blue/green and green/red centered at 490nm and 600nm respectively. To prevent IR saturation of silicon-based sensors, the coating provides a high degree of attenuation in the near infrared region, from 750nm to 1100nm. XB29 also offers complete attenuation of ultraviolet A and B, and deep blue up to 430nm.

For Digital Imaging Systems:

- Commercial Printing Industry: Pre-press Scanners
- Machine Vision Industry: Camera and Lens Systems
- Office and Home Small Equipment Industry: Desktop Scanners, Color Copiers, Digital Copiers.
- Photography/Video/Film Industry: Video & Digital Cameras and Lenses, Photo Scanners
- Remote Sensing: Camera Systems

◗ **XB29 for Eye and Film** is optimized for applications where the human eye or photographic film is the detector. Color imaging is enhanced with increased saturation, accurate hue, and improved contrast and resolution. This version of the SpectraPLUS filter has two stop band regions centered at 490nm and 580nm for blocking the prime color "crossover" wavelengths between blue/green and green/red in the visible spectrum. The XB30 offers high attenuation of ultraviolet A & B. It also attenuates the near infrared in a band centered at 725nm

For Human Eye and Photographic Film Detection:

- Sports Eyewear Industry: Sunglasses, Ski Goggles, Active Sports Glasses
- Lighting Industry: Medical and Dental Lights, Bulb and Reflector coatings
- Photography/Video/Film Industry: Camera Lens, Video, Film and Slide Projectors, Color and Black&White Film Printers, Enlarger Lens
- Sports Optics Industry: Binoculars and spotting scopes, Rifle Scopes

All sensors - human eye, film, and electro-optical - have limitations in how they "see" and record color. Their receptors significantly overlap, as do the wavelengths for the three prime colors of light: red, green, and blue. A photon of light from within this overlap region can leave an incorrect signal on the receptor so that a green photon, for example, can be perceived or recorded as blue or red.

COATING TECHNOLOGY

Transparent Conductive Oxides Overview

Transparent Conductive Oxides (TCOs) are a special class of materials that exhibit both transparency and electronic conductivity simultaneously. These materials have widespread applications in flat-panel displays, thin film photovoltaics, low-e windows, and flexible electronics. The requirements of the these materials are not just limited to transparency and conductivity but also include work function, processing and patterning requirements, morphology, long term stability, lower cost and abundance of materials involved. Spectral edges can be generated with the intrinsic properties of one layer of TCOs. This happens with materials like Indium Tin Oxide (ITO) and Aluminum Zinc Oxide (AZO) that have much stronger k values in one spectral band than another band.

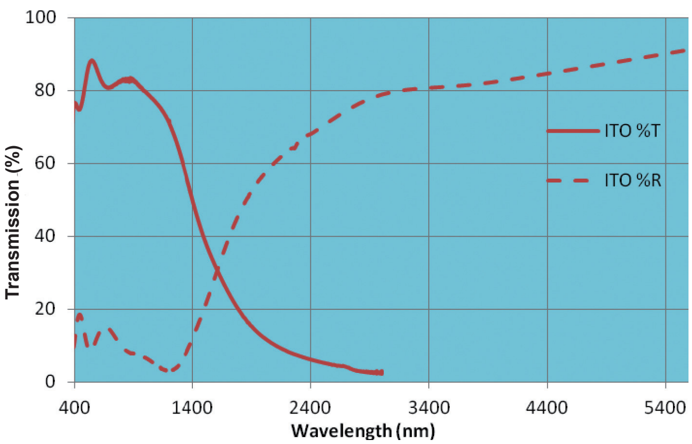


Figure X: Typical ITO Spectral Curve

Curve shows the intrinsic characteristic of ITO to transmit in the visible and reflect like a metal in the IR region. The cross-over frequency (near the plasma frequency) can be moved with changes in deposition parameters.

Description

Currently, ITO is far superior in performance compared to other TCOs and many efforts are being made worldwide to find suitable alternatives. ITO intrinsically has high transparency in the visible and high reflectance in the infrared region. It is commonly used in LCDs and thin film photovoltaic devices. Characteristics of these materials can be widely altered with making changes in deposition parameters. These materials can be integrated with dielectrics to provide wide band IR blocking with thinner layers and low wave-front distortion.

Types

Addressing the wide concern about scarcity and high cost of Indium, Omega is also investigating several other Indium free TCOs, namely,

- Aluminum doped Zinc Oxide
- Fluorine doped Tin Oxide
- Zinc Tin Oxide
- Nickel Oxide and other combinations.

Documentation: Spectrophotometric trace of the attenuation, cut-on, and transmission regions provided. Electronic characteristics such as work function, resistivity and surface roughness are provided upon request.

Specifications

Average Transmission	> 80 % in the visible
Reflectance	High in the IR region
Temperature of Measured Performance	20°C
Operating Temperature Range	-60°C to + 80°C
Humidity Resistance	Per Mil-STD-810E, Method 507.3 Procedure I
Coating Substrates	Optical quality glass
Surface Quality	80/50 scratch/dig per Mil-O-13830A
Sheet Resistance	5-1000 ohms/sq
Surface Roughness	Compatible with the Application
Sizes	Custom dimensions
Barrier Layer	Silicon Dioxide
Process	Ion Assisted Magnetron Sputtering
Work Function	Variable over 4-6eV

In addition to standard specifications, we also produce customized TCO coatings on various kinds of surfaces for many applications.

Organic Semiconductor Overview

Organic materials have been used as standard pigments for over 100 years in dyes, inks, food colors and many plastics. One class of organic materials, aromatic hydrocarbons, are known for their stability, insolubility in water and reduces tendency to migrate into other materials. These compounds also exhibit semiconductive properties. Spectral edges can also be generated with the intrinsic properties of organic semiconductors. This is achieved with materials like Copper Phthalocyanine (CuPc) that have a strong k peak in the visible region caused by the so-called Q-band.

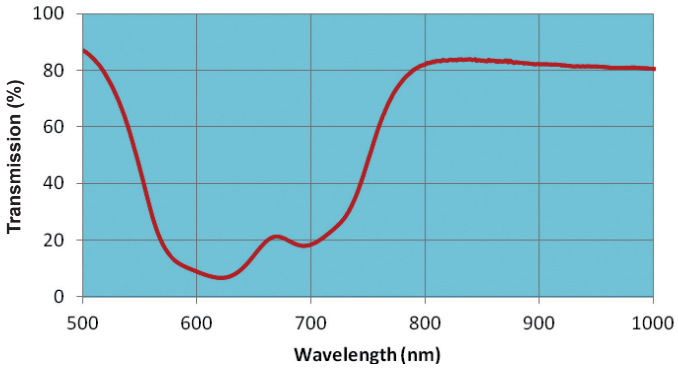


Figure Y: Copper Phthalocyanine Transmission
Typical transmission of CuPc that has significant absorption peak in visible and transmits in IR region.

Description

Organic materials are commonly used in OLEDs, Organic Photovoltaic Devices and Organic FETs. Research is being done worldwide to make these devices commercially available. These materials have significant absorption peaks in the visible and have high transmission in the infrared region. As a result, they can be integrated with other materials to provide blocking with thin layers in optical filters. Other forms of metal-phthalocyanines and perylene derivatives have absorption peaks in different regions of UV, Visible and NIR regions.

Specifications

Blocking	100-150nm wide peaks in visible region
Average Transmission	> 80 % in the IR region
Temperature of Measured Performance	20°C
Operating Temperature Range	-60°C to + 80°C
Humidity Resistance	Per Mil-STD-810E, Method 507.3 Procedure I
Coating Substrates	Optical quality glass
Surface Quality	80/50 scratch/dig per Mil-O-13830A

COATING TECHNOLOGY

◗ ALPHA coating technology

ALPHA coating technology is the culmination of Omega's ongoing research and development regarding filter design and deposition techniques. Employing a proprietary method of controlling the coating process, this technology yields filters with exceptionally high signal-to-noise, as well as, steep transition slopes suitable for the most demanding applications. With ALPHA coating technology , optical systems achieve the highest level of spectral discrimination – images are brighter, contrast is enhanced and instruments perform to the limits of detection. Whenever an optical design demands the utmost level of precision, ALPHA coating technology is the obvious choice.

◗ Features/Benefits/Critical Specifications:

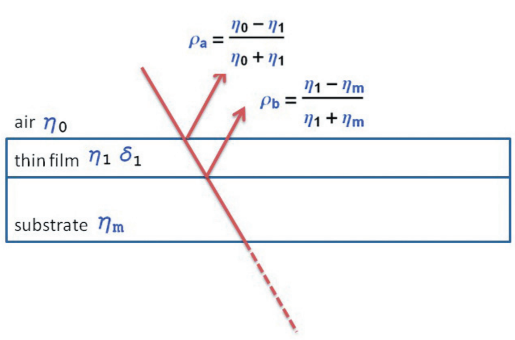
- Extremely sharp transitions from stopband to passband
- Precise, repeatable location of cut-on/cut-off wavelengths, tolerances within +/-0.01 to +/-0.005 of the edge 0.3OD - wavelength (50%)
- Transmission 85% avg., 80% minimum, up to 8% gain with anti-reflection coatings
- Tightly controlled ripple at cut-on
- Nearly uniform transmittance across the passband
- Exceptional attenuation of out-of-band signal
- Single surface coatings suitable for PMT and silicon detectors
- Optical quality transmitted wavefront
- Longpass, shortpass and bandpass spectral profiles

FILTER DESIGN

All boundaries between media are divided into reflected and transmitted portions of the electromagnetic wave. Those portions of the wave not reflected are transmitted across the boundary to a new medium with dissimilar optical properties. These differences cause refraction, or a change in the speed and angle of the wave. A material's refractive index is defined as the ratio of the velocity of light in a vacuum to the velocity of light in that medium. The amount of light reflected is related to the difference between the refractive indices of the media on either side of the boundary; greater differences create greater reflectivity. For non-absorbing media, if there is an increase in refractive index across the boundary, the reflected wave undergoes a phase change of 180º. If there is a decrease no phase change would occur. An optical thin-film coating is a stack of such boundaries, each producing reflected and transmitted components that are subsequently reflected and transmitted at other boundaries. If each of these boundaries is located at a precise distance from the other, the reflected and transmitted components are enhanced by interference.

Unlike "solid" particles, two or more electromagnetic waves can occupy the same space. When occupying the same space, they interfere with each other in a manner determined by their difference in phase and amplitude. Consider what happens when two waves of equal wavelength interfere: when two such waves are exactly out of phase with each other, by 180°, they interfere destructively. If their amplitudes are equal, they cancel each other by producing a wave of zero amplitude. When two such waves are exactly in phase with each other, they interfere constructively, producing a wave of amplitude equal to the sum of the two constituent waves.

An optical thin-film coating is designed so that the distances between the boundaries will control the phase differences of the multiple reflected and transmitted components.



Source: Thin Film Optical Filters by Angus Macleod

When this "stack of boundaries" is placed in a light path, constructive interference is induced at some selected wavelengths, while destructive interference is induced at others.

With the aid of thin-film design software, we apply optical thin-film theory to optimize various coating performance characteristics such as:

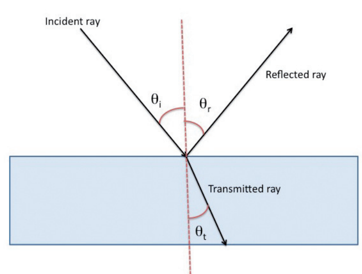
a) The degree of transmission and reflection

b) The size of the spectral range over which transmission, reflection and the transition between them occur

c) The polarization effects at non-normal angles of incidence. These characteristics are influenced by the number of boundaries, the difference in refractive index across each boundary and the various distances between the boundaries within a coating.

When light does not strike an interference filter at normal (normal is orthogonal to the plane of the filter), the situation becomes a bit more complicated. We now must consider the transmission and reflection of light depending on the orientation of the electric field to the plane of incidence. This orientation of the light's electric field to the plane of incidence is called the polarization of the light. The polarization of incident light can be separated into two perpendicular components called "s" and "p". For a complete treatment of the behavior of light of different polarization, we recommend the classic textbook "Optics" by Eugene Hecht. For now, we'll present Fresnel equations that describe the behavior of the two polarizations of light when they interact with a surface.

The diagram below shows the relevant rays to our discussion. We'll keep the notation used in the diagram for the Fresnel equations below: θ_i is the angle of incidence, θ_r is the angle of reflection and θ_t is the refracted angle of transmission.



First, we can use Snell's Law to determine θ_t from θ_i: $n_1 \sin\theta_i = n_2 \sin\theta_t$

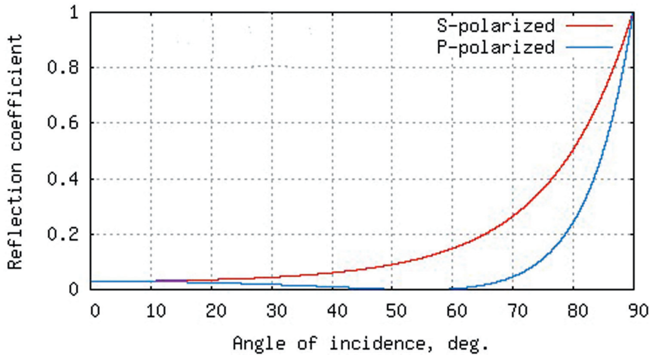
To find the amount of transmitted and reflected light, we use the Fresnel equations:

$$R_s = \left(\frac{n_1\cos\theta_i - n_2\cos\theta_t}{n_1\cos\theta_i + n_2\cos\theta_t}\right)^2 \qquad R_p = \left(\frac{n_1\cos\theta_t - n_2\cos\theta_i}{n_1\cos\theta_t + n_2\cos\theta_i}\right)^2$$

With most of our coatings, absorption is negligible, so transmittance can be found by:

1-R = T.

The following graph shows how the s and p portions of reflectance change as a function of angle of incidence for an air / glass interface:



THE COATING PROCESS

We select coating materials for their refractive and absorptive characteristics at those wavelengths critical to the optical filters application. The coating process requires that materials be selected for their evaporation and condensation properties as well as for their environmental durability.

◗ **Our Range of Deposition Chambers** includes energetic process systems that rely on sputtering to release the solid to its gas phase (manufactured by Leybold Optics: www.leybold-optics.com). Subsequent to release from the solid, the deposition materials are converted from metal to dielectric in a plasma reaction. These reacted dielectric molecules are then densified in a high power ionic bombardment chamber. This process is repeated in a few milliseconds, so layers are deposited with virtually no defects, and with extreme precision. These Leybold Helios systems are claimed to be the most deterministic in the industry.

Our close work with Leybold Optics has led to enhancements and improvements in the resulting coatings. Additional controls have been added to better define the uniformity of the deposition by both physical and magnetic confinements. Other features have been developed to allow a variety of materials, and precise direct control at nearly any wavelength of light.

With large sputtering targets, and a 1 to 2 meter diameter platen, these deposition chambers have capacity that is unsurpassed. The combination of a vast coating region and extremely precise layer control results in the capability to produce any quantity with nearly indistinguishable spectral function. Furthermore, the precise monitor of dense films make designs of extreme phase thickness a straight-forward process, and the resulting transmission within a small fraction of a percent from theoretical.

Additional deposition chambers include the Leybold SYRUSPro 1510. With 1.5 meters in possible capacity using a LION source for assisted condensation, these chambers provide both complexity and precision in a single system.

These high capacity systems identify Omega Optical as not only the ideal supplier to the labs and research communities, but allow for unlimited production of resulting product developments.

Complementing the energetic process systems are nearly thirty Physical Vapor Deposition (PVD) systems relying on evaporation by resistance or electron beam heating.

◗ **Physical Vapor Deposition Coatings** are produced in vacuum chambers at pressure typically less than 10-5 torr. The coating materials are vaporized by a resistive heating source, sputter gun (accelerated Ar ions) or an electron beam. With careful control of conditions such as vaporization rate, pressure, temperature and chamber geometry, the vapor cloud condenses uniformly onto substrates, then returning to their solid state. As a layer of material is deposited, its increasing thickness is typically monitored optically.

For example, when zinc sulfide is deposited onto bare glass, the transmission will fall as zinc sulfide builds a layer on the glass. Based on the magnitude of this transmittance level, the precise thickness of the zinc sulfide layer is known. Once the transmittance falls to the point corresponding with the desired layer thickness, the chamber shutter is closed to prevent further deposition of the zinc sulfide. At this point, a second material will typically be added and monitored in a similar fashion. A multi-layer coating is produced by alternating this cycle (typically 20 to 70 times) with two or more materials.

Successful production of a thin film interference filter relies on accurate and precise deposition of the thin film layers. There are a few different methods available to monitor the thickness of deposited layers. The two most commonly employed at Omega are crystal monitors and optical monitors and can be either automated or manual.

◗ **Crystal Monitoring Small Crystals** (usually quartz) have a natural resonant frequency of vibration. The crystal monitor is placed in the deposition cloud so that the crystal and substrate see directly proportional amounts of deposition regardless of deposition rate, temperature or other factors. As material deposits on the crystal, the vibration of the crystal slows down just like adding mass to an oscillating spring lowers the frequency of oscillation of the spring. Armed with the knowledge of the density of the material we are depositing, we can determine the thickness of the layer deposited.

With Optical Monitoring, the intensity of a single color of light passing through the substrate is continually monitored. As the thickness of a layer increases, the transmission of the substrate will change predictably. Even with many tens of layers, the transmission and reflection off a thin film stack is predictable and easily calculable with the benefit of a computer. While we usually optically monitor using transmitted light, it is also possible to optically monitor with reflected light

Several of our deposition chambers have been outfitted for automated manufacturing. The use of a custom written application in "LabView" tells us when to precisely cut layers at the optimal thickness; using optical monitoring of real-time signal.

For optimization of transmission and reflection regions, we employ a number of proprietary commercial packages. These tools allow for the best compromise in performance at all wavelengths in question.

The Quarter-Wave Stack Reflector is a basic building block of optical thin-film products. It is composed of alternating layers of two dielectric materials in which each layer has an optical thickness corresponding to one-quarter of the principal wavelength. This coating has the highest reflection at the principal wavelength, and transmits at wavelengths both higher and lower than the principal wavelength. At the principal wavelength, constructive interference of the multiple reflected rays maximizes the overall reflection of the coating; destructive interference among the transmitted rays minimizes the overall transmission.

Figure 1 illustrates the spectral performance of a quarter-wave stack reflector. Designed for maximum reflection of 550nm light waves, each layer has an optical thickness corresponding to one quarter of 550nm. This coating is useful for two types of filters: edge filters and rejection band filters.

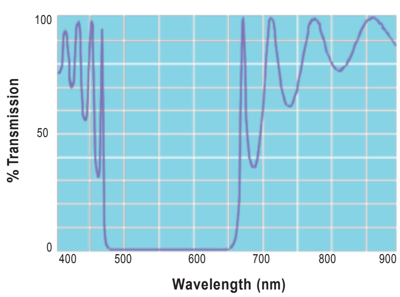


Figure 1 *Quarter-Wave Stack Reflector*

The Fabry-Perot Interferometer, or a single-cavity coating, is formed by separating two thin-film reflectors with a thin-film spacer. In an all-dielectric cavity, the thin-film reflectors are quarter-wave stack reflectors made of dielectric materials.

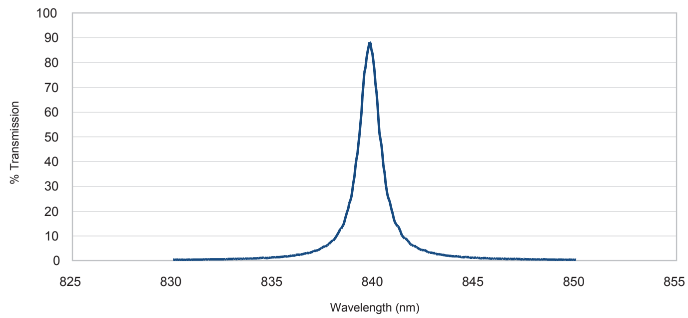


Figure 2 *Single-Cavity Coating*

The spacer, which is a single layer of dielectric material having an optical thickness corresponding to an integral-half of the principal wavelength, induces transmission rather than reflection at the principal wavelength. Light with wavelengths longer or shorter than the principal wavelength will undergo a phase condition that maximizes reflectivity and minimizes transmission. The result is a passband filter. The size of the passband region, the degree of transmission in that region, and the degree of reflection outside that region is determined by the number and arrangement of layers. A narrow passband region is created by increasing the reflection of the quarter-wave stacks as well as increasing the thickness of the thin-film spacer. In a metal-dielectric-metal (MDM) cavity, the reflectors of the solid Fabry-Perot interferometer are thin-films of metal and the spacer is a layer of dielectric material with an integral half-wave thickness. These are commonly used to filter UV light that would be absorbed by all-dielectric coatings.

The Multi-Cavity Passband Coating is made by coupling two or more single-cavities with a matching layer. The transmission at any given wavelength in and near the band is roughly the product of the transmission of the individual cavities. Therefore, as the number of cavities increases, the cut-off edges become steeper and the degree of reflection becomes greater.

When this type of coating is made of all-dielectric materials, out-of-band reflection characteristically ranges from about (.8 x CWL) to (1.2 x CWL). If thin films of metal, such as silver, are substituted for some of the dielectric layers, the metal's reflection and absorption properties extend the range of attenuation far into the IR. These properties cause loss in the transmission efficiency of the band.

As mentioned previously, the choice of materials to be used in a multilayer design is very wide, ranging from metals to the oxides of metals, to the salts and more complex compounds, to the small molecule organics. General features required to be practical include environmental stability, stress, deposition, temperature, transparency, etc. Most of the industry limits the selection to refractory oxides. We have experience with a much wider selection. With our wide range of potential materials, coatings of many varieties are possible. We like to use the expression “there is no end in light.” By this, we mean we will attempt to satisfy any spectral function as one we can produce, until we have proven otherwise.

List of coating materials:

niobium (V) oxide - Nb_2O_5	zinc sulfide - ZnS
germanium - Ge	cryolite - Na_3AlF_6
magnesium fluoride - MgF_2	aluminum - Al
tantalum (V) oxide - Ta_2O_5	yttrium (III) fluoride - YF_3
hafnium (IV) oxide - HfO_2	silver - Ag
zirconium (IV) oxide - ZrO_2	nickel chromium alloy - Inconel
aluminum oxide - Al_2O_3	silicon dioxide - SiO_2
titanium (IV) oxide – TiO_2	gold - Au

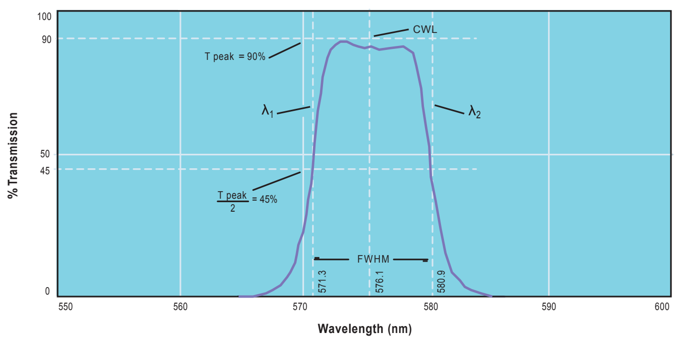


Figure 3 *Multi-Cavity Passband Coating*

Figure 3 illustrates the spectral performance of a 3-cavity bandpass filter. Three features used to identify bandpass filters are center wavelength (CWL), full width at half maximum transmission (FWHM), which characterizes the width of the passband, and peak transmission (%T).

Anti-Reflective Coatings do the opposite of a reflector. At the principal wavelength, it creates destructive interference for the multiple reflected waves, and constructive interference for the multiple transmitted waves. This type of coating is commonly applied to the surfaces of optical components such as lenses, mirrors, and windows. When deposited on the surface of an interference filter, the anti-reflective coating increases net transmission and reduces the intensity of ghost images. It should be noted that a properly designed longpass or shortpass filter is anti-reflective by nature at the relevant wavelengths and doesn’t need a second, additional anti-reflective coating.

▶ *See Application Note: Types of Anti-Reflective Treatments and When to Use Them on page 29*

A Partial Reflector, when manufactured from all dielectric materials, is similar to the quarter-wave stack reflector except that fewer layers are employed so that the reflectance is less than complete. Since virtually none of the light is absorbed the portion not transmitted is reflected. Partial beamsplitters often use this partial reflector stack. Here are a couple examples: A 50/50 beamsplitter will reflect 50% and transmit 50% of the incident light over a given spectral range. A 60/40 will reflect 60% and transmit 40%.

Dielectric/Metal Partial Reflector and Neutral Density Metal Filters are two additional types of partial reflectors we offer. The dielectric/metal partial reflector is manufactured with a combination of metal and dielectric materials and absorbs some portion of the incident light. A neutral density filter, coated with the metal alloy “inconel” is a common metal partial reflector.

Front Surface Coatings are employed when light must interact with the coating before passing through the substrate. Reflective surface coatings eliminate multiple reflections in products such as mirrors and dichroic beamsplitters. They also reduce the amount of energy absorbed by the substrate in some products. Anti-reflective coatings that reduce the degree of difference in admittance at the boundary of a filter and its medium are effective on both the front and back surfaces of a filter.

Refractive oxides, fluorides and metals are surface coating materials chosen for their durability. Many optical components are protected by durable surface coatings. Common surface coatings have undergone testing that simulates many years of environmental stress with no observable signs of cosmetic deterioration and only minimal shift in spectral performance. Metal coatings are often over-coated with a layer of oxide or fluoride material to enhance their durability.

Refractive oxide surface coatings are inherently unstable. The reactive coating process for oxides is critically dependent on deposition parameters. Methods such as ion beam sputtering and plasma coating have been developed to improve coating stability through energetic bombardment to produce a more dense coating. Surface coatings are typically more expensive than dielectric coatings due to lengthy manufacturing cycles, but provide extreme durability, excellent transmitted wavefront characteristics and can survive high temperature applications.

Dielectric Coatings may be protected by a cover glass laminated with optical grade cement. This allows use of materials which have wide ranging indices of refraction that result in increasing spectral control at a reasonable cost. A glass-to-glass lamination around the perimeter of the assembly provides moisture protection.

The dielectric materials used to produce these coatings yield the highest spectral performance. Research has shown that, although more fragile than refractive oxides, a single pair of dielectric materials permits the most complicated and highest performing interference designs. The benefits of this material include deep out-of-band blocking, very high phase thickness coatings with low residual stress, minimal crazing and substrate deformation, consistent and stable spectral performance, and simplicity of deposition which results in affordable cost.

Extended Attenuation it is often necessary when using a light source or a detector that performs over a broad spectral range to extend the range of attenuation provided by a single-coated surface. Additionally, an increased level of attenuation might be necessary if a high-intensity source or a very sensitive detector is used. While some optical systems may be able to provide space for separate reflectors or absorbers, these attenuating components can often be combined with the principal coating in a single assembly.

Adding attenuating components always results in some loss in transmission at the desired wavelengths. Therefore, optical density blocking strategies are devised for an optimum balance of transmission and attenuation. For example, if a detector has no sensitivity beyond 1000 nm, the filter's optical density blocking is designed only to that limit, conserving a critical portion of the throughput.

Extended attenuation sometimes is achieved by selecting thin film coating materials that absorb the unwanted wavelengths but transmit the desired wavelengths. Absorptive color glasses are commonly used as coating substrates or included in filter assemblies for extended attenuation. Dyes can also be added to optical cement to provide absorption. The choices of absorbing media are many, yet all face their own set of unique limitations. Absorbing media are ideal for some blocking requirements such as the "short wavelength side" of a visible bandpass filter. However, these materials don't provide the best levels of transmission, levels of absorption, or transition slopes in all situations. Furthermore, the temperature increase caused by absorption can be great enough to cause significant wavelength shift or material damage.

Dielectric thin-film coatings, either longpass or shortpass or very wide bandpass, are also commonly used to extend attenuation throughout the required spectral region. Deposited onto substrates they are highly transmissive in the desired spectral region and highly reflective where the principal coating "leaks" unwanted wavelengths.

Figures 4 illustrate how several blocking components increase the attenuation of a principal filter component.

Metal thin-film bandpass coatings extend attenuation to the far IR (>100 microns). This approach is simpler than the all dielectric method in that a single component attenuates a greater range. Metal layers are absorptive however and can reduce transmission at desired wavelengths to levels between 10% and 60%. A comparable all dielectric filter, blocked to the desired wavelength, would allow transmission to 95% in theory, in practice would fall short and not achieve the necessary attenuation range.

Our two most common strategies for extending the attenuation of a single coated surface are referred to as "optimized blocking," for filters used with detectors sensitive only in a limited region, and "complete blocking" for filters used with detectors sensitive to all wavelengths. An optimized blocked filter combines a color absorption glass for the short wavelength side of the passband with a dielectric reflector for the long wavelength side of the passband. A completely blocked filter includes a metal thin-film bandpass coating, which is often combined with a color absorption glass to boost short-wavelength attenuation.

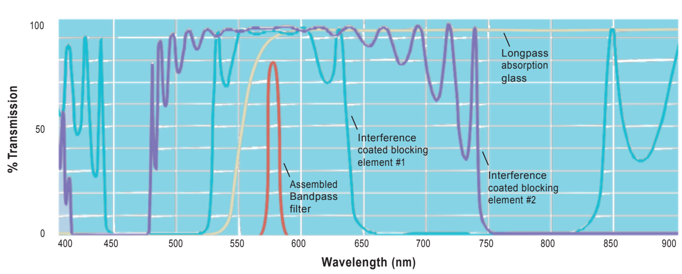


Figure 4 *Bandpass With Extended Attenuation*

Signal-to-Noise (S/N) ratio is often the most important consideration in designing an optical system. It is determined by:

S/N = S / (N1 + N2 + N3) where:

S = desired energy reaching the detector

N1 = unwanted energy transmitted by the filter

N2 = other light energy reaching the detector

N3 = other undesired energy affecting the output (e.g., detector and amplifier noise)

The optimum interference filter is one that reduces unwanted transmitted energy (N1) to a level below the external noise level (N2 and N3), while maintaining a signal level (S) well above the external noise.

Filter Orientation in most applications is with the most reflective, metallic looking surface toward the light source. The opposite surface is typically distinguished by it's more colored or opaque appearance. When oriented in this way, the thermal stress on the filter assembly is minimized. Spectral performance is unaffected by filter orientation. When significant, our filters are labeled with an arrow on the edge, indicating the direction of the light path. Special markings are made for those customers who require consistency with instrument design.

Excessive Light Energy can destroy a filter by degrading the coating or by fracturing the glass. Heat-induced glass damage can be avoided by proper substrate selection and by ensuring that the filter is mounted in a heat conducting sink. Coating damage is more complicated and a coating's specific damage threshold is dependent on a number of factors including coating type, wavelength of the incident energy, angle of incidence and pulse length.

Due to the ability to dissipate heat, a surface oxide coating will be the most damage resistant. A protected dielectric coating will be the most susceptible to damage. Surface fluoride, surface metal, and protected metal coatings will fall between these two extremes. Extensive experience with laser applications guides the selection of substrate materials and coating design best suited to meet specific spectrophotometric and energy handling requirements.

Angle of Incidence and Polarization are important considerations when designing a filter. Most interference coatings are designed to filter collimated light at a normal angle of incidence where the coated surface is perpendicular to the light path. However, interference coatings have certain unique properties that can be used effectively at off-normal angles of incidence. Dichroic beamsplitters and tunable bandpass filters are two common products that take advantage of these properties.

The primary effect of an increase in the incident angle on an interference coating is a shift in spectral performance toward shorter wavelengths. In other words, the principal wavelength of all types of interference filters decreases as the angle of incidence increases. For example, in Figure 5 the 665LP longpass filter (50% T at 665nm) becomes a 605LP filter at a 45° angle of incidence.

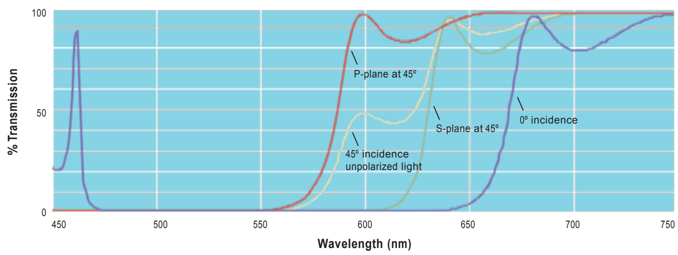


Figure 5 *Angle of Incidence Polarization Effects – Longpass Filter*

The relationship between this shift and angle of incidence is described approximately as:

$$\frac{\lambda_\phi}{\lambda_0} = \frac{\sqrt{N^2 - \sin^2\phi}}{N}$$

Where:
ϕ = angle of incidence
λ_ϕ = principal wavelength at angle of incidence φ
λ_0 = principal wavelength at 0º angle of incidence
N = effective refractive index of the coating

The effective admittance of a coating is determined by the coating materials used and the sequence of thin-film layers in the coating, both of which are variables in the design process. For filters with common coating materials such as zinc sulfide and cryolite, effective refractive index values are typically 1.45 or 2.0, depending upon which material is used for the spacer layer. This relationship is plotted in Figure 6. The actual shifts will vary slightly from calculations based solely on the above equation (alternating SiO_2 and Nb_2O_5 have values of 1.52 and 2.35).

A secondary effect of angle of incidence is polarization. At angles greater than 0º, the component of lightwaves vibrating parallel to the plane of incidence (P-plane) will be filtered differently than the component vibrating perpendicular to the plane of incidence (S-plane). The plane of incidence is geometrically defined by a line along the direction of lightwave propagation and an intersecting line perpendicular to the coating surface. Polarization effects increase as the angle of incidence increases. Figures 5 and 7 illustrate the effects of polarization on a longpass and a bandpass filter. Coating designs can minimize polarization effects when necessary.

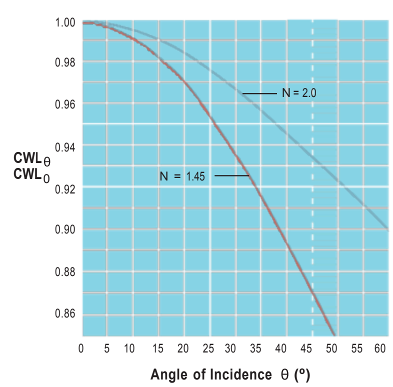


Figure 6
Angle of Incidence Effects

System Speed can have a significant effect on transmission and bandwidth as well as shifting peak wavelength. Faster system speeds result in a loss in peak transmission, an increase in bandwidth and a blue-shift in peak wavelength. These effects can be drastic when narrow-band filters are used in fast systems, and need to be taken into consideration during system design.

When filtering a converging rather than collimated beam of light, the spectrum results from the integration of the rays at all angles

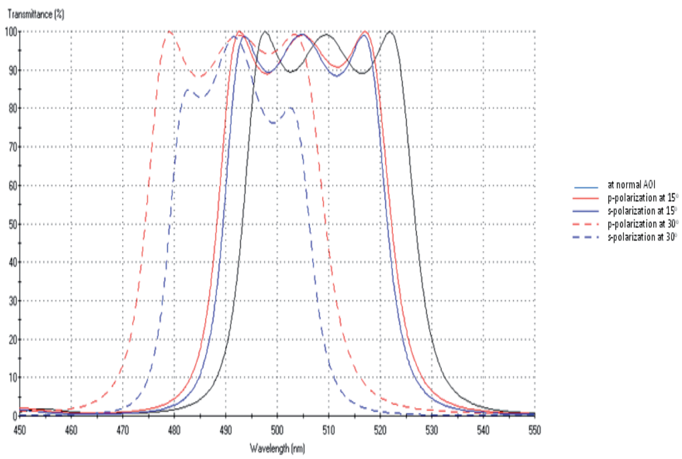


Figure 7 *Angle of Incidence Polarization Effects – Bandpass Filters*

within the cone. At system speeds of f/2.5 and slower (full cone angle of 23° or less), the shift in peak wavelength can be approximately predicted from the filter's performance in collimated light (i.e., the peak wavelength shifts about one-half the value that it would shift in collimated light at the cone's most off-axis angle).

Temperature Effects the performance of an interference filter. Wavelength will shift with temperature changes due to the expansion and contraction of the coating materials. Unless otherwise specified, filters are designed for an operating temperature of 20°C. They will withstand repeated thermal cycling assuming temperature transitions are less than 5°C per minute. An operating temperature range between -60°C and +60°C is recommended. For the refractory oxides temperature ranges from -60°C to 120°C. Filters must be specifically designed for use at temperatures above 120°C or below -100°C. Although the shift is dependent upon the design of the coating, coefficients in Figure 8 provide a good approximation.

For applications where the change in performance divided by the change in temperature is to be minimized, the densified refractory oxide materials are preferred. Consideration must be given to maximize temperature as refractory oxides, even when densified through energetic process, will experience a one-time shift in optical thickness. The magnitude of this is <1% but can be of great importance for passband and edge filters.

Laminated interference filters, particularly those with ultra narrowbands, are subject to potential blue shift with age. This tendency is somewhat stabilized through a process of repeated heat cycling, or curing, at moderately high temperatures for short durations during the manufacturing process. For wavelength critical applications, heat cycling should be called out and ideally a temperature controlled oven implemented to maintain temperature. Prolonged exposure to light, particularly short UV wavelengths, results in solarization and reduced transmission.

Filter Throughput is commonly expressed as Transmission (T) and Optical Density (OD). Transmission is the portion of the total energy at a given wavelength that passes through the filter. A transmittance value is always a portion of unity (between 0 and 1).

When describing the transmitting performance of a filter (usually when throughput is 1%–99%), the preferred expression is "transmittance" or "transmission".

When describing the attenuating performance of a filter (usually when throughput is less than 1%), the preferred expression is "optical density".

Transmission is most often expressed either as a percentage (90%) or as a decimal (90). Optical density is always expressed as the negative logarithm of transmission. Unit conversions are: OD = $-log^{10}T$ or $T = 10^{-OD}$

Wavelength Range	Thermal Coefficient
(nm)	(nm of shift per 1° C change)
300 - 400	0,016
400 - 500	0,017
500 - 600	0,018
600 - 700	0,019
700 - 800	0,020
800 - 900	0,023
900 - 1000	0,026

Figure 8 *Wavelength and Thermal Coefficients*

FILTER DESIGN

Transmitted Wavefront Distortion is measured at the filter's principal wavelength on a Broadband Achromatic Twyman-Green Interferometer or a Shack-Hartmann interferometer. Although many interferometers can measure transmitted wavefront distortion, most are fixed at a single wavelength (often 633nm). For filters that don't transmit this wavelength, these instruments must produce reflected, rather than transmitted, interferograms.

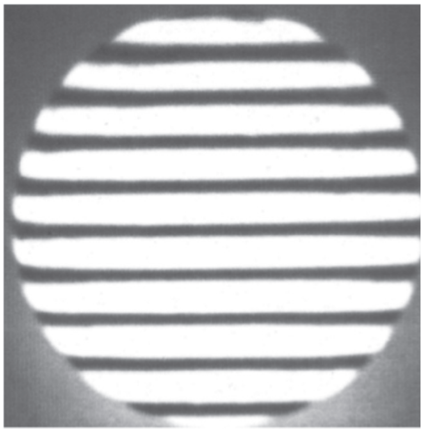


Figure 9

Transmitted wavefront interferogram of a narrow band filter used for telephotometry.

Although reflected interferograms are often used to represent the quality of a transmitted image, there are no reliable means for such interpretation.

▸ *See Application Note: Measuring Transmitted Wavefront Distortion on page 34*

Image Quality Filters: An optical filter's effect on the quality of an image results from the degree it distorts the transmitted wavefront.

In high-resolution imaging systems, filters require multiple layering of various materials (i.e., glasses, coating materials, optical cements, etc.) for high spectral performance. These materials, if used indiscriminately, can degrade a filter's optical performance. This effect can be significantly diminished through material selection, design, process, and testing.

To preserve image quality we select optical grade materials with the highest degree of homogeneity and the best match in refractive index at contacted boundaries. Special coating designs minimize the required number of contacted surfaces that cause internal reflection and fringe patterns. Before coating and assembly, all glasses are polished to requisite flatness and wedge specifications. Our coating and assembly techniques assure uniformity in material as well as spectral properties. With sputtering and other energetic process coatings, very high optical quality can be maintained on monolithic surfaces of fused silica. Multiple substrates of this type may also be assembled to produce a desired spectrum function.

After the filter is assembled, transmitted wavefront distortion can be improved further through a cycle of polishing, evaluating and re-polishing both outer surfaces. Durable anti-reflective coatings are then deposited onto the outer surfaces, reducing the intensity of ghost images while boosting transmission. See Figure 9. The resulting level of performance depends on size, thickness, spectral region and spectral demands of each filter. This approach has been used for filters of the highest standard such as the Space Telescope.

Types of Anti-Reflective Treatments and When to Use Them

Application Note

While no single solution fits all needs, by appropriately selecting the right anti-reflective technique, nearly any optic can be anti-reflected to meet the needs of the user.

– by Dr. Michael Fink, Project Scientist, Omega Optical

From the benign annoyance of a reflection off your car's instrument panel window to the image-destroying reflections off of multiple optical components in a microscope, unwanted reflections plague our lives. Minimizing reflections has become a multimillion dollar industry. Scientific instruments with several optical components, such as modern confocal microscopes and, more commonly, television cameras, would be far less useful without the benefit of anti-reflective coatings.

Discovery

More than 70 years have passed since the first anti-reflective coating was discovered by a Ukrainian scientist working for Zeiss in Germany. While the anti-reflective coating was first implemented on binoculars in the German military, the new finding quickly expanded to a wide variety of optical elements in the research laboratory.

On Reflections

First, it is probably worthwhile to consider why reflections occur. Reflection of light occurs at any surface between two mediums with different indices of refraction. The closer the two indices of refraction, the less light will be reflected. If an optic could be made out of a material with the same index of refraction as air, then there would be no reflections at all. Of course, lenses would not focus light if they didn't have an index of refraction that differed from that of air (or whatever medium they're immersed in).

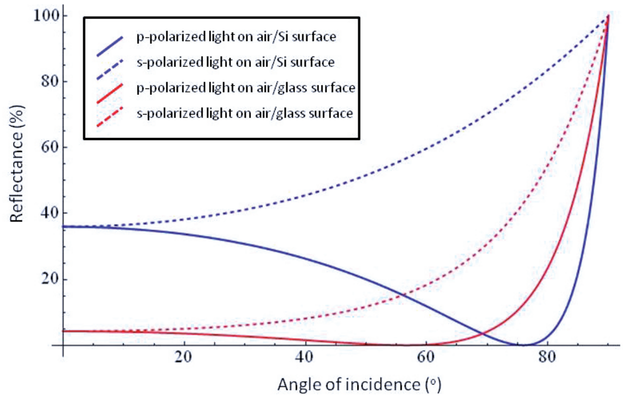


Figure 1 *Percent reflectance of s and p-polarized light off silicon and fused silica surfaces depending on angle of incidence. ($_n$Si = 4.01, $_n$fused silica = 1.46).*

In general, the reflection of light off of a surface will increase as the angle of incidence varies further from normal. However, this is not true for light that is p-polarized. Reflection of p-polarized light will decrease as the angle of incidence increases from normal (0°) to some angle at which there is no reflection. This angle at which there is no reflection of p-polarized light is called Brewster's angle and varies depending on the indices of refraction of the two media. For 1,064 nm light at an interface of air and fused silica, Brewster's angle is approximately 55.4°. Brewster's angle is different depending on the two media that comprise the interface. Figure 1 compares the reflection of s- and p-polarized light for air-fused silica and air-silicon surfaces. At angles of incidence greater than Brewster's angle, the reflection of both s- and p-polarized light increases dramatically as the angle of incidence increases.

Uses and Misuses of Anti-Reflective Treatments

Often, anti-reflective coatings are used to increase transmission of an optic. This is often a valid use of an anti-reflective coating, but it should be noted that this coating does not, by definition, increase transmission. Rather, it only reduces reflections off the incident side of the surface. In some cases, absorptive anti-reflective treatments can actually reduce transmission. In the case of interference filters, an anti-reflective treatment is often superfluous. An interference filter is intentionally reflective at wavelengths that are not being passed, so the total reflection off the optic will not be effectively reduced by an anti-reflective treatment. Furthermore, exposed interference filters are often already anti-reflected at the passed wavelengths, so an extra anti-reflective coating usually has little effect.

In many cases, the enhanced transmission of some anti-reflective coatings is very necessary. In fact, the advent of anti-reflective optics has made new optical instruments containing many-element apparatuses feasible. For example, a modern confocal microscope might have 15 or 20 optical elements in the light path. Borosilicate glass that has not been treated to eliminate reflections typically has a reflectance of about 4% in visible wavelengths per surface. A piece of borosilicate glass with a simple multilayer anti-reflective coating might average 0.7% reflectance per surface. When a single interface is concerned, the difference between 96% transmission and 99.3% transmission seems miniscule. However, in a multi element light path, this difference becomes very significant. If an incident light path crosses 30 air-glass surfaces, the final transmitted light at the end of the path would only be approximately 29% for non-anti-reflection treated optics. An identical path with anti-reflection treated parts would be 81%.

Anti-Reflective Coatings

The predominant method for causing anti-reflection of an optic is by depositing a layer or several layers of compounds onto the surface of the optic. Deposited anti-reflective coatings vary in complexity from single layer to 10 or more layers. Popular deposition methods of chemical anti-reflective coatings include sputtering, chemical vapor deposition, and spin-coating.

Single-Layer Anti-Reflection

Single-layer anti-reflective coatings are the simplest and often the most sensible solution. With just a single layer of a well-chosen compound, reflection at a specific wavelength can be reduced almost to zero. Additionally, unlike multilayer coatings, there is no wavelength or angle of incidence at which the reflection is greater than is reflected off an untreated substrate.[1]

While the "perfect" compound to make an anti-reflective coating for visible wavelengths does not yet exist, single layer anti-reflective coatings still are often implemented in this range.

To anti-reflect a specific wavelength with one layer of coating, ideally a compound would be used that has an index of refraction that is midway between the indices for air and the optical substrate. Additionally, the optical thickness of the anti-reflective layer is usually chosen to be one-quarter wave. If both of these criteria can be met, the theoretical reflection at that specific wavelength is zero. There are practical considerations that prohibit this in the visible wavelengths.

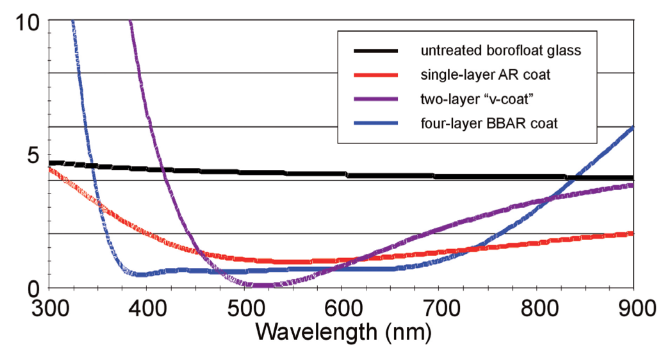


Figure 2 *Theoretical reflectance curves for untreated borosilicate float glass and borosilicate float glass with three different anti-reflective coatings.*

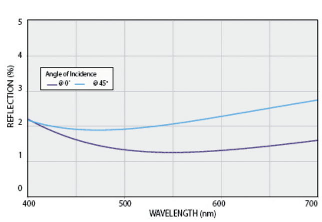


Figure 3 *Reflectance off borosilicate glass surface treated with a single layer of MgF2. The reflectance is not as low as a multi-layer BBAR coating, but it is lower than untreated glass at all wavelengths and incident angles.*

Most glasses used in the optical laboratory today have indices of refraction between 1.4 and 1.6. These values would suggest an optimal anti-reflective coating index of refraction between 1.20 and 1.30. Unfortunately, there are no known suitable compounds that have an appropriate index of refraction, are suitably durable, and can withstand the typical laboratory environment.

One compound that is commonly used for single layer anti-reflective coatings for visible spectrum elements is magnesium fluoride (MgF_2). It has an index of refraction that is close to optimal (~1.38 at 500 nm) and is easily deposited onto glass. With carefully controlled process and substrate temperatures of 200° C to 250° C, a very robust coating can be applied, but otherwise care must be taken while cleaning magnesium fluoride-coated surfaces, as the coating can be rubbed off with vigorous cleaning. A theoretical reflectance curve for a single layer of MgF_2 is shown in figure 2. The reflection gains at off-normal angles of incidence are relatively small for single-layer coatings, as shown in figure 3.

Single-layer anti-reflective coatings are especially popular when anti-reflection in the infrared is desired. Because many of the substrates used in infrared have higher indices of refraction (i.e., silicon, germanium, gallium arsenide, indium arsenide), there are many more choices for an optimal anti-reflective coating compound than for glasses. For example, the above-mentioned infrared substrates all have indices of refraction close to 4. A single layer of zinc sulfide can be used to anti-reflect all of these substrates quite effectively.[2]

V-Coating (Two-Layer Anti-Reflection)

If very low reflection is needed, but at only one specific wavelength, v-coating, a two-layer anti-reflective coating, is often the best solution. By using two layers with contrasting indices of refraction, it is possible to reduce the reflection at a specific wavelength to near zero. A drawback of this technique is that it actually increases reflection at wavelengths other than that for which the coating is optimized (evident on figure 2). If the actual goal is to minimize reflections at multiple wavelengths, v-coating will not produce the desired result.

Multilayer Coatings

For broadband anti-reflection of less than 1% in the visible wavelengths, multilayer coatings are required. Broadband anti-reflective (BBAR) coatings have an advantage of producing very low reflection over a controllable, broad range of wavelengths (figure 2). Beyond the region for which the coating is optimized, such as the v-coating, reflection off the optic is greater than reflection from untreated glass. BBAR coatings suffer slightly larger percentage reflection gains at off-normal angles of incidence when compared with single-layer anti-reflective coatings. Figure 4 illustrates these large reflectance gains at off-normal angles of incidence for multilayer coatings.

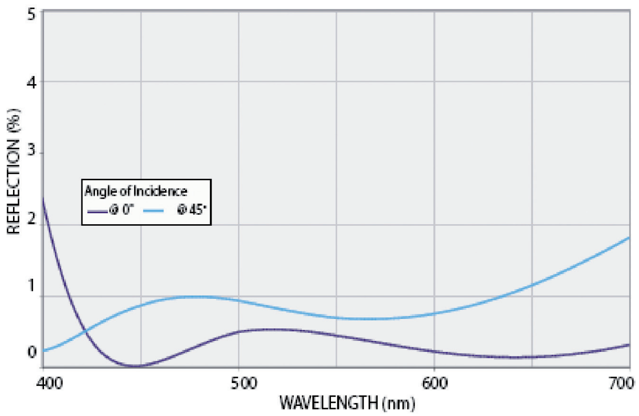


Figure 4 *Multi-layer broadband anti-reflective (BBAR) coatings can achieve reflections below 1% at a broad range of wavelengths, but at the expense of higher out-of-band reflectance and large percentage gains in reflectance at non-normal angles of incidence.*

Materials

Anti-reflection in the visible and near-IR wavelengths can be achieved with a variety of different deposited compounds. Silicon monoxide, yttrium fluoride, and magnesium fluoride are three popular low-index-of-refraction materials. Silicon monoxide is used primarily in the infrared wavelengths, while yttrium fluoride and magnesium fluoride are used most frequently in the visible region. The primary drawback of these compounds is their durability. While anti-reflective coatings utilizing either of these can be cleaned, care must be taken not to cause damage. Anti-reflective coatings also can be made using harder oxide compounds that are more durable, but they tend not to perform quite as well and require that the optic be subjected to high temperatures during deposition. In general, the more energetic (higher temperature) the process that is used to deposit the anti-reflective coating, the more durable the resultant coating is.

Moth-Eye and Random Microstructured Anti-Reflection

The physical structure of moths' eyes gives these insects a unique means of minimizing reflection. Reduced reflections off of moths' eyes can make the difference between their being eaten by a predator or remaining unseen. As a result of this environmental pressure, moths have evolved a regular repeating pattern of 3-D prominences on the surface of their eyes that effectively reduce reflection. With some effort, scientists have been able to duplicate the "moth-eye" pattern on glass to achieve a similar anti-reflection effect.

Initially, it seems non-intuitive that simply changing the surface structure of the glass should reduce reflections off that surface. By changing the initially smooth, flat surface of the glass to a surface that has a regular pattern of prominences that are hundreds of nanometers in size, the surface area has actually increased dramatically. Increased surface area would seem to suggest higher reflection rather than lower.

The reason for the reduced reflection off of a moth-eye surface is that the light no longer has a distinct boundary between the air and glass (or air and eye of the moth). Where there once was a very sharp boundary between air and glass, the transition now occurs over an appreciable fraction of a wavelength. Because reflections only can occur where there is a change in index of refraction and there is no longer a sharp boundary between materials, reflections are drastically reduced. In the visible range on fused silica, moth-eye anti-reflection treatment can achieve broadband reflection off each surface of 0.2% or better.

It is important to note that the size of the microstructures is very important. The structure on moths' eyes is a regular repeating pattern of hexagonal finger-like projections that are spaced roughly 300 nm from each other and rise about 200 nm from the eye's surface. This size of microstructure is optimized roughly for anti-reflection of the visible spectrum. If the structures are made slightly smaller or larger in size, the surface can be optimized to reflect shorter or longer wavelengths, respectively.

For example, arsenic triselenide is used in optics in the 5- to 15-micron range. A typical moth-eye structure for this window of wavelengths might have prominences that rise 3,500 nm from the substrate surface with an average spacing between prominences of about 2,400 nm.[3] Moth-eye structures of approximately this size can be seen in figure 5. Typical transmission improvement of the optic can be as much as 12% to 14% by treating just one side of the optic (figure 6).

One major advantage of microstructured antireflective glass is its ability to withstand high incident energies of nearly 60 J/cm.[4]

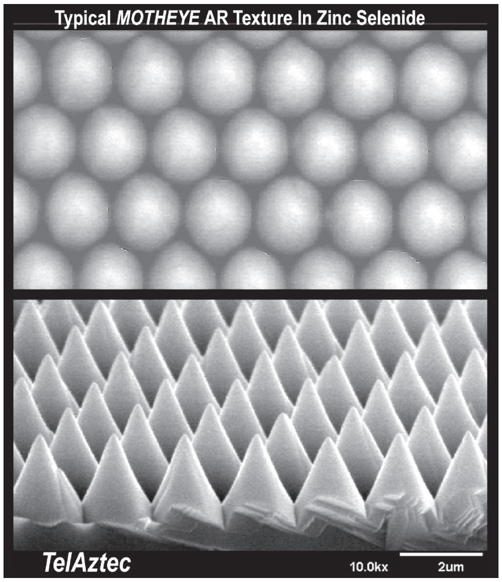


Figure 5 *SEM image of zinc selenide motheye microstructures. (Courtesy of TelAztec, Inc.)*

This is a sizeable improvement over the energy damage threshold of most thin-film anti-reflective coatings. Because the antireflective “coating” is made of the glass itself, it will have an energy damage threshold similar to that of the glass from which the optic is made.

To anti-reflect glass at visible wavelengths, an equally effective and more cost-effective anti-reflective coating can be created by etching the glass in a random pattern. An image of the resultant random spacing of the prominences is shown in figure 7. Treating a fused silica surface to create this random microstructure pattern can decrease broadband visible reflections by 80% to 90%.

Cleaning of microstructured anti-reflective surfaces poses a small problem. Physical cleaning of microstructured surfaces must be done carefully, if at all. The prominences that give the substrate its anti-reflective property can be easily broken off if the cleaning is too vigorous.

Absorptive Anti-Reflective Coatings

Another method for minimizing reflections off an optic is to make the substrate more absorptive. If the goal is to improve transmission through the optic, use of an absorptive optical coating generally will not help. However, absorptive coatings can very effectively absorb light that would otherwise be reflected.

Absorptive coatings are not usually the best solution for high-energy applications because, rather than transmitting the light that is being anti-reflected, that light now is being absorbed by molecules in the optical element, inevitably leading to heating and thermal damage.

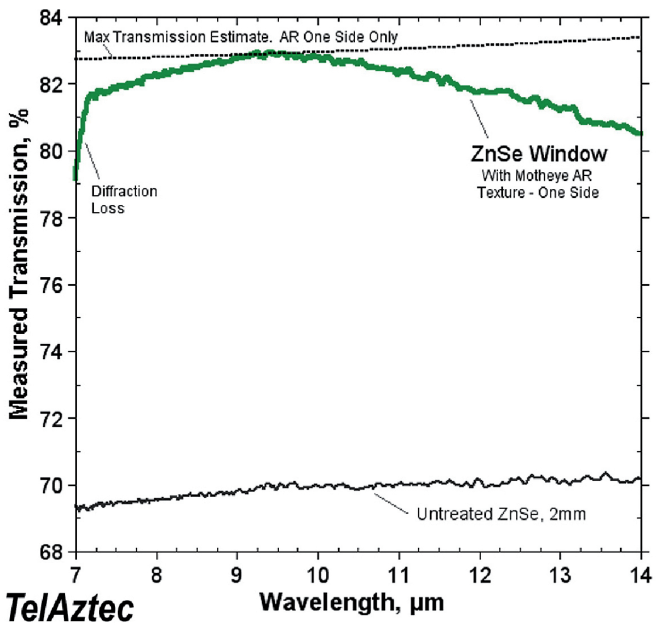


Figure 6 *Percent transmission for a ZnSe window untreated and treated with motheye AR texture on one side. (Courtesy of TelAztec, Inc.)*

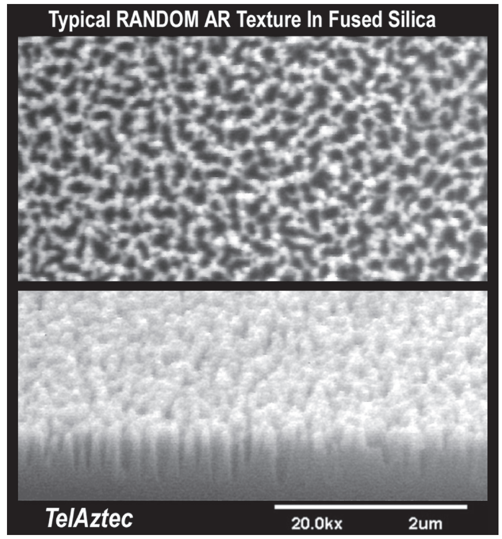


Figure 7

SEM image of random AR microstructures in glass. (Courtesy of TelAztec, Inc.)

Summary

There are a few different options available for building an anti-reflective optic. While no single solution fits all needs, by appropriately selecting the right anti-reflective technique, nearly any optic now can be anti-reflected to meet the needs of the user.

Dr. Michael Fink studied chemistry as an undergraduate at Bates College in Lewiston, ME, where he worked in the laboratory of Dr. Matthew Côté building a scanning tunneling microscope to determine the feasibility of using two color-distinguished oxidation states of tungsten oxide as a digital information storage medium. At the University of Oregon in Eugene, OR, Mike continued his studies, earning his doctorate in chemistry by improving the sensitivity of molecular Fourier imaging correlation spectroscopy in Dr. Andrew Marcus’s lab at the Oregon Center for Optics.

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- 2. Hass G. 1955. Filmed surfaces for reflecting optics. J. Opt. Soc. Am. 45: 945-52.
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- 4. Ibid.

Filter Design Considerations and Your Light Source

Application Note

Overview

Available to system designers today are a wide array of excitation sources. Among the most frequently used are semiconductor lasers, LEDs (light emitting diodes), arc lamps, gas and solid state lasers, gas discharge lamps, and filament lamps. Each of these excitation sources have distinct physical and spectral characteristics which make it an optimum choice for a particular application. In practically all cases however, regardless of which excitation source is selected, the use of a properly designed excitation filter is required to enhance system performance and optimize signal-to-noise ratio.

While an excitation filters role is the same in every system, that is to deliver the desired excitation wavelengths while attenuating unwanted energy, the characteristics of the filter that achieve these goals are highly dependant on both the source characteristics and the overall system environment.

– by Mark Ziter, Senior Applications Engineer, Omega Optical

Filters for Gas and Solid State Lasers

Traditionally, gas lasers have been popular excitation sources. The most common, Argon ion and Krypton ion, provide lines at 488nm, 514nm, 568nm and 647nm. The laser emissions from these sources are precisely placed, exhibit narrow bandwidths, and are not subject to drift. While the output of such lasers are usually thought of as monochromatic, there are often lower energy transitions, spontaneous emissions, and plasma glow present in the output, all contributing to unwanted background. A filter to clean up the laser output and eliminate this noise will greatly enhance the system's signal to noise ratio.

Solid state lasers have properties similar to gas lasers. Along with the well behaved narrow primary laser emissions, these sources produce background noise from unwanted transitions and pump energy.

Excitation interference filters for both gas and solid state lasers share similar design considerations. The narrow bandwidth and wavelength predictability of these lasers means that filters designed for these sources can have very narrow passband widths. Deep out of band blocking to attenuate the background is required to ensure that no unwanted excitation source error energy reaches the detector and deteriorates the signal-to-noise figure

QuantaMAX™ Laser Line Filters (see page 57) are ideally suited to these applications. These filters, designated with an XLL prefix, have high transmission coupled with narrow pass bands, typically less than 0.4% of the laser wavelength. Manufactured with hard oxide surface coatings on monolithic high optical quality substrates, they exhibit exceptional thermal stability, shifting less than a few 1/100th of an Angstrom per deg C. The dense thin film coatings, deposited by energetic process, are unaffected by environmental humidity and their ability to withstand high power densities is unsurpassed in the marketplace.

Filters for Diode Lasers

The output of diode lasers is not as narrow or as precise as the output of gas and solid state lasers. These semiconductor devices have bandwidths in the 2nm to 5nm range. In addition, the actual output wavelength can vary a few nanometers from laser to laser. Compounding this lot to lot variation is the tendency these lasers have to drift with temperature and age. As a consequence, semiconductor lasers have an output wavelength uncertainty of up to +/- 5nm. Therefore, a diode laser designated as a 405nm device could have an output anywhere from 400nm to 410nm. Similarly, a 635nm diode laser may emit as blue as 630nm or as red as 640nm.

Optical interference filters designed for semiconductor lasers must be wide enough to accommodate this uncertainty in output wavelength. Additionally, since a given diode laser will drift with temperature, any ripple in the filter's spectral profile will result in an apparent variation in laser output intensity as the wavelength drifts across the filter passband.

Both of these considerations have been taken into account in the design of our XLD (Laser Diode Clean-Up) Filters. See page 54. Similar to all QuantaMAX™ filters, these are manufactured using ion beam sputtering to produce stable, dense surface coatings on high optical quality substrates. With wider passbands than our Laser Line Filters, the XLD filters will transmit a designated diode laser's output across its range of wavelength uncertainty. Their smooth transmission profiles, with less than +/- 1.5% transmission ripple across the passband, will not impart variation in laser intensity as the diode laser drifts with temperature. These filters' deep out of band blocking will eliminate the secondary emissions that are typical with semiconductor lasers.

Filters for LEDs

Light emitting diodes, or LEDs, are semiconductor devices that emit light as a result of electron-hole recombination across a p-n junction. Due to the absence of stimulated emission and laser oscillation, the spectral output of a LED is much broader than that of a diode laser, typically 30nm to 50nm at the half power points. In addition, the lot to lot wavelength variation of a given LED can be as large as 20nm. Spectral profiles of LEDs show long emission tails with substantial energy that usually extends well into the signal region. Often, the energy in these tails is the same order of magnitude as the signal to be detected.

Filters for LED excitation must attenuate the red tail. In order to allow signal collection as spectrally close as possible to the excitation, the filter needs a very steep blocking slope on its cut-off edge. Additionally, the filter needs to accommodate the wide LED bandwidth and output wavelength variability. Unless system requirements necessitate deep blocking at wavelengths blue of the LED output, there are few requirements on the blue cut-on edge. This edge can have a shallow blocking slope and does not need to be precisely placed. In fact, a short pass design is often the best choice to filter an LED excitation source. A steeply sloped short pass filter will eliminate the LED's red tail and the open ended transmission to the blue will pass the wide, variable LED output. The simplicity of design and high transmission offered by a short pass approach makes this an attractive alternative.

Filters for Hg Arc Lamps

Arc lamps produce light by passing an electric current through vaporized material within a fused quartz tube. The mercury arc lamp is a very popular excitation source for fluorescence microscopy because its spectral content has a number of very strong prominences at useful wavelengths throughout the UV and visible regions. The most commonly used are at 365nm, 405nm, 436nm, 546nm, and 579nm. Fluorescent dyes have been developed with absorption peaks that correspond with these emission lines. In order to take full advantage of these intense lines, we offer fluorescence microscopy sets with excitation filters designed specifically at these wavelengths. These include the XF408 (DAPI), the XF401 (CFP), and the XF406 (mCherry) sets.

Filters for Halogen Lamps

A halogen lamp is a tungsten filament incandescent lamp with the filament enclosed in an environment consisting of a mixture of inert gas and a halogen, such as iodine. The presence of the halogen causes evaporated tungsten to be redeposited back onto the filament, extending the life of the bulb and allowing it to be operated at a high temperature. The halogen lamp spectral output is continuous from the near UV out to the IR.

The continuous output spectrum of the halogen lamp removes all constraints on the wavelength placement and bandwidth of excitation filters designed to function with these sources. Where filters designed for all of the previously discussed sources need to be placed to take advantage of those sources spectral characteristics, no such considerations are required for filters designed to work with halogen lamps. The placement of cut-on and cut-off edges are determined solely by the absorption characteristics of the excited material and the spectral profile of the emission filter with which the excitation filter will function.

The characteristic of the halogen lamp which affords this excitation filter design latitude also increases the filter's blocking burden. The lack of prominences or bright lines means that the out of band energy levels to be blocked are of equal intensity to the desired wavelengths. Consequently, excitation filters for halogen lamps must block very deeply, especially red of the excitation band where the emission band is located. Also, since the Stokes shift of most fluorescence dyes dictates that the excitation and emission filter passbands be in close spectral proximity, a steep blocking slope on the red edge of the excitation pass band is required. A 5 decade slope of 1% or less is usually needed to prevent excitation energy from leaking into the emission range. For the same reason, the red edge spectral placement must be tightly toleranced.

Whatever your light source might be, we are always available to assist in the selection of the right interference filters for the best performance. Please contact us.

Optical Interference Filters for Applications Using a LED Light Source

Application Note

Overview

Light Emitting Diodes, or LEDs, are high efficiency sources of electro-magnetic energy with a wide range of available wavelengths and very high brightness. These devices directly convert electrons to photons, rather than producing photons through blackbody radiation as a consequence of electron conversion to heat. As a result, there is little associated thermal pollution, or wasted energy.

LED Characteristics

although very effective at producing luminous power for scientific applications, LEDs have an assortment of limitations that must be considered. The primary limitation is that although they are very bright in lumens per unit area, they are quite limited in absolute power. A related limitation results from the fact that as current is increased across the light producing junction, the temperature also increases, causing a thermal shift of output wavelength. Whether caused by a change in the temperature of the environment, or by the residual heat of driving the junction to produce more photons, the consequence is that the output wavelength drifts.

Consistency limitations are exacerbated by the tendency of the output wavelength to vary from batch to batch. Minor variations in host impurities result in lot variations of Center Wavelength (CWL) of as much as 10nm, with occasional lots falling outside this range. Selection is a possible solution, but may result supply chain, inconsistencies.

At low levels of output, LEDs exhibit bandwidth (FWHM or HBW) which is typically 30 nm. At greater power outputs, they produce coherent emission which has a distinctive spectral power function. The characteristic of this emission is a region of intense spikes of energy superimposed on the continuum. These spikes have bandwidths which are typically 1 nm and can occur in groups of up to ten bands within a region of 5nm of a central peak.

Although much of the energy of LEDs is emitted in the specified region, there typically are secondary regions of light output. Usually these regions of secondary output are at significantly longer wavelengths, with infrared output at nominally twice the primary wavelength.

Without filtering, the secondary spectral output of LEDs can reduce their effectiveness in devices designed for low level photon conversion, such as fluorescence or Raman scattering. Even if the secondary output is six orders of magnitude less than the primary, it would contribute a critical error in these applications, made even more serious by the enhanced IR sensitivity of silicon based detectors.

Filter Recommendations

When considering filters or filter sets suitable for LED light source, it is important to verify that the LED peak band is transmitted by the excitation filters and reflected by the dichroic mirror. This can be accomplished by a quick check of the filter's spectral description to that of the LED's center wavelength.

For most commercial scientific grade LED sources it is probable that the standard filter sets used with a broad band lightsource, such as a Mercury burner, will suffice.

When using a custom LED, or LED array, a customized optical filter solution may be acquired.

Please contact us for assistance with filter selection.

▶ *See Light Source Reference Charts on page 109*

"CoolLED recommends that excitation filters are used with its LED excitation products. Although LEDs produce a narrowband of excitation, there can be a small "tail" of excitation to shorter and longer wavelengths which may be undesirable for some applications."

Measuring Transmitted Wavefront Distortion

Application Note

Overview

What is Transmitted Wavefront Distortion? If you've ever looked through an old piece of window glass and noticed the image on the other side is distorted, then you are familiar with the effects of transmitted wavefront distortion (TWD) (Figure 1). Transmitted wavefront distortion refers to the deformation of a plane wave of light as it travels through an optical element (Figure 2).

Interference filters and dichroics for fluorescence and astronomy applications demand extraordinarily low levels of TWD. The acceptable TWD tolerance for these applications is often much tighter than can be perceived with the naked eye. When tight tolerances for TWD are required specialized instrument devices are necessary. This article focuses on one such device used by Omega Optical to measure TWD: the Shack-Hartmann wavefront sensor..

– Dr. Michael Fink, Project Scientist, Omega Optical

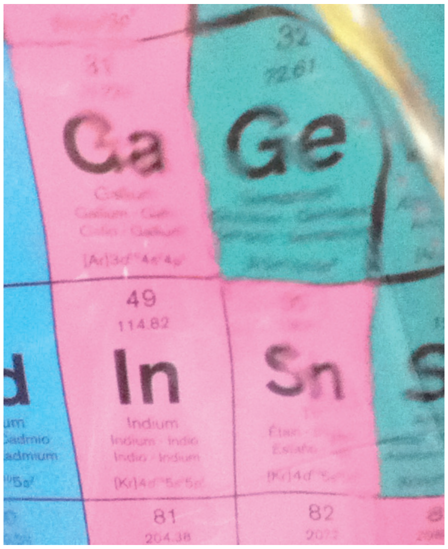


Figure 1

The effect of severe wavefront distortion is visible in this photo taken through a piece of cookware glass.

Methods for Quantifying Transmitted Wavefront Distortion

Interferometric Method

The primary alternative to the Shack-Hartmann detector is interferometry. An interferometric measurement of TWD works by interfering two plane waves. If the plane waves have traveled the same path length and are parallel, the resulting interferogram of the plane waves should be a field with uniform intensity. If we insert an imperfect optic into one of the two interferometer light paths, the optical path length is no longer constant for all parts of the wave. Some parts of the wave will be deflected or phase-shifted more than others due to imperfections of the optic. As a result, when light from the two light paths is recombined, the resulting pattern will no longer be uniform. Places where light destructively interferes will be dark and places where the light constructively interferes will appear bright. Some commonly resulting patterns can be seen below in figure 3.

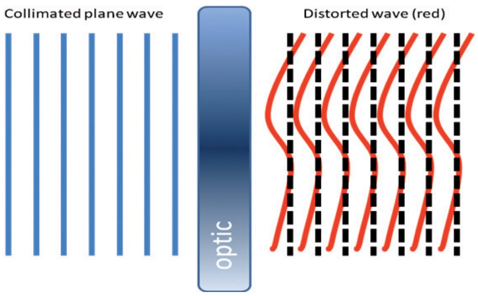


Figure 2

A plane wave travels through a slightly imperfect piece of glass. The resulting plane wave (red) deviates slightly from the original plane wave (black – shown as if it had not passed through any optic.)

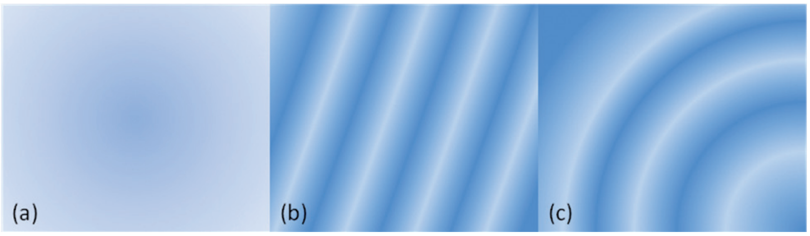


Figure 3

Depiction of interferograms a) Relatively uniformly intense field created by two parallel, plane waves, b) parallel fringes created by plane waves that are not parallel, c) curved fringes created by interfering a plane wave (reference leg of the interferometer) and a plane wave that has been distorted by an intervening optic. Specialized software is used to translate the fringe pattern into a quantitative value of TWD.

Shack-Hartmann Method

"Shack-Hartmann" derives from the names of two researchers who were responsible for advancing one of the primary components of the sensor, the lenslet array. The idea of creating an array of light points by spatial screening was first implemented by Johannes Hartmann in Germany in 1900 . Seventy-one years later, Roland Shack published a paper describing how the screen could be improved by replacing the apertures with tiny lenses . Shack's lenslet array was implemented for the purpose of measuring TWD.

A Shack-Hartmann instrument employs a completely different method for measuring TWD. The following diagram displays a simple Shack-Hartmann setup.

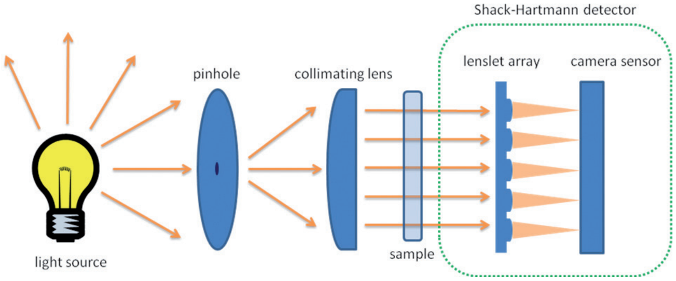


Figure 4 *Shack-Hartmann instrument*

To create a simple Shack-Hartmann based wavefront distortion detection instrument, only a few components are required. In Figure 4, a light source is passed through a pinhole to create a point source of light. That point source is collimated into a beam using a lens. It is in this collimated beam region that the sample will be placed. The light then passes into the Shack-Hartmann sensor.

There are two important components of the Shack-Hartmann sensor: a "lenslet" array (or a "microlens" array) and a camera sensor. The lenslet array is a regular, periodic distribution of tiny lenses. Usually, the lenslets are arranged into square or rectangular array. Behind this array sits the camera sensor. Often this sensor is a CCD array, but in principle, a Shack-Hartmann instrument could work with any camera – even a film camera.

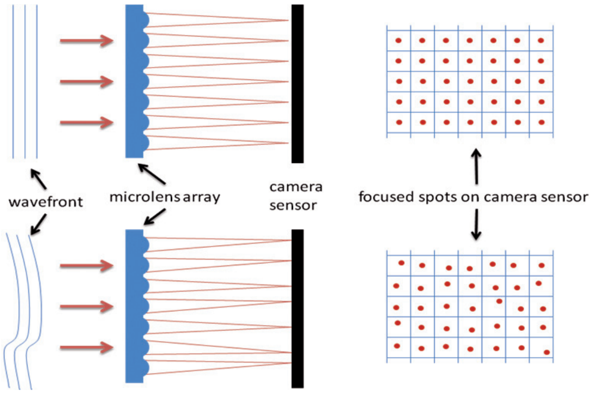


Figure 5

Light is focused onto a camera sensor inside the Shack-Hartmann detector. Each microlens focuses light to a point on the sensor, creating an array of points. In the top diagram, the incident light is a perfect plane wave. In the bottom diagram, the wavefront has been distorted.

Light focused on the camera sensor of a Shack-Hartmann detector will change position depending on the wavefront of the incoming light. In the top scenario, the light is a perfect plane wave and each microlens focuses the light to a point right in the center of its own region of the camera sensor. In the bottom scenario, the wavefront is distorted and the spots are no longer focused in the region directly behind the microlens. Instead, the spots have been displaced. By measuring the displacement of spots the wavefront distortion can be calculated. An actual spotfield from a Thor Labs Shack-Hartmann instrument is shown in Figure 6. A common useful visualization of the wavefront distortion is shown in Figure 7.

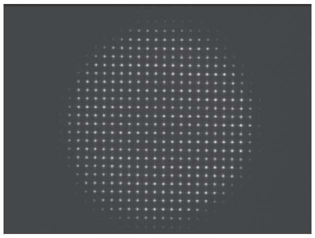


Figure 6

The actual "spotfield" from a Thor Labs Shack-Hartmann detector. Each spot is the light focused by an individual lenslet in a large array of lenslets.

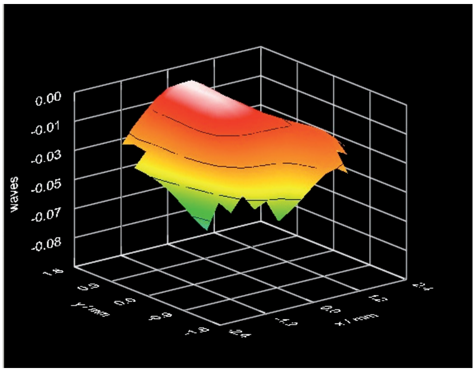


Figure 7

A depiction of TWD data taken from a Thor Labs Shack Hartmann sensor. The z-axis shows magnitude of TWD in waves at 633 nm. The axis of x and y demonstrates spatial position on the sensor.

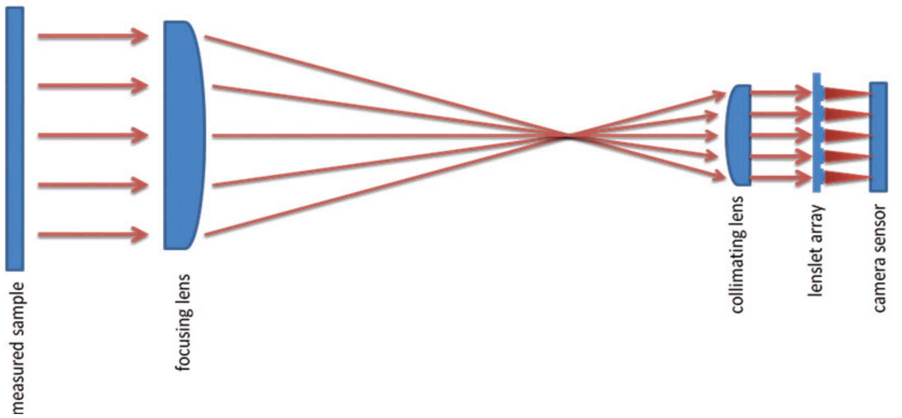


Figure 8

Adding a telescope allows the measured area to be much larger than the sensor.

In a commercial instrument, there are typically refinements made to a basic Shack-Hartmann design. One of the most common refinements is to add a telescope after the beam is collimated.

Adding a telescope (Figure 8) allows the measured area to be much larger than the size of the Shack-Hartmann sensor. Because the price of a sensor goes up very quickly with a larger size, it is much more economical to add a telescope than to buy a larger Shack-Hartmann sensor. Unfortunately, the addition of a telescope results in a loss in spatial resolution of data points. For example, if the collimated beam width at the measured sample is twice as large as the beam width at the sensor, then the data point density is only one-fourth its density without the larger collimated beam. However, with high quality optics even a moderate loss in data point density shouldn't result in severe data corruption problems such as aliasing.

Measuring TWD

The two most commonly recorded wavefront distortion statistics are peak-to-valley wavefront distortion and root-mean-square (RMS) wavefront distortion. Peak-to-valley distortion is the difference between the most positive and most negative values in the field of view. While peak-to-valley distortion only measures the difference between two data points, RMS distortion includes all data points in its calculation. If our data points are x1, x2, etc., this is computed as:

$$x_{rms} = \sqrt{\frac{1}{n} * (x_1{}^2 + x_2{}^2 + x_3{}^2 + \cdots + x_n{}^2)}$$

We currently employ two Shack Hartmann sensors with capability to measure peak-to-valley distortions as small as 1/15th of a 633 nm wave or RMS distortions as small as 1/50th of a 633 nm wave.

Another benefit of using a Shack-Hartmann sensor is its ability to separate distortion into unique "Zernike coefficients". Each Zernike coefficient corresponds with a specific type of aberration. For example, if the sample piece of glass is shaped slightly like a bi-concave lens it will exhibit a high value for the "defocus" coefficient ( ). The Shack-Hartmann software can distinguish aberration corresponding to different coefficients like astigmatism, coma, and tilt or spherical. Knowing the relative values of Zernike coefficients allows for specific correction of an optic by targeted polishing. For example, a common cause of "tilt" is glass that is wedge-shaped when viewed on edge. With additional polishing it is easy to remedy. Figure 9 shows a graphical depiction of the different Zernike coefficients.

Applications of the Shack-Hartmann Instrument

There two main applications of the Shack-Hartmann at Omega Optical; to validate finished product and provide verification that specifications have been met, and for performing in process manufacturing checks. A product can be measured at various points during production pinpointing steps that cause any additional wavefront distortion. Once these wavefront adding steps are discovered the material can be polished to correct for the introduced distortion.

TWD is one of the most critical interference filter specifications for anyone who is concerned with the integrity of the transmitted image. Biology and astronomy applications in particular are very concerned with image integrity. A TWD error that is imperceptible to the human eye in an interference filter could result in an inaccurate distance measurement between the moon and a planet or between organelles in a cell. With the help of a Shack-Hartmann we are certain of the quality of the images a filter will produce.

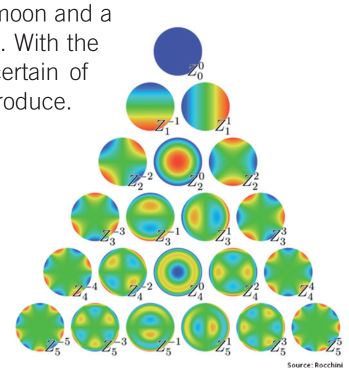


Figure 9

A graphical depiction of the Zernike coefficients. Applied to an optical piece; red indicates a region of positive wavefront distortion and blue indicates a region of negative wavefront distortion.

Stock and Standard products

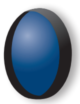
For a quick reference to all products that can be found in this catalog. For application specific products, dichroic beamsplitters, excitation and emission filters see pages 66-67.

The majority of the products we produce are custom manufactured to your specifications.

This capabilities catalog includes our stock products as well as a representation of filters assembled from our component inventory defined by industry standard specifications. The catalog does not reflect our complete line of products and capabilities.

Stock products are labeled as such throughout the catalog, and are available for immediate delivery.

Standard products are available to ship in 5 business days or less utilizing our component inventory.



UV

185BP19	XUV185-19	65
185BP20	XB32	49
190BP20	XB33	49
195BP20	XUV195-20	65
200BP10	XB36	49
200BP20	XB34	49
200BP25	XB35	49
210BP10	XB37	49
214BP10	XB38	49
214BP11	XUV214-11	65
214BP21	XUV214-21	65
220BP10	XB39	49
225BP30	XB01	Visit Website
228BP10	XB40	49
230BP10	XB200	Visit Website
232BP10	XB41	49
234.8NB7	XA01	44
234.9NB7	XA02	44
239BP10	XB42	49
240BP10	XB201	Visit Website
249.7NB7	XA03	44
250BP10	XB43	49
250BP30	XB02	65
253.7BP10	XB44	49
253.7BP12	XUV253.7-12	65
253.7BP25	XUV253.7-25	65
255NB7	XA04	44
260BP10	XB45	49
265.9NB7	XA05	44
265BP10	XB47	49
265BP13	XUV265-13	65
265BP25	XB46	49
265BP26	XUV265-26	65
266BP15	XL01	59
270BP10	XB48	49
280BP10	XB50	49
280BP14	XUV280-14	65
280BP25	XB49	49
280BP28	XUV280-28	65
282NB7	XA06	44
287.8NB7	XA07	44
288.2NB7	XA08	44
289BP10	XB51	49
290BP10	XB202	Visit Website
296.7BP10	XB52	49
300BP10	XB53	49
300BP30	XB03	65
303.9NB3	XA09	44
306.8NB7	XA10	44
310BP10	XB54	49
313BP10	XB55	49
320BP10	XB203	Visit Website
322.1NB2	XA11	44
325NB2	XL02	59
325NB3	XLK02	60
326.5NB4	XA12	44
330BP10	XB204	Visit Website
330WB80	XF1001	73,94
330WB80	XB04	Visit Website
331.1NB2	XA13	44
334BP10	XB56	49
337BP10	XB57	49
337NB3	XLK30	60
340AF15	XF1093	96
340BP10	XB58	49
350BP10	XB59	49
351NB3	XL31	59
351NB3	XLK31	60
355NB3	XL03	59
355NB3	XLK03	60
360BP10	XB60	49
360BP50	XB05	65
364NB4	XL32	59
364NB4	XLK32	60
365BP20	XB07	Visit Website
365QM35	XF1409	72,79
365WB50	XF1005	73,76,80,88,94, 95
370BP10	XB61	49
375BP6	XLD375	54
376BP3	XCC376-3	53
376BP8	XCC376-8	53
377NB3	XL30	59
379.8NB2	XA14	44
380AF15	XF1094	91,96
380BP10	XB62	49
380BP3	XCC380-3	53
380BP8	XCC380-8	53
380QM50	XF1415	72,79
385-485-560TBDR	XF2050	78,92
385-485-560TBEX	XF1057	78
385-502DBDR	XF2041	78,91
386-485-560TBEX	XF1059	78
387AF28	XF1075	73
390-486-577TBEX	XF1458	77
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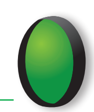
390BP10	XB63	49
396.1NB2	XA15	44



VISIBLE

395-540DBDR	XF2047	91
400-477-575TBDR	XF2048	78,92
400-477-580TBEX	XF1055	78
400-485-558-640QBDR	XF2046	78,92,95
400-485-580TBDR	XF2045	77,78,79,91,92,95
400-495-575TBDR	XF2051	78,92
400-495-575TBEX	XF1098	78
400-500DBEX	XF1048	78
400AF30	XF1076	73
400ALP	XF3097	73,94
400BP10	XB66	49

400DCLP	XF2001	72,73,76,79,80,88,94
400DF15	XF1006	91,92,95
400DF25	XB65	49
400DF50	XB64	49
403.3NB2	XA16	44
405.4NB3	XB68	49
405.8NB2	XA17	44
405-490-555-650QBEX	XF1053	78
405BP10	XB67	49
405BP3	XCC405-3	53
405BP6	XLD405	54
405BP8	XCC405-8	53
405DF40	XF1008	73,76
405NB5	XL33	59
405NB5	XLK33	60
405QM20	XF1408	79,91
407.9NB2	XA18	44
410BP40	XMV410	Visit Website
410DF10	XB69	49
410DRLP	XF2004	73
410DRLP	XF2085	72,79
413.8NB2	XA19	44
415BP3	XCC415-3	53
415BP8	XCC415-8	53
415DCLP	XF2002	96
415WB100	XF1301	93
417.2NB2	XA20	44
420DF10	XB70	49
422.7NB2	XA21	44
424DF44	XCY-424DF44	86
425DF45	XF1009	73,93,94
426.5NB4	XA22	44
426.7NB2	XA23	44
430DF10	XB71	49
430NB2	XL34	59
430NB2	XLK34	60
432NB2	XA24	44
435.8BP10	XB72	49
435.8NB2	XA25	44
435-546-633	XB29	Visit Website
435ALP	XF3088	73
435DRLP	XF2040	73
436-510DBDR	XF2065	78,92
436-510DBEX	XF1078	78
436AF8	XF1201	80,92
436DF10	XF1079	92
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439.7NB2	XA27	44
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440BP8	XLD440	54
440DF10	XB73	49
440QM21	XF1402	72,79
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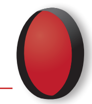
442NB2	XA28	44
442NB2	XL04	59
442NB2	XLK04	60
444QMLP	XRLP444	55
445 -535 -658	XB30	Visit Website
445-510-600TBDR	XF2090	92
445-525-650TBEM	XF3061	78,92
449BP38	XCY-449BP38	86
450AF65	XF3002	73,80,88,95
450BP3	XCC450-3	53
450BP8	XCC450-8	53
450DCLP	XF2006	76
450DF10	XB76	50
450DF25	XB75	50
450DF50	XB74	50
450QM60	XF3410	72,79
450WB80	XB08	58
451.2NB2	XA29	44
452.5NB2	XA30	44
455.4NB2	XA31	44
455DF70	XF1012	73
455DRLP	XF2034	72,73,79,80,88
457.9BP2	XLL457.9	57
457/488/514	XB09	Visit Website
457-528-600TBEM	XF3458	77,79,91
457-528-633TBEM	XF3058	78,92
457NB2	XL05	59
457NB2	XLK05	60
458NB5	XA32	44
460-520-602TBEM	XF3063	78,92
460-520-603-710QBEM	XF3059	78,92
460-550DBEM	XF3054	78,91
460ALP	XF3091	73
460DF10	XB77	50
463QMLP	XRLP463	55
465-535-640TBEM	XF3118	92
465AF30	XF3078	73
467NB2	XA33	44
470-530-620TBEM	XF3116	78,92
470-590DBEM	XF3060	91
470AF50	XF1087	74,84
470BP10	XLD470	54
470DF10	XB78	50
470QM40	XF1416	72
470QM50	XF1411	72
473NB8	XL35	59
473NB8	XLK35	60
475-550DBEM	XF3099	78,92
475-625DBDR	XF2401	77,91
475-625DBEX	XF1420	77
475AF20	XF1072	74,88
475AF40	XF1073	73,74,88
475BP40	XMV475	Visit Website
475DCLP	XF2007	73,93,94,
475QM20	XF1410	72
477.2NB2	XA34	44
477QMLP	XRLP477	55
480AF30	XF3075	73,80,88
480ALP	XF3087	73
480BP3	XCC480-3	53
480BP8	XCC480-8	53
480DF10	XB79	50
480DF60	XF1014	76
480QM20	XF1404	91
480QM30	XF3401	72,79
481.4NB2	XA35	44
484-575DBEX	XF1451	77
485-555-650TBDR	XF2054	78,92
485-555-650TBEX	XF1063	78
485-555DBDR	XF2039	97
485-560DBDR	XF2443	77,91
485-560DBEX	XF1450	77
485AF20	XF1202	80
485DF15	XF1042	91,92,95
485DF22	XF1015	74,76
485DRLP	XF2027	88
486.1DF10	XB80	50
488BP2.1	XLL488	57
488DF10	XB81	50
488NB3	XL06	59
488NB3	XLK06	60
490-550DBDR	XF2043	78,91,95
490-550DBEX	XF1050	78
490-575DBDR	XF2044	77,78,91
490-577DBEX	XF1051	78
490BP40	XMV490	Visit Website
490DF10	XB82	50
490DF20	XF1011	95,96
490QM20	XF1406	79,91
492BP3	XCC492-3	53
492BP8	XCC492-8	53
492QMLP	XRLP492	55
495DF20	XF3005	88
498.7NB2	XA36	44
500AF25	XF1068	74,88
500CFLP	XB10	Visit Website
500DF10	XB85	50
500DF25	XB84	50
500DF50	XB83	50
500DRLP	XF2037	74
500DRLP	XF2077	72,74,88
500QM25	XF1412	72
500RB100	XB18	Visit Website
505BP3	XCC505-3	53
505BP8	XCC505-8	53
505DRLP	XF2010	72,73,74,76,79,80,88
505DRLPXR	XF2031	97
505DRLPXR	XCY-505DRLPXR	86
509BP21	XCY-509BP21	86
510AF23	XF3080	74,88
510ALP	XF3086	73,94
510BP10	XB86	50

510BP3	XCC510-3	53
510BP8	XCC510-8	53
510DF25	XF1080	92,96
510QMLP	XF3404	72
510WB40	XF3043	96
514.5BP2.1	XLL514.5	57
514.5DF10	XB87	50
515-600-730TBEM	XF3067	78,92
515ALP	XF3093	73
515DRLP	XF2008	73
515DRLPXR	XF2058	96
515NB3	XL07	59
515NB3	XLK07	60
518NB2	XA37	44
518QM32	XF3405	72
519QMLP	XRLP519	55
520-580DBEM	XF3056	78,91
520-610DBEM	XF3456	77,91
520AF18	XF1203	80
520BP10	XB88	50
520DF40	XF3003	76
525-637DBEM	XF3457	77,91
525AF45	XF1074	74,88
525BP30	XCY-525BP30	86
525DRLP	XF2030	72,74,88
525QM45	XF1403	72
525WB20	XF3301	86,93
528-633DBEM	XF3057	78,91
530ALP	XF3082	74
530BP10	XB89	50
530DF30	XF3017	80,88
530QM20	XF3415	79
530QM40	XF1417	72
532 /1064	XB11	58
532/694/1064	XB12	58
532BP10	XB90	50
532BP2.2	XLL532	57
532NB3	XL08	59
532NB3	XLK08	60
535.1NB2	XA38	44
535-710DBEM	XF3470	77,91
535AF26	XF3079	88
535AF30	XF1103	74
535AF45	XF3084	74,88,95
535BP10	XLD535	54
535BP40	XMV535	Visit Website
535DF25	XF3011	96
535DF35	XF1019	76
535DF35	XF3007	74,76,88
535DF45	XCY-535DF45	86
535QM30	XF1422	79
535QM50	XF3411	72
537QMLP	XRLP537	55
540AF30	XF1077	74,76
540BP10	XB91	50
540DCLP	XF2013	96
543.5BP2.4	XLL543.5	57
543NB3	XL09	59
543NB3	XLK09	60
545AF35	XF3074	74,88
545AF75	XF3105	73,74
545BP40	XCY-545BP40	86
545DRLP	XF2203	80
545QM35	XF3407	72
545QM75	XF3406	72
546.1BP10	XB92	50
546.1NB3	XB93	50
546.6NB2	XA39	44
546AF10	XF1204	80
546BP3	XCC546-3	53
546BP8	XCC546-8	53
546DF10	XF1020	76
550-640DBEX	XF1062	78
550BP40	XMV550	Visit Website
550CFSP	XF85	96
550DCLP	XF2009	76
550DF10	XB96	50
550DF25	XB95	50
550DF30	XCY-550DF30	86
550DF50	XB94	50
550WB80	XB21	Visit Website
555-640DBDR	XF2053	78
555DF10	XF1043	91,92,95
555DRLP	XF2062	76,80
555QM30	XF1405	91
555QM50	XF1418	72
560AF55	XF1067	74
560BP10	XB97	50
560DCLP	XF2016	74,76
560DF15	XF1045	91,92,95
560DF40	XF1022	74
560DRLP	XF2017	72,74,79,88
560DRSP	XCY-560DRSP	86
560QM55	XF1413	72
561.4BP2.5	XLL561.4	57
565ALP	XF3085	74
565DRLPXR	XF2032	97
565QMLP	XF3408	72
565WB20	XF3302	80,86,88,93
568.2BP2.6	XLL568.2	57
568.2NB3	XB98	50
568NB3	XL36	59
568NB3	XLK36	60
570BP3	XCC570-3	53
570BP8	XCC570-8	53
570DF10	XB99	50
570DRLP	XF2015	74,76,
572AF15	XF1206	80
573QMLP	XRLP573	55
574BP26	XCY-574BP26	86
575ALP	XF3089	72
575DCLP	XCY-575DCLP	86
575DF25	XF1044	76,91,92
575QM30	XF1407	79,91
577DF10	XB100	50
577QM25	XF3416	79
578BP3	XCC578-3	53
578BP8	XCC578-8	53
580AF20	XF1207	80
580DF10	XB101	50
580DF30	XF3022	76,80,88,96
580DRLP	XF2086	72
580QM30	XF1424	79
585DF22	XCY-585DF22	86
585QM30	XF3412	72
585WB20	XF3303	86,93
589.5NB2	XA40	44
590BP40	XMV590	Visit Website
590DF10	XB102	50
590DF35	XF3024	76,95
590DRLP	XF2019	74,80
594NB3	XL10	59
594NB3	XLK10	60
595-700DBEM	XF3066	78
595AF60	XF3083	74,88
595DRLP	XF2029	72,74,79,88
595QM60	XF3403	72
600BP3	XCC600-3	53
600BP8	XCC600-8	53
600CFSP	XB22	50
600DF10	XB105	50
600DF25	XB104	50
600DF50	XB103	50
600DRLP	XF2020	74,76,80
605DF50	XF3019	88
605WB20	XF3304	86,93
607AF75	XF1082	75
610ALP	XF3094	74
610DF10	XB106	50
610DF20	XF1025	76
610DF30	XCY-610DF30	86
610DRLP	XF2014	96
612NB3	XL11	59
612NB3	XLK11	60
614BP21	XCY-614BP21	86
615DF45	XF3025	95
620BP3	XCC620-3	53
620BP8	XCC620-8	53
620DF10	XB107	50
620DF35	XF3020	80
625DF20	XF3309	86,93
625QM50	XF3413	72
627.8NB2	XA41	44
630AF50	XF1069	75
630BP3	XCC630-3	53

630BP8	XCC630-8	53
630DF10	XB108	50
630DF22	XCY-630DF22	86
630DF30	XF3028	76,80
630DRLP	XF2021	76
630QM36	XF3418	79
630QM40	XF1421	91
630QM50	XF1414	72
632.8BP3	XLL632.8	57
633	XB23	58
633NB3.0	XF1026	76
633NB4	XL12	59
633NB4	XLK12	60
635DF55	XF3015	76
635NB4	XL37	59
635NB4	XLK37	60
635QM30	XF1419	72
636.2NB2	XA42	44
638QMLP	XRLP638	55
640AF20	XF1208	80,95
640BP10	XLD640	54
640BP40	XMV640	Visit Website
640DF10	XB109	50
640DF20	XF1027	76
640DF35	XF3023	96
640DRLP	XF2022	76
640DRLP	XCY-640DRLP	86
640QM20	XF1425	79
643.9NB2	XA43	44
645AF75	XF3081	74,76
645QM75	XF3402	72
647.1BP3	XLL647.1	57
647NB4	XL13	59
647NB4	XLK13	60
650BP3	XCC650-3	53
650BP8	XCC650-8	53
650DF10	XB112	50
650DF25	XB111	50
650DF50	XB110	50
650DRLP	XF2035	72,75,76,80
650DRLP	XF2072	75
650NB5	XL38	59
650NB5	XLK38	60
650WB80	XB24	Visit Website
653QMLP	XRLP653	55
655AF50	XF1095	75
655DF30	XF1046	92
655WB20	XF3305	86,93
655WB25	XLK15	60
660BP20	XCY-660BP20	86
660BP3	XCC660-3	53
660BP40	XMV660	Visit Website
660BP8	XCC660-8	53
660DF10	XB113	50
660DF35	XCY-660DF35	86
660DF50	XF3012	76
660DRLP	XF2087	72,79
665WB25	XL15	59
670.8NB2	XA44	44
670DF10	XB114	50
670DF20	XF1028	75
670DF40	XF3030	76
670QMLP	XRLP670	55
671BP3	XLL671	57
675DCSPXR	XF2033	97
676NB4	XL14	59
676NB4	XLK14	60
677QM25	XF3419	79
680ASP	XF1085	75
680DF10	XB115	50
680DRLP	XCY-680DRLP	86
682DF22	XF3031	76,80
685AF30	XF1096	66,75
690ALP	XF3104	75
690DF10	XB116	50
690DRLP	XF2024	75
690DRLP	XF2075	75
690DRLP	XCY-690DRLP	86
692DRLP	XF2082	75
694NB4	XL16	59
694NB4	XLK16	60
695AF55	XF3076	75,88,95
695QM55	XF3409	72
700ALP	XF3095	75
700BP3	XCC700-3	53
700BP8	XCC700-8	53
700CFSP	XF86	96
700DF10	XB119	50
700DF25	XB118	50
700DF50	XB117	50
708DRLP	XF2083	75
710AF40	XF3113	75,86,93
710ASP	XF3100	97
710DF10	XB120	50
710DF20	XCY-710DF20	86
710DF40	XCY-710DF40	86
710DMLP	XCY-710DMLP	86
710QM80	XF3414	72
720DF10	XB121	51
730AF30	XF3114	75
730DF10	XB122	51
740ABLP	XCY-740ABLP	86
740DF10	XB123	51
748LP	XCY-748LP	86
750BP3	XCC750-3	53
750BP8	XCC750-8	53
750DF10	XB126	51
750DF25	XB125	51
750DF50	XB124	51

IR



760DF10	XB127	51
760DRLP	XCY-760DRLP	86
765DF10	XB128	51
766.5NB2	XA45	44
770DF10	XB129	51
775WB25	XL17	59
775WB25	XLK17	60
780BP3.1	XLL780	57
780DF10	XB130	51
780DF35	XF117	96
780NB2	XA46	44
785BP10	XLD785	54
785BP3.2	XLL785	57
785NB4	XL29	59
785NB4	XLK29	60
787DF18	XF1211	75
787DF43	XCY-787DF43	86
787QMLP	XRLP787	55
790BP40	XMV790	Visit Website
790DF10	XB131	51
792QMLP	XRLP792	55
794.7DF1.5	XB134	51
794.7DF10	XB132	51
794.7DF3	XB133	51
800DF10	XB137	51
800DF25	XB136	51
800DF50	XB135	51
800WB80	XF3307	86,93
805DRLP	XF2092	75
808BP3.7	XLL808	57
808WB25	XL39	59
808WB25	XLK39	60
810DF10	XB138	51
816QMLP	XRLP816	55
820DF10	XB139	51
825WB25	XL18	59
825WB25	XLK18	60
830BP3.7	XLL830	57
830DF10	XB140	51
830WB25	XL40	59
830WB25	XLK40	60
838QMLP	XRLP838	55
840DF10	XB141	51
840WB80	XF3308	86,93
843AF35	XF3121	75
850DF10	XB144	51
850DF25	XB143	51
850DF50	XB142	51
850WB25	XL19	59

850WB25	XLK19	60
860DF10	XB145	51
870DF10	XB146	51
875WB25	XL20	59
875WB25	XLK20	60
880DF10	XB147	51
890DF10	XB148	51
900DF10	XB151	51
900DF25	XB150	51
900DF50	XB149	51
910DF10	XB152	51
920DF10	XB153	51
930DF10	XB154	51
940DF10	XB155	51
950DF10	XB158	51
950DF25	XB157	51
950DF50	XB156	51
960DF10	XB159	51
970DF10	XB160	51
976BP4	XLL976	57
980BP4	XLL980	57
980DF10	XB161	51
980WB25	XL41	59
980WB25	XLK41	60
989QMLP	XRLP989	55
990DF10	XB162	51
1000DF10	XB165	52
1000DF25	XB164	52
1000DF50	XB163	52
1010DF10	XB166	52
1020DF10	XB167	52
1030BP10	XB168	52
1040BP10	XB169	52
1047.1BP1.7	XLL1047.1	57
1050BP10	XB170	52
1060BP10	XB171	52
1060NB8	XL21	59
1060NB8	XLK21	60
1064BP1.7	XLL1064	57
1064NB8	XL22	59
1064NB8	XLK22	60
1070BP10	XB172	52
1076QMLP	XRLP1076	55
1080BP10	XB173	52
1090BP10	XB174	52
1100BP10	XB175	52
1152NB10	XL23	59
1152NB10	XLK23	60
1200BP10	XB176	52
1300BP10	XB177	52
1310BP10	XB178	52
1310WB40	XL24	59
1310WB40	XLK24	60
1320NB10	XL25	59
1320NB10	XLK25	60
1330BP10	XB179	52
1335QMLP	XRLP1335	55
1350WB40	XL42	59
1350WB40	XLK42	60
1400BP10	XB180	52
1500BP10	XB181	52
1523NB10	XL26	59
1523NB10	XLK26	60
1550NB10	XL28	59
1550NB10	XLK28	60
1550WB50	XL27	59
1550WB50	XLK27	60
1600BP10	XB182	52
1650BP10	XB183	52
1700BP10	XB184	52
1800BP10	XB185	52
1900BP10	XB186	52
2000BP12	XB187	52
2100BP12	XB188	52
2200BP12	XB189	52
2300BP12	XB190	52
2400BP12	XB191	52
2500BP12	XB192	52
ND 0.05	XND0.05	97
ND 0.1	XND0.1	97
ND 0.2	XND0.2	97
ND 0.3	XND0.3	97
ND 0.4	XND0.4	97
ND 0.5	XND0.5	97
ND 0.6	XND0.6	97
ND 0.7	XND0.7	97
ND 0.8	XND0.8	97
ND 1.0	XND1.0	97
ND 2.0	XND2.0	97
ND 3.0	XND3.0	97
OG530	XF3018	76
OG590	XF3016	76

STANDARD – ANALYTICAL FILTERS

- Narrowband elemental emission line filters
- Designed to work in both arc and spark conditions
- Specific lines chosen for optimal separation from co-existing elements
- Available in 25 diameter
- Custom configurations available upon request

Analytical Filters

Element	CWL	CWL Tolerance	FWHM	FWHM Tolerance	Peak T%	Average Blocking	Minimum Blocking	Product SKU	Description
Beryllium / Be	234.8	+1.1 -.7 nm	7	± 1.4 nm	15%	OD6	OD3	XA01	234.8NB7
Arsenic / As	234.9	+1.1 -.7 nm	7	± 1.4 nm	15%	OD6	OD3	XA02	234.9NB7
Boron / B	249.7	+1.1 -.7 nm	7	± 1.4 nm	15%	OD6	OD3	XA03	249.7NB7
Phosphorus / P	255	+1.1 -.7 nm	7	± 1.4 nm	15%	OD6	OD3	XA04	255NB7
Platinum / Pt	265.9	+1.1 -.7 nm	7	± 1.4 nm	15%	OD6	OD3	XA05	265.9NB7
Hafnium / Ht	282	+1.1 -.7 nm	7	± 1.4 nm	15%	OD6	OD3	XA06	282NB7
Antimony / Sb	287.8	+1.1 -.7 nm	7	± 1.4 nm	15%	OD6	OD3	XA07	287.8NB7
Silicon / Si	288.2	+1.1 -.7 nm	7	± 1.4 nm	15%	OD6	OD3	XA08	288.2NB7
Germanium / Ge	303.9	+.6 -.4 nm	3	± .4 nm	15%	OD5	OD3	XA09	303.9NB3
Bismuth / Bi	306.8	+1.1 -7 nm	7	± 1.4 nm	15%	OD5	OD3	XA10	306.8NB7
Iridium / Ir	322.1	+.5 -.2 nm	2	± .4 nm	25%	OD5	OD3	XA11	322.1NB2
Copper / Cu	326.5	+.6 -.4 nm	4	± .8 nm	30%	OD5	OD3	XA12	326.5NB4
Tantalum / Ta	331.1	+.5 -.2 nm	2	± .4 nm	25%	OD5	OD3	XA13	331.1NB2
Molybdenum / Mo	379.8	+.3 -.2 nm	2	± .5 nm	25%	OD5	OD3	XA14	379.8NB2
Aluminum / Al	396.1	+.3 -.2 nm	2	± .4 nm	20%	OD	OD4	XA15	396.1NB2
Manganese / Mn	403.3	+.3 -.2 nm	2	± .4 nm	30%	OD5	OD4	XA16	403.3NB2
Lead / Pb	405.8	+.3 -.2 nm	2	± .4 nm	30%	OD5	OD4	XA17	405.8NB2
Niobium / Nb	407.9	+.3 -.2 nm	2	± .4 nm	35%	OD5	OD4	XA18	407.9NB2
Cerium / Ce	413.8	+.3 . nm	2	± .4 nm	35%	OD5	OD4	XA19	413.8NB2
Gallium / Ga	417.2	+.3 -.2 nm	2	± .4 nm	35%	OD5	OD4	XA20	417.2NB2
Calcium / Ca	422.7	+.3 -.2 nm	2	± .4 nm	35%	OD5	OD4	XA21	422.7NB2
Chromium / Cr	426.5	+.6 -.4 nm	4	± .8 nm	45%	OD5	OD4	XA22	426.5NB4
Carbon / C	426.7	+.3 -.2 nm	2	± .4 nm	35%	OD5	OD4	XA23	426.7NB2
Tungsten / W	432	+.3 -.2 nm	2	± .4 nm	40%	OD5	OD4	XA24	432NB2
Mercury / Hg	435.8	+.3 -.2 nm	2	± .4 nm	40%	OD5	OD4	XA25	435.8NB2
Vanadium / V	437.9	+.3 -.2 nm	2	± .4 nm	40%	OD5	OD4	XA26	437.9NB2
Iron / Fe	439.7	+.3 -.2 nm	2	± .4 nm	40%	OD5	OD4	XA27	439.7NB2
Nickel / Ni	442	+.3 -.2 nm	2	± .4 nm	40%	OD5	OD4	XA28	442NB2
Indium / In	451.1	+.3 -.2 nm	2	± .4 nm	40%	OD5	OD4	XA29	451.2NB2
Tin / Sn	452.5	+.3 -.2 nm	2	± .4 nm	40%	OD5	OD4	XA30	452.5NB2
Barium / Ba	455.4	+.3 -.2 nm	2	± .4 nm	40%	OD5	OD4	XA31	455.4NB2
Cesium / Cs	458	+.8 -.5 nm	5	± 1 nm	55%	OD5	OD4	XA32	458NB5
Strontium / Sr	467	+.3 -.2 nm	2	± .4 nm	45%	OD5	OD4	XA33	467NB2
Zirconium / Zr	477.2	+.3 -.2 nm	2	± .4 nm	45%	OD5	OD4	XA34	477.2NB2
Cobalt / Co	481.4	+.3 -.2 nm	2	± .4 nm	40%	OD5	OD4	XA35	481.4NB2
Titanium / Ti	498.7	+.3 -.2 nm	2	± .4 nm	50%	OD5	OD4	XA36	498.7NB2
Magnesium / Mg	518	+.3 -.2 nm	2	± .4 nm	50%	OD5	OD4	XA37	518NB2
Thallium / Tl	535.1	+.3 -.2 nm	2	± .4 nm	50%	OD5	OD4	XA38	535.1NB2
Silver / Ag	546.6	+.3 -.2 nm	2	± .4 nm	50%	OD5	OD4	XA39	546.6NB2
Sodium / Na	589.5	+.3 -.2 nm	2	± .4 nm	50%	OD5	OD4	XA40	589.5NB2
Gold / Au	627.8	+.3 -.2 nm	2	± .4 nm	50%	OD5	OD4	XA41	627.8NB2
Zinc / Zn	636.2	+.3 -.2 nm	2	± .4 nm	50%	OD5	OD4	XA42	636.2NB2
Cadmium / Cd	643.9	+.3 -.2 nm	2	± .4 nm	50%	OD5	OD4	XA43	643.9NB2
Lithium / Li	670.8	+.3 -.2 nm	2	± .4 nm	50%	OD5	OD4	XA44	670.8NB2
Potassium / K	766.5	+.3 -.2 nm	2	± .4 nm	50%	OD5	OD4	XA45	766.5NB2
Rubidium / Rb	780	+.3 -.2 nm	2	± .4 nm	50%	OD5	OD4	XA46	780NB2

Throughout our history, we have designed and manufactured custom filters and standard prescription filters to the highest imaging quality standards for astronomers, atmospheric scientists, and aerospace instrumentation companies worldwide. Applications include both terrestrial and space-based observational instruments. We are the supplier of choice for a wide variety of prestigious universities, observatories, government agencies, and international consortia. As instrument technologies and applications evolve, we work collaboratively with our customers to develop solutions for the spectral, optical, and environmental demands that will define observational astronomy and aerospace applications in the future.

Hubble Space Telescope (HST)

We have played a key role as the supplier of interference filters throughout the existence of the Wide Field Planetary Camera 2 and 3 (WFPC2, WFPC3), in service from 1993 – to date. Our contribution of broad-band and medium band filters, covering the ultraviolet to near infrared spectrum, helped extend the world's view to the furthest reaches of space through observations of the Hubble Deep and Ultra-Deep Fields. Closer to home, the now iconic “Pillars of Creation” in the Eagle Nebula, demonstrating star birth in stellar nurseries, was a major achievement in astronomical imaging. We are pleased to have been instrumental in the investigation of countless phenomena from galactic super clusters to intricate nebulas and the first direct observation of an extra-solar planet. As a supplier of filters for the next generation WFPC3 we are proud to continue our support as NASA extends its reach to the edge of the visible universe.

Mars Rovers

Our filters continue to explore the Martian landscape on the recently launched Curiosity as well as both the Spirit and Opportunity Rovers. The original launch of Spirit and Opportunity utilized a total of 3 sensor systems sending images of Mars in unprecedented clarity. Since 2004 the "Pancam" has delivered high resolution multispectral images using a total of 16 filters divided between two detectors. Among the many mineralogical discoveries, our filters helped prove that water was present on the surface of Mars, furthering the consideration that life may have once existed on the red planet.

Custom Filters & Sets

Our ability to customize filters for imaging systems sets us apart from other filter companies. With over 25 deposition chambers in service employing a range of coating technologies from reactive sputtering and ion-assisted refractory oxide to physical vapor deposition, we have the most important capacity for a filter supplier, design flexibility. Below are general guidelines of our capabilities:

- **Wavelength Range:** 185nm – 2500nm
- **Bandwidths:** minimum 0.15nm to several hundred nm
- **Design Considerations:** Critical throughput, band-shape and bandwidth requirements
- **Size:** 2mm – 210mm
- **Sets:** Matching physical and optical performance attributes
- **Materials:** Space-flight compatible

High Spectral Performance

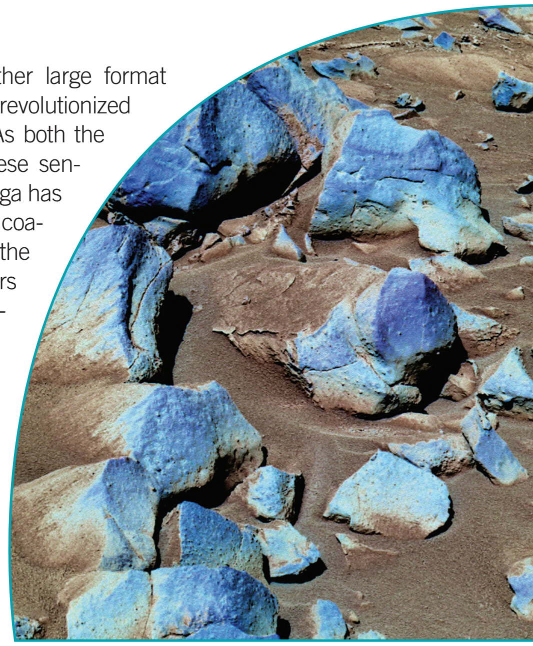
We achieve maximum throughput while adhering to critical band-shape tolerances from the UV to NIR. Placement of cut-on/cut-off edges are carefully controlled and optical densities in excess of OD6 ensure that adjacent spectral regions do not impart noise on one another through crosstalk.

Optical Performance

As critical to the spectral performance of our filters is the preparation and care taken in the choice of substrates. Each filter is polished to guarantee optimum image quality.

Large format filters

The use of CCD and other large format imaging detectors has revolutionized the study of astronomy. As both the size and sensitivity of these sensors have increased, Omega has pushed the envelope of coating technology to meet the need for large format filters up to 210mm. Our designs achieve the highest level of uniformity while maintaining the critical surface quality and transmitted wave-front requirements so critical to precision imaging.



Martian surface.
Photo courtesy of NASA/JPL/Cornell

Photometric Sets

Common to the astronomy community is the need for precision photometric sets. Omega manufactures a wide range of interference filters for color imaging from Bessel, SDSS, and Johnson/Cousins in custom configurations to accommodate specific detector sensitivities. In addition to the materials and construction of our photometric sets, filter matching is an important consideration. Consistency between filters in relation to band shape, cut-on/cut-off, placement of adjacent spectral regions, throughput, attenuation, sensitivity to system focal ratio, as well as operating temperature, is controlled within strict tolerances.

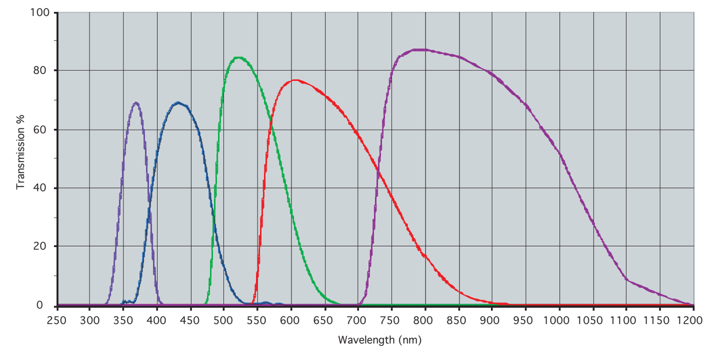
Bessel Sets

Omega Optical Bessel Photometric Sets are manufactured to the highest optical standards as defined by M. Bessel. In addition to our stock Bessel sets, custom filters are available to compensate for such aberrations as atmospheric light pollution and dedicated imaging applications.

- **TWD** ¼ wave (or better) per inch
- **Wedge** <30 arc seconds
- **Surface Quality:** E/E as defined by Mil-C-48497A
- **Anti-Reflective Coating:** multi-layer dielectric AR coating on both surface. R typically <0.5% for optimal transmission & reduce ghosting.
- **Anti-Reflective Coating Durability:** to moderate abrasion as defined by Mil-48497A
- **Curves:** Spestrophotometric curves are provided for each filter set.

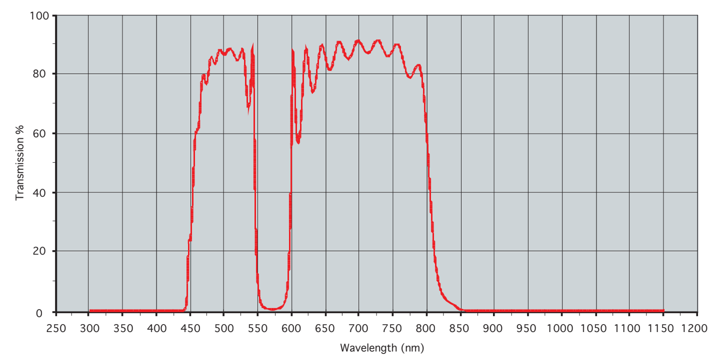
▶ **Please see our website for all options.**

Bessel Filter Sets



Curves, *left to right:* **U, B, V, R, I**

V+R Dual Band Bessel Filter with light pollution surpression



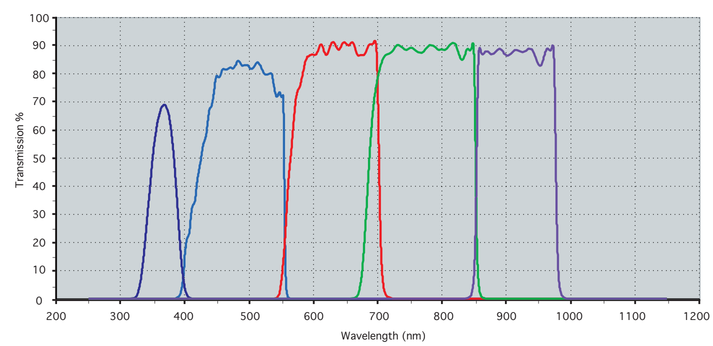
SDSS Photometric Set

(Sloan Digital Sky Survey)

We now offer a new photometric filter set matching the specifications set forth by the Sloan Digital Sky Survey. These filters, comprising the u' g' r' i' z' (ultraviolet, green, red, near infrared, and infrared) spectrum, cover wavelengths from 3543 to 9134 angstroms. Our new set takes advantage of new glass types to provide higher transmission and sharper edges.

▶ **Please see our website for all options.**

SDSS Photometric Set



Projects

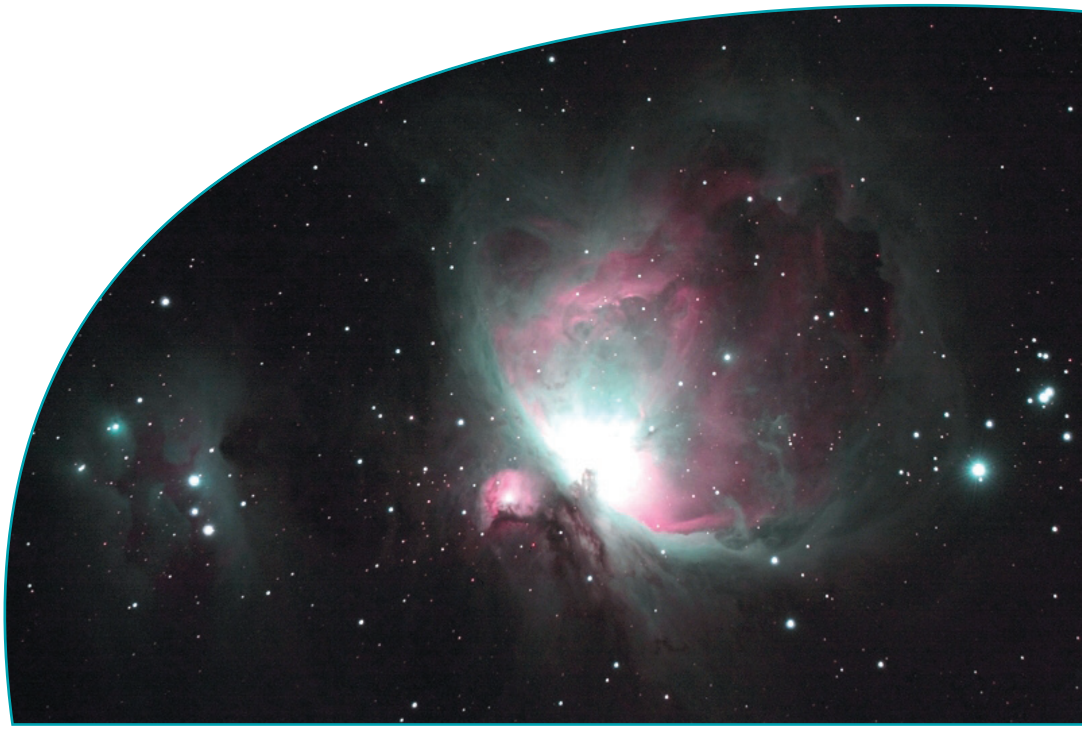
Omega Optical has many years of experience designing and manufacturing imaging system filters critical to astronomy and aerospace applications for organizations such as:

- **AURA** - **A**ssociation of **U**niversities for **R**esearch in **A**stronomy
- **Canadian-France-Hawaii Telescope**
- **ESA Giotto Mission**
- **European Southern Observatory Very Large Telescope**
  - **- CONICA - CO**udé **N**ear **I**nfrared **CA**mera (VLT)
  - **- OSIRIS**
- **Canadian Space Agency**
  - **- BRITE- BRI**ght **T**arget **E**xplorer Constellation
- **GRANTECAN**
- **NASA JPL Star Dust Project**
- **NASA JPL Hubble Space Telescope WFPC2 & WFPC3**
- **NASA JPL Martian Rovers** Spirit and Opportunity
- **Observatories of the Carnegie Institute of Washington**
- **US Naval Observatory**

Optical Filter Capabilities

Our filters are used for a wide range of astronomy studies. Following is a partial list of products utilized by researchers, universities, observatories and government agencies.

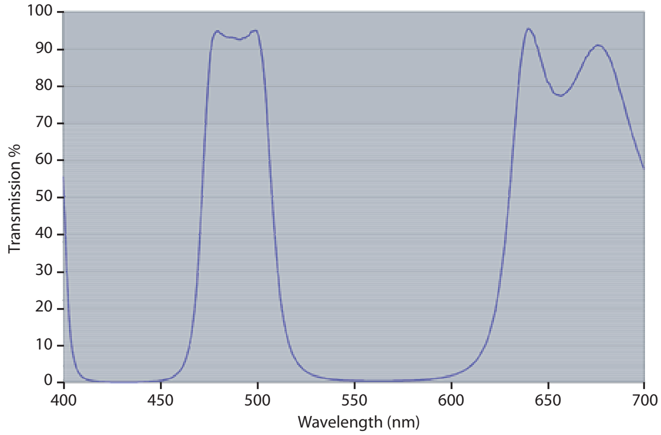
- **Solar Observation:**
  H-alpha
  H-beta
- **Nebula and Cometary Studies:**
  OII
  OIII
  SII
  CII
  CIII
- **IR Astronomy:**
  J, H, K Bands
- **Photometric Sets**
  Bessel (UBVRI)
  Johnson/Cousins (UBVRI)
  Stromgren (UBVY) – Beta Wide & Narrow
  SDSS (u', g', r', I', z')
  Thuan-Gunn
  V+R Dual Band Bessel Filter with Light Pollution Supression
- **Other**
  Detector Compensation
  Harris R
  Mould R-I



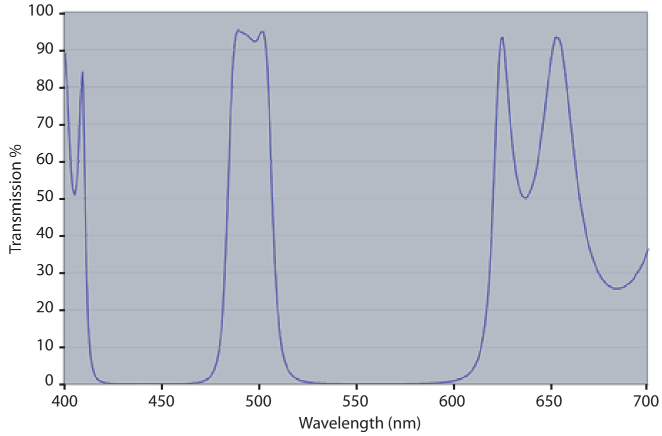
Brian W. Allan, MSc., PhEng. shot the M42 nebula using Omega Optical's VHT filter, TeleVue 102 with 0.8 reducer (700 mm) and Canon 50D camera.

Designed to benefit both visual and CCD imaging, each filter is crafted with the knowledge that every photon counts. With this principle in mind, our coatings achieve transmission in excess of 90%, while tightly controlled parallelism and transmitted wavefront keep the image crisp and distortion free. Each design also attenuates the critical 540-590nm range where light pollution is most prevalent. In eliminating these wavelengths, the contrast between intricate nebulas, faint galaxies and the background of space is more apparent.

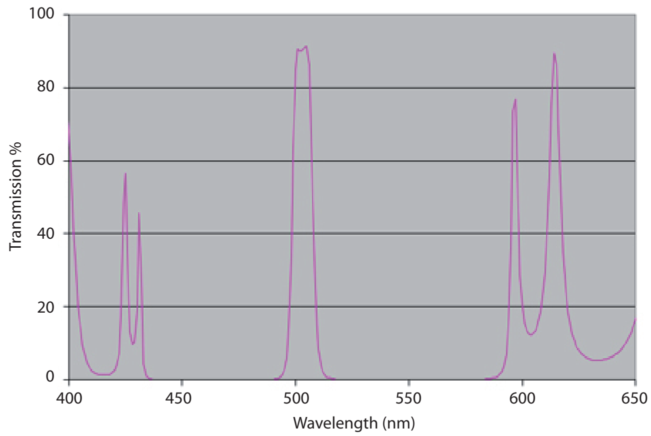
Amateur Astronomy filters are available in both **1-1/4" and 2" diameter** threaded rings and are housed in a protective case for storage. Interference coatings are single-surface, ion beam sputtered for maximum resistance to environmental stress.



Measured spectral data for typical **VHT** filter



Measured spectral data for typical **NPB** filter



Measured spectral data for typical **HPOIII** filter

▶ **Please see our website for all options.**

Customer Reviews

I recently purchased GCE, NPB and VHT filters from you. I have used the VHT filter to shoot Orion nebula (M42) and it has been my best shot ever!

Brian, Sundre, Alberta, Canada

The filter just works. It really does enhance the galactic structure and shape. It just does the job. The galaxies I looked at really "popped" and did not look like a subtle fuzz against bright sky.

Howard, Cleveland, Ohio

I am still loving the VHT and NPB filters... they are the best...

Darren, Brisbane, Australia

Our line of standard interference filters is representative of typical industry specifications. Available to ship in 5 business days. Need sooner? Please contact us.

Bandpass Filters - UV

Center Wavelength (nm)	FWHM	Peak T%	Minimum Optical Density	Product SKU	Description
185	20	12%	4	XB32	185BP20
190	20	12%	4	XB33	190BP20
200	20	12%	4	XB34	200BP20
200	25	12%	3	XB35	200BP25
200	10	12%	3	XB36	200BP10
210	10	12%	3	XB37	210BP10
214	10	12%	3	XB38	214BP10
220	10	12%	3	XB39	220BP10
228	10	12%	3	XB40	228BP10
232	10	12%	3	XB41	232BP10
239	10	12%	3	XB42	239BP10
250	10	12%	3	XB43	250BP10
253.7	10	12%	3	XB44	253.7BP10
260	10	12%	3	XB45	260BP10
265	25	20%	3	XB46	265BP25
265	10	12%	3	XB47	265BP10
270	10	12%	3	XB48	270BP10
280	25	20%	3	XB49	280BP25
280	10	12%	3	XB50	280BP10
289	10	12%	3	XB51	289BP10
296.7	10	12%	3	XB52	296.7BP10
300	10	12%	3	XB53	300BP10
310	10	12%	3	XB54	310BP10
313	10	12%	3	XB55	313BP10
334	10	25%	3	XB56	334BP10
337	10	25%	3	XB57	337BP10
340	10	25%	3	XB58	340BP10
350	10	25%	3	XB59	350BP10
360	10	25%	3	XB60	360BP10
370	10	25%	3	XB61	370BP10
380	10	25%	3	XB62	380BP10
390	10	25%	3	XB63	390BP10

Bandpass Filters - Visible

Center Wavelength (nm)	FWHM	Peak T%	Minimum Optical Density	Product SKU	Description
400	50	40%	4	XB64	400DF50
400	25	40%	4	XB65	400DF25
400	10	35%	4	XB66	400BP10
405	10	35%	4	XB67	405BP10
405.4	3	30%	4	XB68	405.4NB3
410	10	50%	4	XB69	410DF10
420	10	50%	4	XB70	420DF10
430	10	50%	4	XB71	430DF10
435.8	10	50%	4	XB72	435.8BP10
440	10	60%	4	XB73	440DF10

Our line of standard interference filters is representative of typical industry specifications. Available to ship in 5 business days. Need sooner? Please contact us.

Bandpass Filters - Visible *Continued*

Center Wavelength (nm)	FWHM	Peak T%	Minimum Optical Density	Product SKU	Description
450	50	60%	4	XB74	450DF50
450	25	60%	4	XB75	450DF25
450	10	60%	4	XB76	450DF10
460	10	60%	4	XB77	460DF10
470	10	60%	4	XB78	470DF10
480	10	70%	4	XB79	480DF10
486.1	10	70%	4	XB80	486.1DF10
488	10	70%	4	XB81	488DF10
490	10	70%	4	XB82	490DF10
500	50	70%	4	XB83	500DF50
500	25	70%	4	XB84	500DF25
500	10	70%	4	XB85	500DF10
510	10	70%	4	XB86	510BP10
514.5	10	70%	4	XB87	514.5DF10
520	10	70%	4	XB88	520BP10
530	10	70%	4	XB89	530BP10
532	10	70%	4	XB90	532BP10
540	10	70%	4	XB91	540BP10
546.1	10	70%	4	XB92	546.1BP10
546.1	3	70%	4	XB93	546.1NB3
550	50	65%	4	XB94	550DF50
550	25	65%	4	XB95	550DF25
550	10	65%	4	XB96	550DF10
560	10	65%	4	XB97	560BP10
568.2	3	65%	4	XB98	568.2NB3
570	10	65%	4	XB99	570DF10
577	10	65%	4	XB100	577DF10
580	10	65%	4	XB101	580DF10
590	10	65%	4	XB102	590DF10
600	50	65%	4	XB103	600DF50
600	25	65%	4	XB104	600DF25
600	10	65%	4	XB105	600DF10
610	10	65%	4	XB106	610DF10
620	10	65%	4	XB107	620DF10
630	10	65%	4	XB108	630DF10
640	10	65%	4	XB109	640DF10
650	50	65%	4	XB110	650DF50
650	25	65%	4	XB111	650DF25
650	10	65%	4	XB112	650DF10
660	10	65%	4	XB113	660DF10
670	10	65%	4	XB114	670DF10
680	10	65%	4	XB115	680DF10
690	10	65%	4	XB116	690DF10
700	50	75%	4	XB117	700DF50
700	25	75%	4	XB118	700DF25
700	10	75%	4	XB119	700DF10
710	10	75%	4	XB120	710DF10

Our line of standard interference filters is representative of typical industry specifications. Available to ship in 5 business days. Need sooner? Please contact us.

Bandpass Filters - Visible *Continued*

Center Wavelength (nm)	FWHM	Peak T%	Minimum Optical Density	Product SKU	Description
720	10	75%	4	XB121	720DF10
730	10	75%	4	XB122	730DF10
740	10	75%	4	XB123	740DF10
750	50	75%	4	XB124	750DF50
750	25	75%	4	XB125	750DF25
750	10	75%	4	XB126	750DF10

Bandpass Filters - IR

Center Wavelength (nm)	FWHM	Peak T%	Minimum Optical Density	Product SKU	Description
760	10	75%	4	XB127	760DF10
765	10	75%	4	XB128	765DF10
770	10	75%	4	XB129	770DF10
780	10	75%	4	XB130	780DF10
790	10	75%	4	XB131	790DF10
794.7	10	75%	4	XB132	794.7DF10
794.7	3	75%	4	XB133	794.7DF3
794.7	1.5	75%	4	XB134	794.7DF1.5
800	50	75%	4	XB135	800DF50
800	25	75%	4	XB136	800DF25
800	10	75%	4	XB137	800DF10
810	10	75%	4	XB138	810DF10
820	10	75%	4	XB139	820DF10
830	10	75%	4	XB140	830DF10
840	10	75%	4	XB141	840DF10
850	50	75%	4	XB142	850DF50
850	25	75%	4	XB143	850DF25
850	10	75%	4	XB144	850DF10
860	10	75%	4	XB145	860DF10
870	10	75%	4	XB146	870DF10
880	10	75%	4	XB147	880DF10
890	10	75%	4	XB148	890DF10
900	50	75%	4	XB149	900DF50
900	25	75%	4	XB150	900DF25
900	10	75%	4	XB151	900DF10
910	10	75%	4	XB152	910DF10
920	10	75%	4	XB153	920DF10
930	10	75%	4	XB154	930DF10
940	10	75%	4	XB155	940DF10
950	50	75%	4	XB156	950DF50
950	25	75%	4	XB157	950DF25
950	10	75%	4	XB158	950DF10
960	10	75%	4	XB159	960DF10
970	10	75%	4	XB160	970DF10
980	10	75%	4	XB161	980DF10
990	10	75%	4	XB162	990DF10

Our line of standard interference filters is representative of typical industry specifications. Available to ship in 5 business days. Need sooner? Please contact us.

Bandpass Filters - IR

Center Wavelength (nm)	FWHM	Peak T%	Minimum Optical Density	Product SKU	Description
1000	50	40%	4	XB163	1000DF50
1000	25	45%	4	XB164	1000DF25
1000	10	45%	4	XB165	1000DF10
1010	10	45%	4	XB166	1010DF10
1020	10	45%	4	XB167	1020DF10
1030	10	45%	4	XB168	1030BP10
1040	10	45%	4	XB169	1040BP10
1050	10	45%	4	XB170	1050BP10
1060	10	45%	4	XB171	1060BP10
1070	10	45%	4	XB172	1070BP10
1080	10	45%	4	XB173	1080BP10
1090	10	45%	4	XB174	1090BP10
1100	10	40%	4	XB175	1100BP10
1200	10	40%	4	XB176	1200BP10
1300	10	40%	4	XB177	1300BP10
1310	10	40%	4	XB178	1310BP10
1330	10	40%	4	XB179	1330BP10
1400	10	40%	4	XB180	1400BP10
1500	10	40%	4	XB181	1500BP10
1600	10	40%	4	XB182	1600BP10
1650	10	40%	4	XB183	1650BP10
1700	10	40%	4	XB184	1700BP10
1800	10	60%	4	XB185	1800BP10
1900	10	60%	4	XB186	1900BP10
2000	12	65%	4	XB187	2000BP12
2100	12	60%	4	XB188	2100BP12
2200	12	60%	4	XB189	2200BP12
2300	12	60%	4	XB190	2300BP12
2400	12	60%	4	XB191	2400BP12
2500	12	55%	4	XB192	2500BP12

Specifications

	CWL Range	Specification	Blocking Range
Blocking	185 - 200 nm	OD 4 Min.	UV to FAR IR
	200 - 313 nm	OD 6 Avg. / OD 3 Min.	UV to FAR IR
	334 - 390 nm	OD 6 Avg. / OD 3 Min.	UV to 1,300 nm
	400 - 1,000 nm	OD 6 Avg. / OD 4 Min.	UV to 1,150 nm
	1,000 - 1,700 nm	OD 4 Min.	UV to FAR IR
	1,800 - 2,500 nm	OD 4 Min.	UV to 3,000 nm
Physical	Size	25, 50, 50 x 50 mm	
	Thickness	< 7.0 mm	

50x50 size is not available for products in the following ranges 185 - 313 nm, and 1000 - 2500 nm.

CUSTOM CONFIGURATIONS AVAILABLE UPON REQUEST

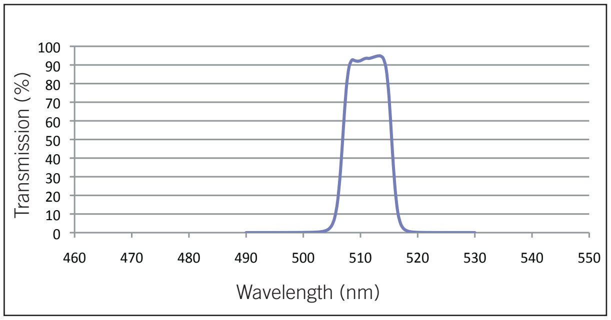
QuantaMAX™ for Clinical Chemistry and Biomedical Instrumentation Filters

Center Wavelength (nm)	Bandwidth (nm)	Transmission (Peak)	Product SKU	Description
376	3	> 50%	XCC376-3	376BP3
376	8	> 50%	XCC376-8	376BP8
380	3	> 50%	XCC380-3	380BP3
380	8	> 50%	XCC380-8	380BP8
405	3	> 90%	XCC405-3	405BP3
405	8	> 90%	XCC405-8	405BP8
415	3	> 90%	XCC415-3	415BP3
415	8	> 90%	XCC415-8	415BP8
450	3	> 90%	XCC450-3	450BP3
450	8	> 90%	XCC450-8	450BP8
480	3	> 90%	XCC480-3	480BP3
480	8	> 90%	XCC480-8	480BP8
492	3	> 90%	XCC492-3	492BP3
492	8	> 90%	XCC492-8	492BP8
505	3	> 90%	XCC505-3	505BP3
505	8	> 90%	XCC505-8	505BP8
510	3	> 90%	XCC510-3	510BP3
510	8	> 90%	XCC510-8	510BP8
546	3	> 90%	XCC546-3	546BP3
546	8	> 90%	XCC546-8	546BP8
570	3	> 90%	XCC570-3	570BP3
570	8	> 90%	XCC570-8	570BP8
578	3	> 90%	XCC578-3	578BP3
578	8	> 90%	XCC578-8	578BP8
600	3	> 90%	XCC600-3	600BP3
600	8	> 90%	XCC600-8	600BP8
620	3	> 90%	XCC620-3	620BP3
620	8	> 90%	XCC620-8	620BP8
630	3	> 90%	XCC630-3	630BP3
630	8	> 90%	XCC630-8	630BP8
650	3	> 90%	XCC650-3	650BP3
650	8	> 90%	XCC650-8	650BP8
660	3	> 90%	XCC660-3	660BP3
660	8	> 90%	XCC660-8	660BP8
700	3	> 90%	XCC700-3	700BP3
700	8	> 90%	XCC700-8	700BP8
750	3	> 90%	XCC750-3	750BP3
750	8	> 90%	XCC750-8	750BP8

Specifications

Physical	Size	6 x 6, 10, 12.5 and 15 mm
	Tolerance	+0.0/-0.2 mm
	Thickness	2 mm
Blocking	OD ≥ 5 average UV-1100 nm	
Surface Quality	E/E per MIL-C-48497A	
Filter Construction	Single substrate surface coated	

XCC510-8 – actual representation



CUSTOM CONFIGURATIONS AVAILABLE UPON REQUEST

QUANTAMAX™ LASER DIODE CLEAN-UP FILTERS

- Rejects undesirable diode emissions
- Exceptional transmission >90%

QuantaMAX

In the fast growing category of applications and instrumentation that utilize laser sources such as Raman Spectroscopy, Confocal and Multiphoton Microscopy, and Flow Cytometry, it is critical to eliminate all unwanted laser background, scatter, and plasma in order to optimize signal-to-noise. Laser line and shortpass edge filters can be used to clean-up the signal at the laser source. Longpass edge and laser rejection filters can be used for rejecting unwanted noise at the detector.

- **Laser Diode Filters** are designed to maximize transmission of the primary emission wavelength of the diode, while eliminating secondary extended emissions that are typical of laser diodes. The precision plane parallel substrates allow for minimum beam deviation and low wavefront error. It is also possible to tilt tune these filters to optimize the peak output of the laser diode/filter combination.

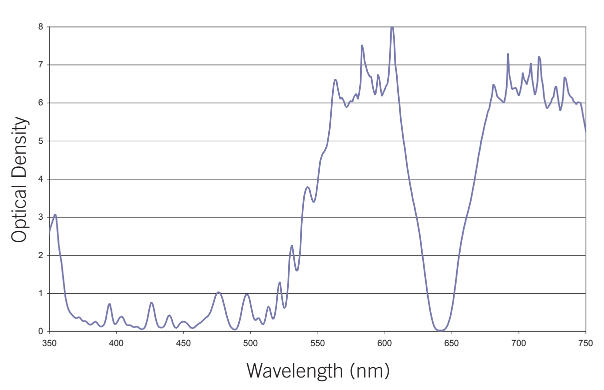
QuantaMAX™ Laser Diode Clean-Up Filters

Laser Diode (nm)	T% and Bandwidth	Product SKU	Description
375	> 90% over 6 nm	XLD375	375BP6
405	> 90% over 6 nm	XLD405	405BP6
440	> 90% over 8 nm	XLD440	440BP8
470	> 90% over 10 nm	XLD470	470BP10
535	> 90% over 10 nm	XLD535	535BP10
640	> 90% over 10 nm	XLD640	640BP10
785	> 90% over 10 nm	XLD785	785BP10

Specifications

Physical	**Size**	Stock and custom sizes available
	Thickness	< 4.0 mm
Transmission Ripple	< +/- 1.5% typical	
Angle of Incidence	0.0° +/- 5.0°	
Transmitted Wavefront Error	< 0.5 λ over the clear aperture at 633 nm	
Beam Deviation	< 15 arc seconds	
Surface Quality	E/E per MIL-C-48497A	
Filter Construction	Single substrate surface coated	

XLD640 – actual representation



CUSTOM CONFIGURATIONS AVAILABLE UPON REQUEST

For current product listings, specifications, and pricing:
www.omegafilters.com • sales@omegafilters.com
1.866.488.1064 (toll free within USA only) • +1.802.254.2690 (outside USA)

- Improved signal-to-noise
- Excellent laser rejection solution

QuantaMAX

Laser Edge Longpass Filters

Recent developments in sputter coatings have produced a series of QuantaMAX™ Laser Edge Longpass interference filters to attenuate, or block, scattered energy from reaching your detector, therefore improving critical signal-to-noise.

At the detector, both desired and unwanted scatter will be present, with the signal orders of magnitude lower than the scatter. Scatter is the result of minor irregularities and characteristic of the system optics and application, including uncontrolled light from the sample and filter holder. Combined with advances in laser and detector technology, our laser edge longpass filters are part of a revolution in Raman spectroscopy, expanding the use and applications of this analytical method.

QuantaMAX™ Laser Edge Longpass interference filters are an excellent laser rejection solution when used in a collimated light path on the detector side of the system. These filters attenuate shorter wavelengths to ~0.7 edge wavelength and transmit 95% of Stokes Raman or fluorescence signal and exhibit very high contrast between the Rayleigh and Raman transmission. Angle tuning is required for optimal performance.

QuantaMAX™ Laser Edge Longpass Filters

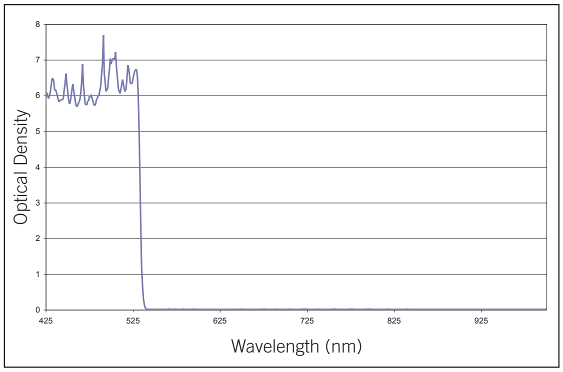
Laser Line (nm)	Transmission (Peak)	Product SKU	Description
441.6	95% average to 1100 nm	XRLP444	444QMLP
457.9	95% average to 1100 nm	XRLP463	463QMLP
473.0	95% average to 1100 nm	XRLP477	477QMLP
488.0	95% average to 1100 nm	XRLP492	492QMLP
514.5	95% average to 1100 nm	XRLP519	519QMLP
532.0	95% average to 1100 nm	XRLP537	537QMLP
568.2	95% average to 1100 nm	XRLP573	573QMLP
632.8	95% average to 1100 nm	XRLP638	638QMLP
647.1	95% average to 1100 nm	XRLP653	653QMLP
664.0	95% average to 1100 nm	XRLP670	670QMLP
780.0	95% average to 1800 nm	XRLP787	787QMLP
785.0	95% average to 1800 nm	XRLP792	792QMLP
808.0	95% average to 1800 nm	XRLP816	816QMLP
830.0	95% average to 1800 nm	XRLP838	838QMLP
980.0	95% average to 1800 nm	XRLP989	989QMLP
1064.0	95% average to 2000 nm	XRLP1076	1076QMLP
1319.0	95% average to 2000 nm	XRLP1335	1335QMLP

Product SKU denotes cut-on edge

Specifications

Physical	Size	Stock and custom sizes available
	Thickness	< 4.0 mm
Transmission Ripple	< +/- 1.5% typical	
Blocking	≥ OD 5 at laser wavelength	
Edge Slope	<1% from OD 0.3-OD 5	
Angle of Incidence	0.0° - 10.0° tunable	
Transmitted Wavefront Error	< 0.5 λ over the clear aperture at 633 nm	
Beam Deviation	< 15 arc seconds	
Surface Quality	E/E per MIL-C-48497A	
Filter Construction	Single substrate surface coated	

XLRP537 – actual representation



CUSTOM CONFIGURATIONS AVAILABLE UPON REQUEST

Angle Tuning Edge Filters

All edge filters can be angle tuned to achieve optimal signal to noise. Angle tuning the filter will blue shift the transmission curve and allow Raman signals closer to the laser line to pass through the filter, at some expense to blocking, at the laser line. The filter can be oriented up to about 15°, normal normal incidence.

At a 15° angle of incidence, the cut-on wavelength of the longpass edge filter will shift blue at approximately 1% of the cut on value at normal incidence. A filter that cuts on at 600nm with normal orientation will cut on at 594nm when tipped to 15°. A consequence of this blue shift is that the blocking at the laser line will decrease by approximately 2 levels of optical density.

A secondary feature of angle tuning is that reflected energy is redirected from the optical axis. For longpass edge filters, select a filter with an edge that is to the red of the desired cut off and adjust the filter angle until optimal performance is achieved.

For more than 40 years Omega Optical has been a leading manufacturer of high performance optical interference filters for a wide range of applications in Raman spectroscopy.

Raman Spectroscopy General Overview

Raman spectroscopy provides valuable structural information about materials. When laser light is incident upon a sample, a small percentage of the scattered light may be shifted in frequency. The frequency shift of the Raman scattered light is directly related to the structural properties of the material. A Raman spectrum provides a "fingerprint" that is unique to the material. Raman spectroscopy is employed in many applications including mineralogy, pharmacology, corrosion studies, analysis of semiconductors and catalysts, in situ measurements on biological systems, and even single molecule detection. Applications will continue to increase rapidly along with further improvements in the technology. A Raman signature provides positive material identification of unknown specimens to a degree that is unmatched by other spectroscopy's. Raman spectroscopy presents demanding requirements for the detection and resolution of narrow-bands of light with very low intensity and minimal frequency shift relative to the source. We are committed to supporting this science with optical coatings of the highest phase thickness and resulting superior performance.

Raman Scattering

When a probe beam of radiation described by an electric field **E** interacts with a material, it induces a dipole moment, **μ**, in the molecules that compose the material: $\mu = a \times E$ where **a** is the polarizability of the molecule. The polarizability is a proportionality constant describing the deformability of the molecule. In order for a molecule to be Raman-active, it must possess a molecular bond with a polarizability that varies as a function of interatomic distance. Light striking a molecule with such a bond can be absorbed and then re-emitted at a different frequency (Raman-shifted), corresponding to the frequency of the vibrational mode of the bond. If the molecule is in its ground state upon interaction with the probe beam, the light can be absorbed and then re-emitted at a lower frequency, since energy from the light is channeled into the vibrational mode of the molecule. This is referred to as Stokes-shifted Raman scattering. If the molecule is in a vibrationally excited state when it interacts with the probe beam, the interaction can cause the molecule to give up its vibrational energy to the probe beam and drop to the ground state. In this case, the scattered light is higher in frequency (shorter wavelength than the probe beam). This is referred to as anti-Stokes Raman scattering, which under normal conditions is much less common than Stokes scattering. The most common occurrence is that light is absorbed and re-emitted at the same frequency. This is known as Rayleigh, or elastic scattering.

Both Rayleigh and Raman scattering are inefficient processes. Typically only one part in a thousand of the total intensity of incident light is Rayleigh scattered, while for Raman scattering this value drops to one part in a million. Thus, a major challenge in Raman spectroscopy is to attenuate the light that is elastically scattered in order to detect the inelastically scattered Raman light.

Blocking Rayleigh Scattering

In order to obtain high signal-to-noise in Raman measurements, it is necessary to block Rayleigh scattering from reaching the detector while transmitting the Raman signal. It's possible to use a double or triple grating spectrometer to accomplish rejection of the background signal. However, this results in low (~10%) throughput of the desired Raman signal. In many cases a better alternative is to use a Raman notch or Raman edge filter. Notch filters transmit both Stokes and anti-Stokes Raman signals while blocking the laser line. Edge filters (also known as barrier filters) transmit either Stokes (longpass) or anti-Stokes (shortpass).

Important considerations in the choice of an edge filter:

1. How well does the filter block out the Rayleigh scattering? Depending on the geometry of the experiment and the sample, blocking of > OD5 at the laser line is usually sufficient.

2. How steep is the edge, or transition from blocking to transmitting? The steepness of the edge required depends on the laser wavelength and the proximity of the Raman shifted signal of interest to the laser line. If the laser wavelength is 458nm, one would require > OD5 blocking at 458nm, and as high as possible transmission only 4nm away (at 462nm) in order to see a Stokes mode 200 cm-1 from the laser line. If the laser wavelength is 850nm, one would require blocking at 850nm and transmission at 865nm (15nm away from the laser line) in order to detect a signal at 200cm-1. Therefore, the slope of a filter that is required to look at a low frequency mode is steeper at bluer laser wavelengths.

QuantaMAX

◗ Laser Line Interference Filters

At the laser source, while output is typically thought of as monochromatic and is described by a prominent line and a single output wavelength, there are often lower levels of transitions, plasma and glows, all of which create background errors. Additionally, laser sources can shift in wavelength depending on power, temperature and even manufacturing tolerances. Transmitting pure excitation energy requires a laser clean-up interference filter to control the unwanted energy.

Laser line interference filter are narrow bandpass filters centered on the resonance of the laser, that attenuate the background plasma and secondary emissions which often results in erroneous signals. In the case of diode lasers and light emitting diodes (LED), our laser line filters can be used to make the light output more monochromatic. In the case of gas lasers, these same filters can eliminate plasma in the deep blue wavelength region. Laser line interference filters provide 60-90% throughput (the only exception is UV) with spectral control from 0.85 to 1.15 of the center wavelength (CWL) of the filter. To control a much wider spectral range from the deep UV to the IR an accessory blocker can be used. All laser filters are designed with high laser damage thresholds of up to 1 watt/cm^2.

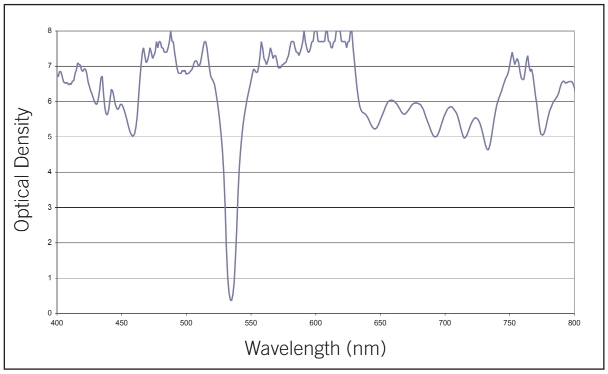
QuantaMAX™ – Laser Line Filters

Wavelength (nm)	Transmission (Peak)	Bandwidth (nm)	OD5 Range (nm)	Product SKU	Description
VISIBLE					
441.6	> 90%	1.7	380 – 700	XLL441.6	441.6BP1.9
457.9	> 90%	1.7	380 – 700	XLL457.9	457.9BP2
488.0	> 90%	1.9	380 – 700	XLL488	488BP2.1
514.5	> 90%	2.0	400 – 770	XLL514.5	514.5BP2.1
532.0	> 90%	2.0	400 – 770	XLL532	532BP2.2
543.5	> 90%	2.1	400 – 770	XLL543.5	543.5BP2.4
561.4	> 90%	2.1	400 – 770	XLL561.4	561.4BP2.5
568.2	> 90%	2.2	400 – 770	XLL568.2	568.2BP2.6
632.8	> 90%	2.4	500 – 900	XLL632.8	632.8BP3
647.1	> 90%	2.5	500 – 900	XLL647.1	647.1BP3
671.0	> 90%	2.6	500 – 900	XLL671	671BP3
NEAR INFRARED					
780.0	> 90%	3.0	585 – 1100	XLL780	780BP3.1
785.0	> 90%	3.0	585 – 1100	XLL785	785BP3.2
808.0	> 90%	3.1	585 – 1100	XLL808	808BP3.7
830.0	> 90%	3.2	585 – 1100	XLL830	830BP3.7
976.0	> 90%	3.7	800 – 1300	XLL976	976BP4
980.0	> 90%	3.7	800 – 1300	XLL980	980BP4
1047.1	> 90%	4.0	900 – 1500	XLL1047.1	1047.1BP1.7
1064.0	> 90%	4.0	900 – 1500	XLL1064	1064BP1.7

Specifications

Physical	Size	12.5, 25 and 50 mm
	Thickness	< 4.0 mm
Angle of Incidence	0.0° - 10.0° tunable	
Transmitted Wavefront Error	< 0.5 λ over the clear aperture at 633 nm	
Beam Deviation	< 15 arc seconds	
Surface Quality	E/E per MIL-C-48497A	
Filter Construction	Single substrate surface coated	

XLL532 – actual representation



◗ **CUSTOM CONFIGURATIONS AVAILABLE UPON REQUEST**

Our line of standard interference filters is representative of typical industry specifications. Available to ship in 5 business days. Need sooner? Please contact us.

Laser Rejection Interference Filters

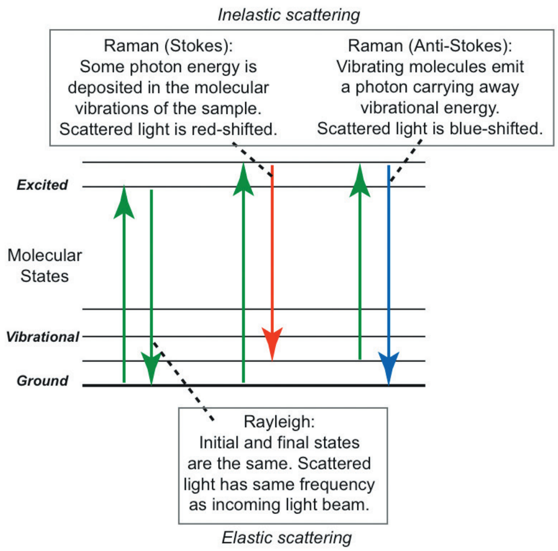
At the detector both scatter and signal will be present with the scatter orders of magnitude higher than the signal. To improve signal to noise both laser rejection and laser edge filters can be used to attenuate, or block, the scattered energy from reaching the detector.

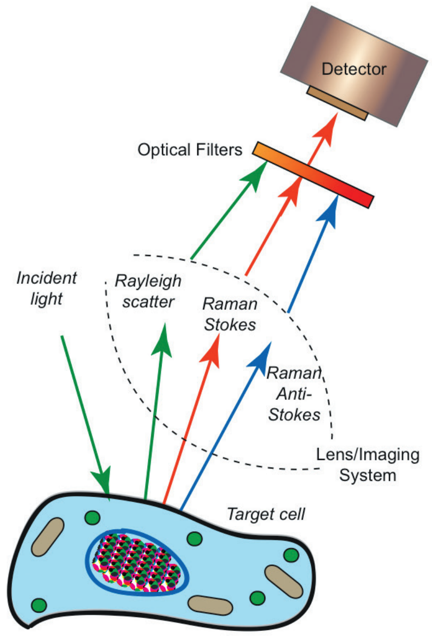
Laser rejection filters are designed to block more than 99.9% of light in a 15 to 40 nm bandwidth. The average transmission outside the stop-band is 75% except in those spectral regions where higher and lower harmonics cause relatively high reflection. Spectrally designed rejection band filters reflect more than one spectral band or perform at off normal angles of incidence. Rejection filters provide the ability to measure both Stokes and anti-Stokes signals simultaneously and have tunability for variable laser lines. Laser edge filters can also be used for laser rejection, providing deeper blocking of the laser line and steeper edges, for small Stokes shifted applications.

QuanatMAX Laser Edge Filters (see page 53) can also be used for laser rejection, providing deeper blocking of the laser line and steeper edges, for small Stokes shifted applications.

Laser Rejection Filters

Blocked Wavelengths	Transmission (Peak)	Optical Density	Product SKU	Description	Size	Thickness	Filter Application
457, 488, 514	≥ 60% Blue, Green and Red	OD3	XB09	457/488/514	25 mm	≤ 3 mm	Argon Multi-Line Laser Protection
532, 1064	≥ 80%	OD4	XB11	532/1064	25 mm	≤ 4 mm	Yag & 2nd Yag
532, 694, 1064	≥ 75%	OD5	XB12	532/694/1064	25 mm	≤ 5 mm	Yag, Ruby, 2nd Yag
632	≥ 75% Blue and Red	OD3	XB23	633	25 mm	≤ 3 mm	HeNe Laser Protection





In Raman scattering, target cell organelles produce different degrees of red-shift, forming the basis for molecular spectroscopy.

Image courtesy of www.biomedcentral.com

CUSTOM CONFIGURATIONS AVAILABLE UPON REQUEST

Our line of standard interference filters is representative of typical industry specifications. Available to ship in 5 business days. Need sooner? Please contact us.

Laser Line Filters - Limited blocking

Laser Line	CWL	CWL Tolerance	FWHM	FWHM Tolerance	Transmission (Peak)	Blocking Range	Product SKU	Description
4th Nd Yag	266	+ 2.2,-1.5 nm	15	± .3 nm	≥ 20%	UV - FIR	XL01	266BP15
HeCd	325	+.3,-.2 nm	2	± .4 nm	≥ 25%	.9 - 1.1 X CWL	XL02	325NB2
N2	337	+.4,-.3 nm	3	± .6 nm	≥ 40%	.85 - 1.15 X CWL	XL30	337NB3
Argon-Ion	351	+.4,-.3 nm	3	± .6 nm	≥ 60%	.85 - 1.15 X CWL	XL31	351NB3
3rd Nd Yag	355	+.4,-.3 nm	3	± .6 nm	≥ 60%	.9 - 1.1 X CWL	XL03	355NB3
Argon	364	+.6,-.4 nm	4	± .8 nm	≥ 60%	.85 - 1.15 X CWL	XL32	364NB4
Blue Diode/DPSS	405	+.6,-.4 nm	5	± .8 nm	≥ 60%	.85 - 1.15 X CWL	XL33	405NB5
Blue Diode/DPSS	430	+.3,-.2 nm	5	± .4 nm	≥ 60%	.85 - 1.15 X CWL	XL34	430NB2
HeCd	442	+.3,-.2 nm	2	± .4 nm	≥ 60%	.85 - 1.15 X CWL	XL04	442NB2
Argon	457	+.3,-.2 nm	2	± .4 nm	≥ 60%	.85 - 1.15 X CWL	XL05	457NB2
Argon	473	+1.2,-.8 nm	8	± 1.6 nm	≥ 70%	.85 - 1.15 X CWL	XL35	473NB8
Argon	488	+.4,-.3 nm	3	± .6 nm	≥ 80%	.85 - 1.15 X CWL	XL06	488NB3
Argon	515	+.4,-.3 nm	3	± .6 nm	≥ 80%	.85 - 1.15 X CWL	XL07	515NB3
2nd Nd Yag	532	+.4,-.3 nm	3	± .6 nm	≥ 80%	.85 - 1.15 X CWL	XL08	532NB3
HeNe Green	543	+.4,-.3 nm	3	± .6 nm	≥ 80%	.85 - 1.15 X CWL	XL09	543NB3
Argon/Argon Krypton	568	+.4,-.3 nm	3	± .6 nm	≥ 80%	.85 - 1.15 X CWL	XL36	568NB3
HeNe Yellow	594	+.4,-.3 nm	3	± .6 nm	≥ 80%	.85 - 1.15 X CWL	XL10	594NB3
HeNe Yellow	612	+.4,-.3 nm	3	± .6 nm	≥ 80%	.85 - 1.15 X CWL	XL11	612NB3
HeNe Red	633	+.6,-.4 nm	4	± .8 nm	≥ 80%	.85 - 1.15 X CWL	XL12	633NB4
Red Diode	635	+.6,-.4 nm	4	± .8 nm	≥ 80%	.85 - 1.15 X CWL	XL37	635NB4
Krypton	647	+.6,-.4 nm	4	± .8 nm	≥ 80%	.85 - 1.15 X CWL	XL13	647NB4
Red Diode	650	+.6,-.4 nm	5	± .8 nm	≥ 80%	.85 - 1.15 X CWL	XL38	650NB5
Krypton	676	+.6,-.4 nm	4	± .8 nm	≥ 80%	.85 - 1.15 X CWL	XL14	676NB4
AlGaAs	665	+3.7,-2.5 nm	25	± 5 nm	≥ 80%	.85 - 1.15 X CWL	XL15	665WB25
RUBY	694	+.6,-.4 nm	4	± .8 nm	≥ 80%	.85 - 1.15 X CWL	XL16	694NB4
AlGaAs	775	+3.7,-2.5 nm	25	± 5 nm	≥ 85%	.85 - 1.15 X CWL	XL17	775WB25
Sapphire	785	+0.7, -0.6 nm	4	± 1 nm	≥ 80%	.85 - 1.15 X CWL	XL29	785NB4
Diode	808	+3.7,-2.5 nm	25	± 5 nm	≥ 80%	.85 - 1.15 X CWL	XL39	808WB25
AlGaAs	825	+3.7,-2.5 nm	25	± 5 nm	≥ 85%	.85 - 1.15 X CWL	XL18	825WB25
GaAlAs	830	+3.7,-2.5 nm	25	± 5 nm	≥ 80%	.85 - 1.15 X CWL	XL40	830WB25
AlGaAs	850	+3.7,-2.5 nm	25	± 5 nm	≥ 85%	.85 - 1.15 X CWL	XL19	850WB25
AlGaAs	875	+3.7,-2.5 nm	25	± 5 nm	≥ 85%	.85 - 1.15 X CWL	XL20	875WB25
InGaAs	980	+3.7,-2.5 nm	25	± 5 nm	≥ 80%	.85 - 1.15 X CWL	XL41	980WB25
1st Nd Yag	1060	+1.2,-.8 nm	8	± 1.6 nm	≥ 85%	.85 - 1.15 X CWL	XL21	1060NB8
1st Nd Yag	1064	+1.2,-.8 nm	8	± 1.6 nm	≥ 80%	.85 - 1.15 X CWL	XL22	1064NB8
HeNe IR	1152	+1.5,-1 nm	10	± 2 nm	≥ 80%	.85 - 1.15 X CWL	XL23	1152NB10
InGaAsP	1310	+6,-4 nm	40	± 8 nm	≥ 80%	.85 - 1.15 X CWL	XL24	1310WB40
Nd Yag	1320	+1.5,-1 nm	10	± 2 nm	≥ 80%	.85 - 1.15 X CWL	XL25	1320NB10
Diode	1350	+3.7,-2.5 nm	40	± 5 nm	≥ 80%	.85 - 1.15 X CWL	XL42	1350WB40
HeNe IR	1523	+1.5,-1 nm	10	± 2 nm	≥ 80%	.85 - 1.15 X CWL	XL26	1523NB10
InGaAsP	1550	+7.5,-5 nm	50	± 10 nm	≥ 80%	.85 - 1.15 X CWL	XL27	1550WB50
InGaAsP	1550	+1.5,-1 nm	10	± 2 nm	≥ 80%	.85 - 1.15 X CWL	XL28	1550NB10

CUSTOM CONFIGURATIONS AVAILABLE UPON REQUEST

STANDARD – LASER LINE FILTERS

- Centered on the laser resonance
- Clean up the unwanted energy
- Available in 25 mm diameter

Laser Line Filters - Fully blocked

The Transmission (Peak) is a value of an unblocked filter. The addition of a blocking component will reduce the Transmission (Peak) by 20%.

Laser Line	CWL	CWL Tolerance	FWHM	FWHM Tolerance	Transmission (Peak)	Blocking Range	Product SKU	Description
HeCd	325	+.3,-.2 nm	2	± .4 nm	≥ 25%	UV - 2500 nm	XLK02	325NB2
N2	337	+.4,-.3 nm	3	± .6 nm	≥ 40%	UV - 2500 nm	XLK30	337NB3
Argon-Ion	351	+.4,-.3 nm	3	± .6 nm	≥ 60%	UV - 2500 nm	XLK31	351NB3
3rd Nd Yag	355	+.4,-.3 nm	3	± .6 nm	≥ 60%	UV - 2500 nm	XLK03	355NB3
Argon	364	+.6,-.4 nm	4	± .8 nm	≥ 60%	UV - 2500 nm	XLK32	364NB4
Blue Diode/DPSS	405	+.6,-.4 nm	5	± .8 nm	≥ 60%	UV - 2500 nm	XLK33	405NB5
Blue Diode/DPSS	430	+.3,-.2 nm	5	± .4 nm	≥ 60%	UV - 2500 nm	XLK34	430NB2
HeCd	442	+.3,-.2 nm	2	± .4 nm	≥ 60%	UV - 2500 nm	XLK04	442NB2
Argon	457	+.3,-.2 nm	2	± .4 nm	≥ 60%	UV - 2500 nm	XLK05	457NB2
Argon	473	+1.2,-.8 nm	8	± 1.6 nm	≥ 70%	UV - 2500 nm	XLK35	473NB8
Argon	488	+.4,-.3 nm	3	± .6 nm	≥ 80%	UV - 2500 nm	XLK06	488NB3
Argon	515	+.4,-.3 nm	3	± .6 nm	≥ 80%	UV - 2500 nm	XLK07	515NB3
2nd Nd Yag	532	+.4,-.3 nm	3	± .6 nm	≥ 80%	UV - 2500 nm	XLK08	532NB3
HeNe Green	543	+.4,-.3 nm	3	± .6 nm	≥ 80%	UV - 2500 nm	XLK09	543NB3
Argon/Argon Krypton	568	+.4,-.3 nm	3	± .6 nm	≥ 80%	UV - 2500 nm	XLK36	568NB3
HeNe Yellow	594	+.4,-.3 nm	3	± .6 nm	≥ 80%	UV - 2500 nm	XLK10	594NB3
HeNe Yellow	612	+.4,-.3 nm	3	± .6 nm	≥ 80%	UV - 2500 nm	XLK11	612NB3
HeNe Red	633	+.6,-.4 nm	4	± .8 nm	≥ 80%	UV - 2500 nm	XLK12	633NB4
Red Diode	635	+.6,-.4 nm	4	± .8 nm	≥ 80%	UV - 2500 nm	XLK37	635NB4
Krypton	647	+.6,-.4 nm	4	± .8 nm	≥ 80%	UV - 2500 nm	XLK13	647NB4
Red Diode	650	+.6,-.4 nm	5	± .8 nm	≥ 80%	UV - 2500 nm	XLK38	650NB5
Krypton	676	+.6,-.4 nm	4	± .8 nm	≥ 80%	UV - 2500 nm	XLK14	676NB4
AlGaAs	665	+3.7,-2.5 nm	25	± 5 nm	≥ 80%	UV - 2500 nm	XLK15	665WB25
RUBY	694	+.6,-.4 nm	4	± .8 nm	≥ 80%	UV - 2500 nm	XLK16	694NB4
AlGaAs	775	+3.7,-2.5 nm	25	± 5 nm	≥ 85%	UV - 2500 nm	XLK17	775WB25
Sapphire	785	+0.7, -0.6 nm	4	± 1 nm	≥ 80%	UV - 2500 nm	XLK29	785NB4
Diode	808	+3.7,-2.5 nm	25	± 5 nm	≥ 80%	UV - 2500 nm	XLK39	808WB25
AlGaAs	825	+3.7,-2.5 nm	25	± 5 nm	≥ 85%	UV - 2500 nm	XLK18	825WB25
GaAlAs	830	+3.7,-2.5 nm	25	± 5 nm	≥ 80%	UV - 2500 nm	XLK40	830WB25
AlGaAs	850	+3.7,-2.5 nm	25	± 5 nm	≥ 85%	UV - 2500 nm	XLK19	850WB25
AlGaAs	875	+3.7,-2.5 nm	25	± 5 nm	≥ 85%	UV - 2500 nm	XLK20	875WB25
InGaAs	980	+3.7,-2.5 nm	25	± 5 nm	≥ 80%	UV - 2500 nm	XLK41	980WB25
1st Nd Yag	1060	+1.2,-.8 nm	8	± 1.6 nm	≥ 85%	UV - 1500 nm	XLK21	1060NB8
1st Nd Yag	1064	+1.2,-.8 nm	8	± 1.6 nm	≥ 80%	UV - 1500 nm	XLK22	1064NB8
HeNe IR	1152	+1.5,-1 nm	10	± 2 nm	≥ 80%	UV - 1350 nm	XLK23	1152NB10
InGaAsP	1310	+6,-4 nm	40	± 8 nm	≥ 80%	UV - 1800 nm	XLK24	1310WB40
Nd Yag	1320	+1.5,-1 nm	10	± 2 nm	≥ 80%	UV - 1800 nm	XLK25	1320NB10
Diode	1350	+3.7,-2.5 nm	40	± 5 nm	≥ 80%	UV - 1800 nm	XLK42	1350WB40
HeNe IR	1523	+1.5,-1 nm	10	± 2 nm	≥ 80%	UV - 1800 nm	XLK26	1523NB10
InGaAsP	1550	+7.5,-5 nm	50	± 10 nm	≥ 80%	UV - 1800 nm	XLK27	1550WB50
InGaAsP	1550	+1.5,-1 nm	10	± 2 nm	≥ 80%	UV - 1800 nm	XLK28	1550NB10

CUSTOM CONFIGURATIONS AVAILABLE UPON REQUEST

For current product listings, specifications, and pricing:
www.omegafilters.com • sales@omegafilters.com
1.866.488.1064 (toll free within USA only) • +1.802.254.2690 (outside USA)

- Full Width Half Max (FWHM) or bandwidth (BW) of 40 nm
- Transmission >90%

QUANTAMAX™ MACHINE VISION FILTERS

When designing or improving a vision system, light management is a critical consideration. Using optical filters to control light selection is a simple and affordable solution to improving contrast, resolution and stability. Historically, photographic filters have been used in vision systems, but they lack the desired performance characteristics for today's systems.

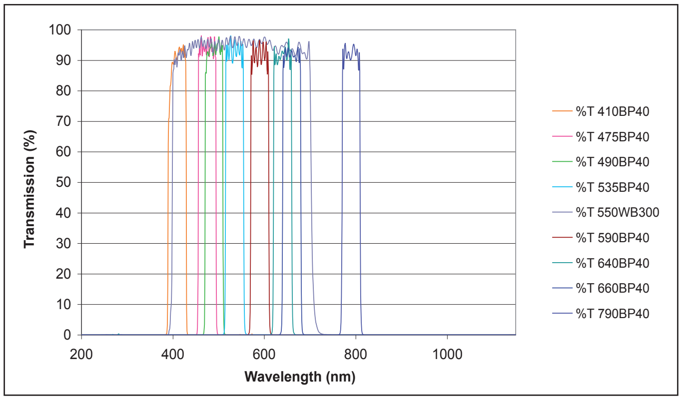
With many years of experience behind us we have developed optical filters for Machine Vision applications with superior physical and spectral attributes. Typically produced with robust sputtered oxide coatings these filters have a virtually unlimited lifetime as they are resistant to heat, humidity, vibration and cleaning solvents. The use of single substrates results in low TWD (transmitted wavefront distortion). Spectral properties include high in-band transmission, deep blocking out of band, and a high level of stability. Systems can benefit from the high transmission when using lower power LED light sources or viewing faint signals such as in fluorescence applications where UV excitation is used to view visible fluorescence. LED sources can vary from the specified peak output therefore it is important that the bandwidth of the filter takes this into consideration. The width of the band as well as the wavelength location can also be optimized to accommodate "blue shift" associated with viewing light at angles off normal as is common in machine vision applications. The controlled passband also serves to limit the wavelength range the lens needs to focus on resulting in greater resolution. Photographic filters generally block light in the region of 400-700 nm in relation to the film which they were designed to be used with. Current CCD and CMOS detectors have sensitivity from the UV to 1100 nm. Our optical filters for Machine Vision provide deep density blocking over this full range resulting in greater contrast and stability in changing ambient light conditions therefore improving accuracy and speed.

For these reasons optical filters should be considered a critical element in controlling the variable of light in a vision system. **For assistance in designing the appropriate solution for your application, please contact us. We will be happy to assist.**

Specifications

Physical	Size	Stock and custom sizes available
	Thickness	2 mm
Transmission	> 90 %	
Blocking	OD 5	
Surface Quality	E/E per MIL-C-48497A	
Filter Construction	Single substrate surface coated	

Omega Optical Filters for Machine Vision



Machine Vision - the Application of Computer Vision and Analysis

Common uses of the technology span many industries and applications including:

- Industries: Pharmaceutical, Automotive, Food/Beverage Inspection, Recycling, Life Sciences, Medical Diagnostics, Aerospace, Security.
- Applications: Image Processing, Biometrics, Printing, Robot Guidance, Pattern Recognition, Diagnostics.

In many instances, machine vision performs roles previously handled by human beings. Often times, they can be found in inspection systems requiring high speed, high magnification, 24-hour operation and/or repeatable measurements.

Frequently, sensors used in Machine Vision have detection wavelengths over a broad range of the spectrum from the UV through near infrared. Without proper filtering and attenuation of unwanted signal, the sensors would be ineffective as the registration of unwanted light creates high levels of noise. Interference filters increase the signal to noise ratio allowing for proper discrimination of desired wavelengths while blocking all other light.

3RD MILLENNIUM FILTERS

- Steep slopes
- Specified by the critical cut-on/cut-off edges
- Standard 25 mm diameter off the shelf components

3RD Millennium filters are manufactured using Omega Optical's proprietary ALPHA coating technology, a process which produces exceptionally steep cut-on and cut-off slopes. The result is precise location of cut-on and cut-off edges, the ability to place transmission and rejection regions extremely close together, and higher attenuation between the passband and the rejection band. These filters are produced in custom engineered coating equipment that progresses from raw material to complete assemblies in a shortened manufacturing cycle. The coating chamber is load-locked so that it remains under stable high vacuum conditions between coating cycles.

- Control and design of manufacturing processes lead to yield and product uniformity
- Short manufacturing cycles results in controlled inventories and shorter lead times

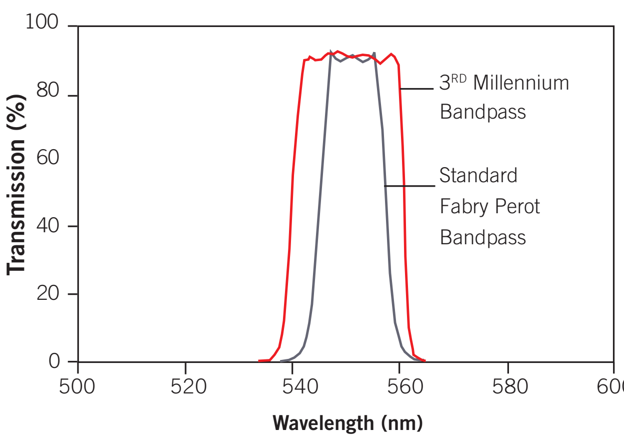
Specifying by the critical cut-on and cut-off edges will result in much more accurate band placement and bandwidth.

Bandpass filters are made using a combination of an ALPHA longpass (cut-on) and ALPHA shortpass (cut-off). Longpass and shortpass filters are each made using a single surface coating. Passbands can be made wider and still achieve the blocking requirements of narrower, less steep designs. Wider bandpass filters outperform narrower standard designs with improved transmission, deeper blocking, and improved signal-to-noise.

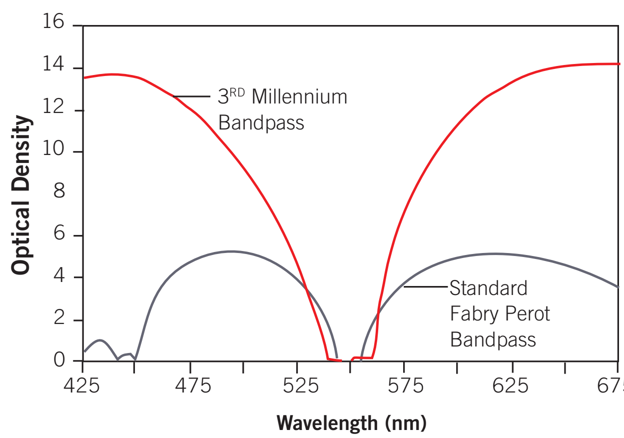
3RD Millennium part numbers are unassigned. To order a 3RD Millennium filter:

Longpass – specify a cut-on wavelength	Example: Product SKU 3RD650LP
Shortpass – specify a cut-off wavelength	Example: Product SKU 3RD520SP
Bandpass – specify a cut-on & cut-off wavelength	Example: Product SKU 3RD580-600

Actual Transmission



Typical Optical Density



- Steep slopes
- Specified by the critical cut-on/cut-off edges
- Standard 25 mm diameter off the shelf components

3RD Millennium Filters

3RD Millennium filters are offered every 10 nm from 400-700 nm, every 20 nm from 700-800 nm and every 50 nm from 800 nm to 1100 nm.

Filter Type	Wavelength Range	Transmission	Attenuation Range	Attenuation
Longpass	Cut-On from 400-700 nm at every 10 nm Cut-On from 700-800 nm at every 20nm Cut-On from 800-1100 nm at every 50 nm	≥ 90% peak	UV to cut-on	OD 6
Shortpass	Cut-Off from 400-700 nm at every 10 nm Cut-Off from 700-800 nm at every 20 nm Cut-Off from 800-1100 nm at every 50 nm	≥ 90% peak	Cut-off to 1.3x cut-off	OD 6
Bandpass	Cut-On + Cut-Off from 400-700 nm at every 10 nm 700-800 nm at every 20 nm 800-1100 nm at every 50 nm	≥ 80% peak	UV to 1.3x cut-off	OD 6

Attenuation Extension:

When using a silicon detector, in some cases a blocker filter is required to extend the attenuation range to 1100 nm nominally. For optimal performance we recommend locating a separate blocking filter in a position remote from the 3RD Millennium filter.

▶ **Please see page 94 for IR Blocking Filters.**

Specifications

Physical	**Size**	25 mm
	Thickness	5.5 mm
	Clear Aperture	21.3 mm
Filter Construction	Single substrates, air spaced	

i-line Optical Filters

Omega Optical's new generation i-line filters feature greatly improved i-line intensity delivered to the resist, surpassing the standard OEM filters. Filters are qualified to the highest manufacturing standards, characterized photometrically and are packaged in a nitrogen-purged ESD bag.

These products are designed for litho tools in the photolithography process such as LSI and LCD Steppers with high power Mercury Lamps. This high performance filter resolves monochromatic wavelengths reaching the photomask substrate so that optimum resolution is achievable. These filters effectively transmit the five lines of the fine structure of the Mercury i-line with bandwidth, center wavelength, and filter construction designed to allow maximum throughput and filter life.

We offer custom engineered filters as well as standard i-line filters.

Features

These filters are manufactured using durable coatings deposited via dual magnetron reactive sputtering to assure stability over time and varying environmental conditions. Purified fused silica substrates, rather than borosilicate, are used to assure the highest optical quality and spectral stability.

Photometric Performance

Our i-line filters are thoroughly characterized photometrically. The bandpass transmission is evaluated along four radii at half inch intervals (125 & 165mm diameter product) using a research-grade spectrophotometer. A filter with uniform bandpass characteristics across the entire surface yields the greatest intensity delivered to the resist. Our filters typically exceed intensity levels offered by OEM replacement filters by 10-20%.

Photolithography Mask Aligner Filters

In addition, we offer mask aligner optical filters that provide improved exposures and sharper, straighter feature walls of the SU-8 photoresist. This filter provides a nominal cut-on wavelength of 360nm, blocking shorter wavelengths and transmitting the longer wavelengths including the useful 365, 405 & 436nm mercury lines. It is 90% transparent to visible light (or provides 90% transmission), allowing for proper visualization of mask alignment through the filter glass.

i-line Filters

Omega Part Number	Canon Part Number	Filter Type Bandpass	Size	CWL	Peak T%	Q (1/100)*	Temperature Max	Typical Lifetime (Hrs)
2009687	BN-9-7513-000	i-line filter	165 mm	365.5 ± 0.6 nm	≥ 90%	2–3	1250 C	>10,000
2006838	BN-9-7269-000	i-line filter	124 mm	365.5 ± 0.6 nm	≥ 90%	2–3	1250 C	>10,000
2009180	BN-9-6635-000	i-line filter FRA/AA	29.9 mm	365.5 ± 1.2 nm	≥ 90%	≤ 2	1250 C	>10,000
2008168		g-line filter	165 mm	436 ± 0.8 nm	≥ 90%	2–3	1250 C	>10,000
2008169		g-line filter	124 mm	436 ± 0.8 nm	≥ 90%	2–3	1250 C	>10,000

***Note:** Definition of "Q": Q(1/100) = 1%BW/FWHM

Mask Aligner Filters

Omega Part Number	Filter Description	Dimensions
2007308	PL-360LP	127 x 127 x 2 mm
2008110	PL-360LP	165.1 x 165.1 x 2 mm
2008101	PL-360LP	171.5 x 171.5 x 2 mm
2008111	PL-360LP	215.9 x 215.9 x 2 mm

Note: MicroChem recommends Omega Optical's PL-360LP optical filter for use with its SU-8 photoresist.

Specifications: Mask aligner filters are available in a variety of sizes to fit most mask aligner systems. Call with requests for custom specifications.

UV CAPABILITIES

We currently offer UV bandpass filters from 185 nm to 400 nm as triple-cavity MDM (metal dielectric metal) coatings, providing extremely high out-of-band attenuation and transmission, as high as the thin film coating materials will allow. Our UV filter offer also includes metal shortpass filters with long wavelength attenuation. A filter with OD 4 from the visible and through the IR can pass 30% of the shortest UV.

MDM interference filters are often the most efficient in the UV when high S/N is required, due to the long wavelength response of typical detectors. Our UV/MDM filters are typically OD5 to OD 8 on average. Filters are typically manufactured in single to four cavity FP Fabry Perot' designs with precise rectangular passbands.

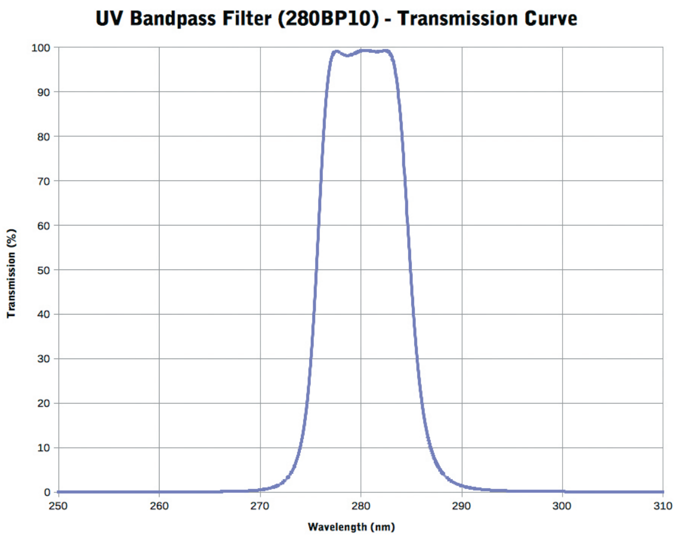
Our UV filter range includes high-performance dielectric UV coatings as well. These coatings are particularly efficient in throughput and provide precise feature wavelength location as well as very sharp transmission slope. Bandpass, edge filters (longpasss and shortpass) and beamsplitters are among our standard capabilities.

UV Longpass and Shortpass (edge filters) are currently manufactured using our proprietary **ALPHA** coating technology (see page 20). Most commonly used in Raman studies, these edge filters typically exhibit peak transmission at > 80% with steep, precisely placed edges, blocking the laser in excess of OD4 within a few nanometers of an emission region.

A common approach for the UV/MDM is to use as a pre-filter for an all-dielectric passband filter of a few to 10nm in HBW (Half bandwidth). With nearly no loss in the dielectric the resulting transmission is that of the metal filter. This combination gives very low background signal. For ultimate performance in the UV a reflection filter will be selected. These filters can pass greater than 90% of a UV band, yet attenuate the longer wavelengths to OD 4, throughout the longer wavelength regions. Reflection filters must be "designed in" solutions, as multiple reflective surfaces are required.

From protected/overcoated Aluminum mirrors, to the most effective wide band reflector for the atmospheric window, to efficient dielectric selective mirrors, our capabilities in this region are broad. Selective reflectors can be built as stop-bands with < ± 10 nm bandwidth, to wider bands up to 60 nm in width. These coatings can be used at normal incidence or at any angle required. Polarization and angle sensitivity are important considerations in the design of these products.

In 2012, this product line will see improvements with the introduction of UV interference filters manufactured with sputter coating technology; QuantaMAX™ produced on our Leybold Helios systems. Our initial offering will begin with UV filters from 290 nm to 400 nm and towards the end of 2012 we expect to produce filters closer to 250 nm.



Whatever your requirement is, large or small, please contact us for assistance. We have a large catalog of UV filters available to ship within 5 business days.

FLUORESCENCE FILTERS REFERENCE TABLE

Excitation Filters by CWL (center wavelength)

Product SKU	Descriptor	Page #
XF1001	330WB80	73,94
XF1093	340AF15	96
XF1409	365QM35	72,79
XF1005	365WB50	73,76,80,88,94, 95
XF1415	380QM50	72,79
XF1094	380AF15	91,96
XF1057	385-485-560TBEX	78
XF1059	386-485-560TBEX	78
XF1075	387AF28	73
XF1458	390-486-577TBEX	77
XF1052	390-486-577TBEX	77
XF1058	390-486-577TBEX	78
XF1055	400-477-580TBEX	78
XF1098	400-495-575TBEX	78
XF1048	400-500DBEX	78
XF1076	400AF30	73
XF1006	400DF15	91,92,95
XF1053	405-490-555-650QBEX	78
XF1408	405QM20	79,91
XF1008	405DF40	73,76
XF1301	415WB100	93
XF1009	425DF45	73,93,94
XF1078	436-510DBEX	78
XF1201	436AF8	80,92
XF1079	436DF10	92
XF1071	440AF21	73,88,96
XF1402	440QM21	72,79
XF1012	455DF70	73
XF1411	470QM50	72
XF1087	470AF50	74,84
XF1416	470QM40	72
XF1410	475QM20	72
XF1072	475AF20	74,88
XF1073	475AF40	73,74,88
XF1420	475-625DBEX	77
XF1404	480QM20	91
XF1014	480DF60	76
XF1451	484-575DBEX	77
XF1450	485-560DBEX	77
XF1063	485-555-650TBEX	78
XF1202	485AF20	80
XF1042	485DF15	91,92,95
XF1015	485DF22	74,76
XF1406	490QM20	79,91
XF1050	490-550DBEX	78

Excitation Filters by CWL (center wavelength)

Product SKU	Descriptor	Page #
XF1051	490-577DBEX	78
XF1011	490DF20	95,96
XF1412	500QM25	72
XF1068	500AF25	74,88
XF1080	510DF25	92,96
XF1203	520AF18	80
XF1074	525AF45	74,88
XF1403	525QM45	72
XF1417	530QM40	72
XF1422	530QM30	79
XF1103	535AF30	74
XF1019	535DF35	76
XF1077	540AF30	74,76
XF1204	546AF18	80
XF1020	546DF10	76
XF1062	550-640DBEX	78
XF1405	555QM25	91
XF1418	555QM50	72
XF1043	555DF10	91,92,95
XF1413	560QM55	72
XF1067	560AF55	74
XF1045	560DF15	91,92,95
XF1022	560DF40	74
XF1206	572AF15	80
XF1044	575DF25	76,91,92
XF1407	575QM30	79,91
XF1207	580AF20	80
XF1424	580QM30	79
XF1082	607AF75	75
XF1025	610DF20	76
XF1421	630QM40	91
XF1414	630QM50	72
XF1069	630AF50	75
XF1026	633NB3.0	76
XF1419	635QM30	72
XF1425	640QM20	79
XF1208	640AF20	80,95
XF1027	640DF20	76
XF1095	655AF50	75
XF1046	655DF30	92
XF1028	670DF20	75
XF1085	680ASP	75
XF1096	685AF30	66,75
XF1211	787DF18	75

Dichroic Beamsplitters by Cut-On

Product SKU	Descriptor	Page #
XF2050	385-485-560TBDR	78,92
XF2041	385-502DBDR	78,91
XF2047	395-540DBDR	91
XF2048	400-477-575TBDR	78,92
XF2046	400-485-558-640QBDR	78,92,95
XF2045	400-485-580TBDR	77,78,79,91,92,95
XF2051	400-495-575TBDR	78,92
XF2001	400DCLP	72,73,76,79,80,88,94
XF2004	410DRLP	73
XF2085	410DRLP	72,79
XF2002	415DCLP	96
XF2040	435DRLP	73
XF2065	436-510DBDR	78,92
XF2090	445-510-600TBDR	92
XF2006	450DCLP	76
XF2034	455DRLP	72,73,79,80,88
XF2007	475DCLP	73,93,94,
XF2401	475-625DBDR	77,91
XF2054	485-555-650TBDR	78,92
XF2039	485-555DBDR	97
XF2443	485-560DBDR	77,91
XF2027	485DRLP	88
XF2043	490-550DBDR	78,91,95
XF2044	490-575DBDR	77,78,91
XF2037	500DRLP	74
XF2077	500DRLP	72,74,88
XF2010	505DRLP	72,73,74,76,79,80,88
XF2031	505DRLPXR	97
XF2008	515DRLP	73
XF2058	515DRLPXR	96
XF2030	525DRLP	72,74,88
XF2013	540DCLP	96
XF2203	545DRLP	80
XF2009	550DCLP	76
XF2053	555-640DBDR	78
XF2062	555DRLP	76,80
XF2016	560DCLP	74,76
XF2017	560DRLP	72,74,79,88
XF2032	565DRLPXR	97
XF2015	570DRLP	74,76,
XF2086	580DRLP	72
XF2019	590DRLP	74,80
XF2029	595DRLP	72,74,79,88
XF2020	600DRLP	74,76,80
XF2014	610DRLP	96

Dichroic Beamsplitters
by Cut-On

Product SKU	Descriptor	Page #
XF2021	630DRLP	76
XF2022	640DRLP	76
XF2035	650DRLP	72,75,76,80
XF2072	650DRLP	75
XF2087	660DRLP	72,79
XF2033	675DCSPXR	97
XF2024	690DRLP	75
XF2075	690DRLP	75
XF2082	692DRLP	75
XF2083	708DRLP	75
XF2092	805DRLP	75

Emission Filters by CWL
(center wavelength)

Product SKU	Descriptor	Page #
XF3097	400ALP	73,94
XF3088	435ALP	73
XF3061	445-525-650TBEM	78,92
XF3002	450AF65	73,80,88,95
XF3410	450QM60	72,79
XF3458	457-528-600TBEM	77,79,91
XF3058	457-528-633TBEM	78,92
XF3063	460-520-602TBEM	78,92
XF3059	460-520-603-710QBEM	78,92
XF3054	460-550DBEM	78,91
XF3091	460ALP	73
XF3118	465-535-640TBEM	92
XF3078	465AF30	73
XF3116	470-530-620TBEM	78,92
XF3060	470-590DBEM	91
XF3099	475-550DBEM	78,92
XF3075	480AF30	73,80,88
XF3087	480ALP	73
XF3401	480QM30	72,79
XF3005	495DF20	88
XF3080	510AF23	74,88
XF3404	510QMLP	72
XF3086	510ALP	73,94
XF3043	510WB40	96
XF3067	515-600-730TBEM	78,92
XF3093	515ALP	73
XF3405	518QM32	72
XF3056	520-580DBEM	78,91
XF3456	520-610DBEM	77,91
XF3003	520DF40	76
XF3457	525-637DBEM	77,91
XF3301	525WB20	86,93
XF3057	528-633DBEM	78,91
XF3082	530ALP	74
XF3415	530QM20	79
XF3017	530DF30	80,88
XF3411	535QM50	72
XF3079	535AF26	88
XF3084	535AF45	74,88,95
XF3011	535DF25	96
XF3007	535DF35	74,76,88
XF3470	535-710DBEM	77,91
XF3407	545QM35	72
XF3074	545AF35	74,88
XF3406	545QM75	72

Emission Filters by CWL
(center wavelength)

Product SKU	Descriptor	Page #
XF3105	545AF75	73,74
XF3408	565QMLP	72
XF3085	565ALP	74
XF3302	565WB20	80,86,88,93
XF3089	575ALP	72
XF3416	577QM25	79
XF3022	580DF30	76,80,88,96
XF3412	585QM30	72
XF3303	585WB20	86,93
XF3024	590DF35	76,95
XF3066	595-700DBEM	78
XF3403	595QM60	72
XF3083	595AF60	74,88
XF3019	605DF50	88
XF3304	605WB20	86,93
XF3094	610ALP	74
XF3025	615DF45	95
XF3020	620DF35	80
XF3413	625QM50	72
XF3309	625DF20	86,93
XF3028	630DF30	76,80
XF3418	630QM36	79
XF3015	635DF55	76
XF3023	640DF35	96
XF3081	645AF75	74,76
XF3402	645QM75	72
XF3305	655WB20	86,93
XF3012	660DF50	76
XF3030	670DF40	76
XF3419	677QM25	79
XF3031	682DF22	76,80
XF3104	690ALP	75
XF3409	695QM55	72
XF3076	695AF55	75,88,95
XF3095	700ALP	75
XF3414	710QM80	72
XF3113	710AF40	75,86,93
XF3100	710ASP	97
XF3114	730AF30	75
XF3307	800WB80	86,93
XF3308	840WB80	86,93
XF3121	843AF35	75
XF3018	OG530	76
XF3016	OG590	76

FLUORESCENCE FILTER SETS REFERENCE TABLE

Fluorescence Filter Sets Reference Table

Filter Set SKU	Product Category	Page #
XF401	QuantaMAX™, M-FISH	72,79
XF402	QuantaMAX™	72
XF403	QuantaMAX™, M-FISH	72,79
XF404	QuantaMAX™	72
XF405	QuantaMAX™	72
XF406	QuantaMAX™	72
XF407	QuantaMAX™	72
XF408	QuantaMAX™, M-FISH	72,79
XF409	QuantaMAX™	72
XF410	QuantaMAX™	72
XF411	QuantaMAX™	72
XF412	QuantaMAX™	72
XF413	QuantaMAX™	72
XF414	QuantaMAX™	72
XF416	QuantaMAX™	72
XF421	QuantaMAX™ M-FISH	79
XF422	QuantaMAX™ M-FISH	79
XF424	QuantaMAX™ M-FISH	79
XF425	QuantaMAX™ M-FISH	79
XF452	QuantaMAX™ Dual Band	91
XF453	QuantaMAX™ Dual Band	77
XF454	QuantaMAX™ Dual Band	77
XF467	QuantaMAX™ Triple Band	77
XF452-1	Pinkel	91
XF453-1	Pinkel	91
XF454-1	Pinkel	91
XF467-1	Pinkel, M-FISH	79,91
XF02-2	Standard	73,94
XF04-2	Ratio Imaging	96
XF05-2	Quantum Dots	73,94
XF06	Standard	73,80
XF09	Standard	76
XF100-2	Standard	74
XF100-3	Standard	74
XF101-2	Standard	74
XF102-2	Standard	74
XF103-2	Standard	74
XF104-2	Standard	74
XF105-2	Standard	74
XF106-2	Standard	73
XF108-2	Standard	74
XF110-2	Standard	75
XF111-2	Standard	74
XF114-2	Standard	73
XF115-2	Standard	73
XF116-2	Standard	74
XF119-2	Standard	73
XF130-2	Standard	73
XF131	Standard	73

Filter Set SKU	Product Category	Page #
XF13-2	Standard	73
XF135	Multi-band - Dual	78
XF135-1	Pinkel	92
XF138-2	Standard	75
XF140-2	Standard	75
XF141-2	Standard	75
XF14-2	Standard	73
XF142-2	Standard	75
XF148	Standard	75
XF149	Standard	73
XF151-2	FRET	88
XF152-2	FRET	88
XF154-1	Pinkel	92
XF155	Sedat	95
XF156	Sedat	95
XF157	Sedat	95
XF158	FRET	88
XF159	FRET	88
XF16	Ratio Imaging	96
XF160	FRET	88
XF162	FRET	88
XF163	FRET	88
XF164	FRET	88
XF165	FRET	88
XF166	FRET	88
XF167	FRET	88
XF173	Standard	74
XF175	Standard	74
XF179	Standard	76
XF18-2	Standard	73
XF201	M-FISH	80
XF202	M-FISH	80
XF203	M-FISH	80
XF204	M-FISH	80
XF206	M-FISH	80
XF207	M-FISH	80
XF208	M-FISH	80
XF21	Standard	76
XF23	Standard	74
XF25	Standard	76
XF300	Quantum Dots	93
XF301-1	Quantum Dots	93
XF301-2	Quantum Dots	93
XF302-1	Quantum Dots	93
XF302-2	Quantum Dots	93
XF303-1	Quantum Dots	93
XF303-2	Quantum Dots	93
XF304-1	Quantum Dots	93
XF304-2	Quantum Dots	93

Filter Set SKU	Product Category	Page #
XF305-1	Quantum Dots	93
XF305-2	Quantum Dots	93
XF306-1	Quantum Dots	93
XF306-2	Quantum Dots	93
XF307-1	Quantum Dots	93
XF307-2	Quantum Dots	93
XF308-1	Quantum Dots	93
XF308-2	Quantum Dots	93
XF309-1	Quantum Dots	93
XF309-2	Quantum Dots	93
XF320	Quantum Dots	94
XF32	Standard	76
XF35	Standard	76
XF37	Standard	76
XF38	Standard	76
XF40-2	Standard	74
XF43	Standard	76
XF45	Standard	76
XF46	Standard	76
XF47	Standard	76
XF48-2	Standard	75
XF50	Multi-band - Dual	78
XF50-1	Pinkel	91
XF52	Multi-band - Dual	78
XF52-1	Pinkel	91
XF53	Multi-band - Dual	78
XF53-1	Pinkel	91
XF56	Multi-band - Triple	78
XF57	Multi-band - Quad Set	78
XF57-1	Pinkel	92
XF59-1	Pinkel	91
XF63	Multi-band - Triple	78
XF63-1	Pinkel	92
XF66	Multi-band - Triple	78
XF67	Multi-band - Triple	78
XF67-1	Pinkel	92
XF68	Multi-band - Triple	78
XF68-1	Pinkel	92
XF69	Multi-band - Triple	78
XF69-1	Pinkel	92
XF72	Ratio Imaging	96
XF76	Standard	76
XF88-2	FRET	88
XF89-2	FRET	88
XF92	Multi-band - Dual	78
XF93	Multi-band - Triple	78
XF93-1	Pinkel	92

QUANTAMAX™ and STANDARD FILTERS for FLUORESCENCE

Our fluorescence filter product line is comprised of Stock QuantaMAX™ and Standard Vivid and Basic excitation, emission and dichroic interference filters, and filter sets.

For the visualization of fluorescence and imaging from deep UV absorbing compounds such as the aromatic amino acids Tyrosine and Tryptophan, to near IR absorbing dyes such as Indocyanine Green (ICG) Omega Optical offers a variety of interference filters and filter sets We have an impressive history of collaborating with researchers to identify filters that are uniquely compatible with specific fluorophores, as well as filters that are effective for fluorophores in a particular experimental design and optical set-up. These products are produced utilizing our multiple coating technologies, ion- assist, magnetron sputtering and physical vapor deposition, to best match the filter specifications to the application.

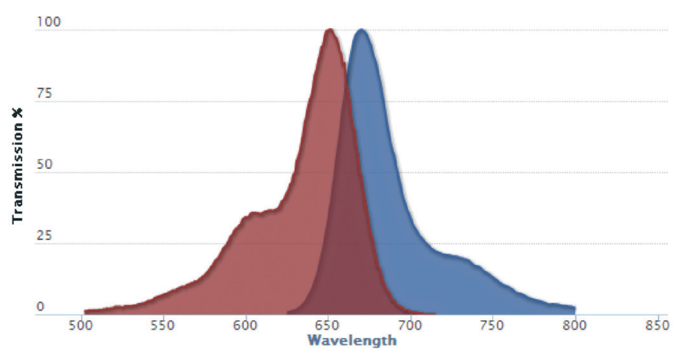
QuantaMAX™ - STOCK INTERFERENCE FILTERS

QuantaMAX™ are individual excitation, emission and dichroic filters and filter sets designed around the most commonly used fluorophores used in fluorescence detection and imaging. **QuantaMAX™** (QMAX) filters are engineered and manufactured to meet the increased demands required of today's imaging systems.

Fluorophore Optimized:

Organic fluorophores, whether a small molecule such as a cyanine dye, or a larger mass protein, such as e-GFP, absorb and emit photons in a highly wavelength dependent manner. This characteristic of a fluorescent compound can be illustrated by its specific fluorescence spectral curve, which describes the relative probabilities of the absorption and emission of photons across the wavelength spectrum. Figure 1 shows the excitation and emission curve for Cy5. This fluorophore is widely used in fluorescence techniques and exhibits an excitation absorption maximum at 649nm and emission maximum at 670nm. The slight separation of the two is called the Stokes shift and provides a spectral "window" through which researchers can (through the use of the appropriate interference filters) separate the incoming excitation light from the emitted fluorescence.

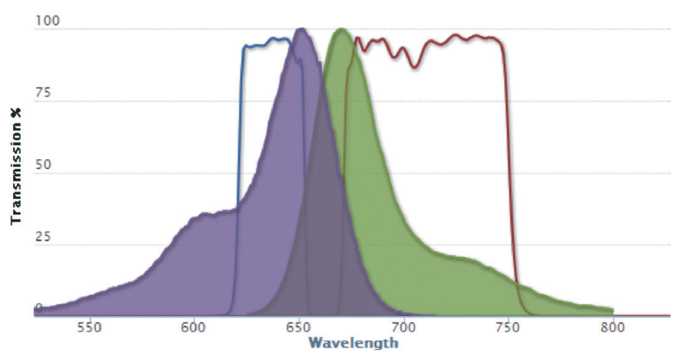
Figure 1 Excitation and Emission curves of Cy5



Given the small Stokes Shift of 20 nm or less of many of the typical fluorophores used in fluorescence systems, the demands placed on the filters to provide high transmission in the passband and deep out of band blocking are considerable, as generating high image contrast at low excitation light levels is a desirable condition in many protocols, particularly live cell imaging. The ability to place the excitation and emission filter pair's passbands very close to the absorption and emission maximums of a particular fluorophore is a critical feature for obtaining this contrast. A filter set's critical edges (the facing edges of the excitation and emission filters) are designed with a slope of 1% or less to allow for the closest placement of the two filters without sacrificing excitation light attenuation. *(See figure 2 and 3)*

QuantaMAX™ - Stock interference filter sets provide optimal pass band placement to achieve efficient specific photon collection while simultaneously rejecting stray light and minimizing spectral bleed-through from spectrally close fluorophores.

Figure 2 Transmission curve of XF407 set for Cy5 (showing steep edge slope)



Substrate Specifications:

Each filter is produced on a single substrate which has been polished to < 15 arc seconds or better. This allows for minimal beam deviation and in most imaging systems leads to registrations shifts of 1 pixel or less. Excitation and emission filter substrates utilize a range of optical substrates which are optimized for low light scatter and high transmission through the pass band region of the filter. The use of certain high quality absorption glasses in the design of these filters also offers the benefit of an increased ability to attenuate off axis rays such as those found in instruments using high system speeds or less than optimally collimated light sources such as light emitting diodes (LED).

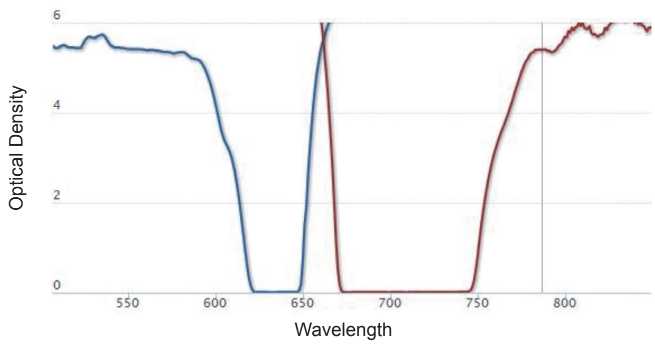
Dichroic mirror substrates utilize UV-grade fused silica to take advantage of the high level of internal uniformity of this glass, therefore offering excellent transmitted wave-front distortion (TWD) and transmission values across the operational range of the substrate.

QuantaMAX™ - Stock filters are available for immediate shipment; 25 mm round emission and excitation and 25.7 x 36 mm dichroic. Additional sizes are available upon request.

Spectral Performance:

Single fluorophore **QuantaMAX™** interference filters and filter sets provide 90% minimum transmission across the pass-band, and routinely exhibit values greater. When using a sensitive detection technique such as fluorescence, a key to achieving high levels of contrast is to minimize non-specific light from reaching the detector. A typical research grade CCD camera has a quantum efficiency range from ~350-1100 nm. By designing each filter to offer near band blocking of ≥ OD 6, and extended blocking to > OD 5, QMAX filters offer outstanding noise suppression though the entire integrated range of the detector.

Figure 3 Optical Density curve of XF407 set



VIVID AND BASIC - STANDARD INTERFERENCE FILTERS

Vivid and Basic - Standard interference filters and filter sets may be comprised of our speedy small volume manufacturing process or large component inventory. They are not immediately available off-the-shelf but are available to ship in 5 business days *(expedited deliveries are available upon request)*, and are customized to your physical and spectral requirements. Applications involving novel fluorophores or multiplexing systems where customized bandwidths are a must are examples of where a product from the standard filter program can be offered to optimize the system performance. The strategy of small lot builds and the incorporation of off-the-shelf components provides for filters of nearly any characteristic to be produced in a fast and economical fashion.

Vivid Filters:

The Vivid product line utilizes a proprietary method of monitoring and controlling the coating process. This technology yields filters with exceptionally high signal to noise and steep transistion slopes, making them suitable for demanding applications. Vivid filters offer precise and accurate location of cut on and cut off edges with tolerances of +/- 0.01 – +/- 0.05 % of the 50% wavelength edge.

Basic Filters:

The Basic filters offer excellent performance at a reasonable cost. These filters and filter sets are optimized for the specified application and utilize multi-cavity, Fabry-Perot designs to achieve a rectangular bandpass shape with very steep edges and deep blocking up to OD6 outside the passband.

Flexible and efficient manufacturing:

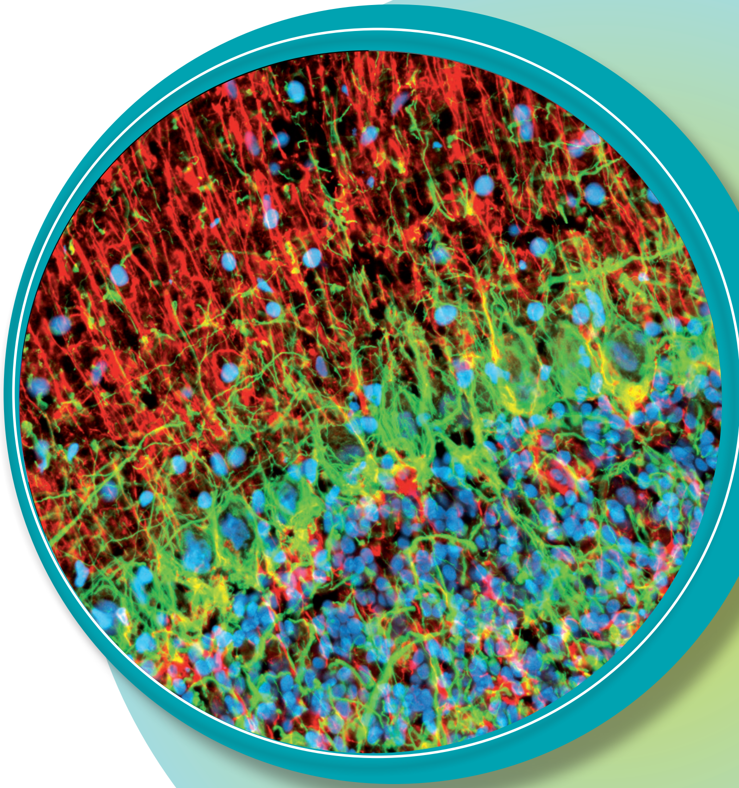
Vivid and Basic - Standard interference filters are assembled from our component inventory library of thousands of filter and blockers, along with our speedy turn-around manufacturing capabilities, to provide solutions for unique applications. Some examples of these applications are narrow band Quantum dot specific filters, ratio imaging filters, UV activated photo-switchable proteins, along with many of the less commonly used fluorophores such as Indocyanine Green. These products will meet the requirements for both industry and research where a stock catalog part may not provide the ideal characteristics for the application and without the added cost of a custom manufactured filter and associated lead times.

Specifications:

Vivid and Basic - Standard filters are designed to functional specifications of the best optical performance at a reasonable price and delivery. Typically, **standard** band-pass excitation filters reach minimum 75 % transmission. **Standard** filters that do not require extended blocking can exhibit up to 80-90 % transmission. Standard long and short-pass filters will average > 90 % transmission over the specified operating spectral range. All imaging filters are polished to ≥ 15 arc seconds parallelism and anti-reflection coating applied to minimize deviation and reflection. Dichroic mirrors are built on the same high quality substrate material as those in the **stock** program for imaging qualities.

SUMMARY

Given the vast number of fluorescent dyes and applications in use in laboratories today, a solutions approach to maximizing the available filter options has been developed to provide premium performance. **QuantaMAX™ - Stock** filters provide precision single substrate coated high contrast filters for the most common applications in fluorescence and are available for immediate shipment. **Vivid and Basic - Standard** filters provide a valuable pathway for meeting the requirements of researchers whose needs exist outside the **stock** program, and want the benefits of high contrast, imaging quality fluorescence detection filters at a reasonable cost.



- Excitation and emission filters: 18, 20, 22, and 25 mm round
- Dichroic beamsplitters: 18 x 26, 20 x 28, 21 x 29, and 25.7 x 36 mm rectangular. Dichroics also available as 18, 20, 22, and 25 mm round
- Purchase as sets or as individual components

QuantaMAX™ Single Band Filters

Arranged by fluorophores and emission wavelength.

Dyes	Fluorescent Proteins	Filter Set SKU	Applications	Components		
				Type	Product SKU	Description
DAPI Hoechst 33342 & 33258 AMCA/AMCA-X		XF408	Optimized for Hg lamp. Narrower excitation bandwidth than XF403 set. Can decrease phototoxicity of UV light exposure.	Excitation Dichroic Emission	XF1409 XF2001 XF3410	365QM35 400DCLP 450QM60
Alexa Fluor® 350, DAPI, Hoescsht 33342 & 33258	BFP	XF403	Wide excitation bandwith filter may cause cellular damage in live cell applications. This set is ideal for imaging BFP (Blue Fluorescent Protein) and BFP2.	Excitation Dichroic Emission	XF1415 XF2085 XF3410	380QM50 410DRLP 450QM60
SpectrumAqua®	CFP, eCFP, mCFPm, Cerulean, CyPet	XF401	This filter set is designed for optimal signal capture of CFP and to minimize spectral bleedthrough of YFP and spectrally similar fluors.	Excitation Dichroic Emission	XF1402 XF2034 XF3401	440QM21 455DRLP 480QM30
Alexa Fluor® 488, Cy2®, FITC	eGFP, CoralHue Azami Green, Emerald	XF404	This set is designed for both excellent brightness and contrast, offering ≥ OD 6 at the ex/em crossover. Also designed for use in multi-label systems, with minimal excitation of dyes such as Texas red and similar fluors.	Excitation Dichroic Emission	XF1416 XF2077 XF3411	470QM40 500DRLP 535QM50
Cy2® Fluorescein (FITC) Alexa Fluor® 488	eGFP	XF409	Longpass emission filter captures highest amounts of fluorescent signal, though is not as discriminating as a bandpass filter set. Background may be increased. Most useful in single label applications.	Excitation Dichroic Emission	XF1416 XF2010 XF3404	470QM40 505DRLP 510QMLP
Fluorescein (FITC) Alexa Fluor® 488, Cy2®	CoralHue Midoriishi-Cyan, eGFP	XF410	Narrowband filters can help to reduce sample auto-fluorescence. Useful for discrimination from red emitting fluorophores such as mRFP.	Excitation Dichroic Emission	XF1410 XF2077 XF3405	475QM20 500DRLP 518QM32
Fluorescein (FITC) Alexa Fluor® 488 Cy2®, DiO, Fluo-4	eGFP	XF411	This set offers wide passbands for very high brightness while still giving good contrast. May exhibit some spectral bleedthough with TRITC – like fluorophores.	Excitation Dichroic Emission	XF1411 XF2077 XF3406	470QM50 500DRLP 545QM75
Rhodamine Green™ Alexa Fluor® 532	YFP, ZsYellow1	XF412	This filter set is optimized for YFP and for minimizing CFP bleedthrough.	Excitation Dichroic Emission	XF1412 XF2030 XF3407	500QM25 525DRLP 545QM35
Alexa Fluor® 546, 555 Cy3®, Rhodamine 2, TRITC	DsRed2, mTangerine	XF405	Yellow-orange emission for DsRed2, TRITC and others.	Excitation Dichroic Emission	XF1417 XF2017 XF3412	530QM40 560DRLP 585QM30
TRITC Cy3®, Alexa Fluor® 555 MitoTracker® Orange	DsRed2, DsRed-Express	XF413	Longpass emission filter.	Excitation Dichroic Emission	XF1403 XF2017 XF3408	525QM45 560DRLP 565QMLP
TRITC, Alexa Fluor® 555 Cy3®, MitoTracker® Orange	CoralHue Kusabira Orange, DsRed2, DsRed-Express, mOrange, mTangerine	XF402	High brightness and contrast set for TRITC and similar fluors. Offers > OD6 attenuation at the ex/em crossover.	Excitation Dichroic Emission	XF1403 XF2017 XF3403	525QM45 560DRLP 595QM60
Alexa Fluor® 568, 594 Mito-Tracker® Red	HcRed, mCherry, Jred	XF406	Red emission and good discrimination from eGFP in co-expression systems.	Excitation Dichroic Emission	XF1418 XF2086 XF3413	555QM50 580DRLP 625QM50
Texas Red®/Texas Red®-X Cy3.5® MitoTracker® Red	HcRed, HcRed1, mRaspberry, MRFP1	XF414	Set offers wider passbands than XF406, giving high brightness and contrast to red emitting fluors such as Texas Red.	Excitation Dichroic Emission	XF1413 XF2029 XF3402	560QM55 595DRLP 645QM75
Alexa Fluor® 647, Cy5®		XF407	This set offers a wide emission filter for maximal photon capture and a narrower excitation filter for minimizing simultaneous excitation of red dyes such as Texas red.	Excitation Dichroic Emission	XF1419 XF2087 XF3414	635QM30 660DRLP 710QM80
Cy5®, Alexa Fluor® 647 DiD (DilC18(5))	mPlum APC (allophycocyanin)	XF416	Difficult to see emissions at these wavelengths with the unaided eye. B/W camera is typically used to capture signal.	Excitation Dichroic Emission	XF1414 XF2035 XF3409	630QM50 650DRLP 695QM55

CUSTOM CONFIGURATIONS AVAILABLE UPON REQUEST

Our line of standard interference filters is representative of typical industry specifications. Available to ship in 5 business days. Need sooner? Please call.

Vivid Single Band Filters

Arranged by fluorophores and emission wavelength.

Fluorophores	Filter Set SKU	Applications	Components		
			Type	Product SKU	Description
DAPI Hoechst 33342 & 33258 AMCA/AMCA-X	XF02-2	Wide band excitation filter with longpass emission filter.	Excitation Dichroic Emission	XF1001 XF2001 XF3097	330WB80 400DCLP 400ALP
DAPI Hoechst 33342 & 33258 AMCA/AMCA-X	XF05-2	Good with mercury arc lamp.	Excitation Dichroic Emission	XF1005 XF2001 XF3097	365WB50 400DCLP 400ALP
GeneBLAzer™ (CCF2)	XF106-2	Combines blue and green emission colors.	Excitation Dichroic Emission	XF1076 XF2040 XF3088	400AF30 435DRLP 435ALP
DAPI Hoechst 33342 & 33258 AMCA/AMCA-X	XF06	Optimized for Hg lamp.	Excitation Dichroic Emission	XF1005 XF2001 XF3002	365WB50 400DCLP 450AF65
BFP, LysoSensor™ Blue (pH5)	XF131	Similar narrow UV excitation to XF129-2, but with bandpass emission filter.	Excitation Dichroic Emission	XF1075 XF2004 XF3002	387AF28 410DRLP 450AF65
Cascade Yellow™ SpectrumAqua® SYTOX® Blue	XF13-2		Excitation Dichroic Emission	XF1008 XF2040 XF3091	405DF40 435DRLP 460ALP
Sirius	XF149	This filter set is designed for imaging the ultramarine emitting fluorescent protein, Sirius. Sirius was first reported as a pH insensitive and photostable derivative mseCFP-Y66F from Aequorea Victoria by Tomosugi, Matsuda, Nagai et al in the Nature Methods in May 2009. Sirius has the lowest emission wavelength of 424nm among currently described fluorescent proteins and has great characteristics for use in acidic environments. The fluorescent protein can be used as a donor in FRET and dual-FRET experiments.	Excitation Dichroic Emission	XF1005 XF2004 XF3078	365WB50 410DRLP 465AF30
Pacific Blue™	XF119-2		Excitation Dichroic Emission	XF1076 XF2040 XF3078	400AF30 435DRLP 465AF30
CFP SpectrumAqua®	XF130-2	Longpass emission filter set for CFP. May exhibit higher background than bandpass sets, and have higher bleedthrough from other blue light excited fluors such as FITC or eGFP.	Excitation Dichroic Emission	XF1071 XF2034 XF3087	440AF21 455DRLP 480ALP
CFP SpectrumAqua®	XF114-2	Narrow bandpass excitation filter specific for CFP. Designed to minimize co-excitation of YFP.	Excitation Dichroic Emission	XF1071 XF2034 XF3075	440AF21 455DRLP 480AF30
Fura Red™ (high calcium) DiA (4-Di-16-ASP)	XF18-2	Broad excitation filter.	Excitation Dichroic Emission	XF1012 XF2008 XF3093	455DF70 515DRLP 515ALP
eGFP, Cy2® Fluorescein (FITC) Alexa Fluor® 488	XF115-2	Longpass emission filter may show more auto-fluorescence.	Excitation Dichroic Emission	XF1073 XF2010 XF3086	475AF40 505DRLP 510ALP
Alexa Fluor® 430 Cascade Yellow™ Lucifer Yellow	XF14-2	Set designed for large Stoke's shift fluors with green emission, such as Alexa 430 and Mithramiycin. Wide bandpass emission filter for capturing majority of fluorescence photons.	Excitation Dichroic Emission	XF1009 XF2007 XF3105	425DF45 475DCLP 545AF75

CUSTOM CONFIGURATIONS AVAILABLE UPON REQUEST

Excitation and emission filters: 18, 20, 22, and 25 mm round

Dichroic beamsplitters: 18 x 26, 20 x 28, 21 x 29, and 25.7 x 36 mm rectangular. Dichroics also available as 18, 20, 22, and 25 mm round

Purchase as sets or as individual components

Vivid Single Band Filters *Continued*

Arranged by fluorophores and emission wavelength.

Fluorophores	Filter Set SKU	Applications	Components Type	Product SKU	Description
eGFP Fluorescein (FITC) Alexa Fluor® 488, Cy2®	XF116-2	Narrowband filters can help to reduce sample auto-fluorescence. Also useful for discriminating from red emitting fluorophores such as mRFP.	Excitation Dichroic Emission	XF1072 XF2037 XF3080	475AF20 500DRLP 510AF23
eGFP, Fluorescein (FITC) Alexa Fluor® 488 Cy2®, DiO, Fluo-4	XF100-2	High transmission and good contrast set for FITC, eGFP like fluors. Exhibiting steep slopes and good out of band blocking.	Excitation Dichroic Emission	XF1073 XF2010 XF3084	475AF40 505DRLP 535AF45
eGFP, Fluorescein (FITC) Alexa Fluor® 488 Cy2®, DiO, Fluo-4	XF100-3	This set consists of wide bandpass filters for collecting maximal excitation and emission energy.	Excitation Dichroic Emission	XF1087 XF2077 XF3105	470AF50 500DRLP 545AF75
YFP Rhodamine Green™ Alexa Fluor® 532	XF105-2	Longpass emission filter set for YFP.	Excitation Dichroic Emission	XF1068 XF2030 XF3082	500AF25 525DRLP 530ALP
Fluorescein (FITC) Alexa Fluor® 488 Cy2®, BODIPY® FL	XF23	Better photopic color rendition.	Excitation Dichroic Emission	XF1015 XF2010 XF3007	485DF22 505DRLP 535DF35
YFP Rhodamine Green™ Alexa Fluor® 532	XF104-2	Optimized filter set for YFP. Excellent contrast set with good discrimination for CFP.	Excitation Dichroic Emission	XF1068 XF2030 XF3074	500AF25 525DRLP 545AF35
DsRed2	XF111-2	Long pass emission filter for red fluorophors. Can provide more signal than bandpass emission filter, though background may increase.	Excitation Dichroic Emission	XF1077 XF2015 XF3089	540AF30 570DRLP 575ALP
TRITC Cy3®, Alexa Fluor® 555 MitoTracker® Orange	XF101-2	Longpass emission filter.	Excitation Dichroic Emission	XF1074 XF2017 XF3085	525AF45 560DRLP 565ALP
tdTomato	XF173		Excitation Dichroic Emission	XF1103 XF2015 XF3083	535AF30 570DRLP 595AF60
TRITC, Alexa Fluor® 555 Cy3®, DsRed2 MitoTracker® Orange	XF108-2	High brightness and contrast set for TRITC, Cy3 and similar dyes.	Excitation Dichroic Emission	XF1074 XF2017 XF3083	525AF45 560DRLP 595AF60
XRITC Cy3.5®, MitoTracker® Red SNARF®-1 (high pH), Alexa Fluor® 568/594	XF40-2	Longpass emission filter set for XRITC, 5-ROX, and Cy3.5. Brighter emission with lower signal to noise than XF41 bandpass equivalent.	Excitation Dichroic Emission	XF1022 XF2019 XF3094	560DF40 590DRLP 610ALP
Texas Red®/Texas Red®-X Cy3.5® MitoTracker® Red	XF102-2	This set is designed for high brightness and contrast. Optimized for Texas Red, Alexa 594 and similar dyes.	Excitation Dichroic Emission	XF1067 XF2029 XF3081	560AF55 595DRLP 645AF75
mCherry	XF175		Excitation Dichroic Emission	XF1067 XF2020 XF3081	560AF55 600DRLP 645AF75
Propidium Iodide Ethidium bromide Nile Red	XF103-2	Wide passband filter set is designed for high brightness and contrast. Will provide higher PI signal than XF179.	Excitation Dichroic Emission	XF1074 XF2016 XF3081	525AF45 560DCLP 645AF75

CUSTOM CONFIGURATIONS AVAILABLE UPON REQUEST

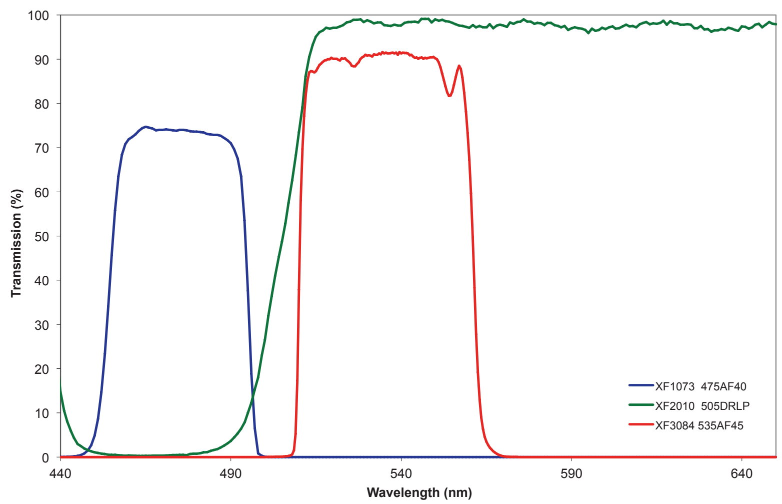
For current product listings, specifications, and pricing:
www.omegafilters.com • sales@omegafilters.com
1.866.488.1064 (toll free within USA only) • +1.802.254.2690 (outside USA)

Vivid Single Band Filters *Continued*

Arranged by fluorophores and emission wavelength.

Fluorophores	Filter Set SKU	Applications	Components Type	Product SKU	Description
ICG (Indocyanine Green)	XF148	The use the ICG fluorescence method for monitoring of hepatic funtion and liver blood flow has become a popular technique in recent years. This filter set allows for imaging of ICG without interference from hemoglobin or water absorption.	Excitation	XF1211	787DF18
			Dichroic	XF2092	805DRLP
			Emission	XF3121	843AF35
Alexa Fluor® 660/680, Cy5.5®	XF138-2	Best with Red Diode & HeNe lasers.	Excitation	XF1085	680ASP
			Dichroic	XF2075	690DRLP
			Emission	XF3104	690ALP
Cy5®, Alexa Fluor® 647 APC (allophycocyanin) DiD (DilC18(5))	XF110-2	It is very difficult to see emissions at these wavelengths with the unaided eye. B/W camera is typically used to capture signal.	Excitation	XF1069	630AF50
			Dichroic	XF2035	650DRLP
			Emission	XF3076	695AF55
Alexa Fluor® 633/647, Cy5®	XF140-2	Hg Arc lamp.	Excitation	XF1082	607AF75
			Dichroic	XF2072	650DRLP
			Emission	XF3076	695AF55
Alexa Fluor® 680, Cy5.5®	XF48-2	Non-visual detection. An IR sensitive detector must be used.	Excitation	XF1028	670DF20
			Dichroic	XF2024	690DRLP
			Emission	XF3095	700ALP
Alexa Fluor® 660/680, Cy5.5®	XF141-2	Non-visual detection. An IR sensitive detector must be used.	Excitation	XF1095	655AF50
			Dichroic	XF2082	692DRLP
			Emission	XF3113	710AF40
Alexa Fluor® 700	XF142-2	Non-visual detection. An IR sensitive detector must be used.	Excitation	XF1096	685AF30
			Dichroic	XF2083	708DRLP
			Emission	XF3114	730AF30

XF100-2
Representation of Typical Standard Filter Performance



CUSTOM CONFIGURATIONS AVAILABLE UPON REQUEST

- Excitation and emission filters: 18, 20, 22, and 25 mm round
- Dichroic beamsplitters: 18 x 26, 20 x 28, 21 x 29, and 25.7 x 36 mm rectangular. Dichroics also available as 18, 20, 22, and 25 mm round
- Purchase as sets or as individual components

Basic Single Band Filters

Arranged by fluorophores and emission wavelength.

Fluorophores	Filter Set SKU	Applications	Components		
			Type	Product SKU	Description
GFP (sapphire) Cascade Yellow™	XF76	Set designed for fluors with large Stoke shifts such as Cascade Yellow and GFP-Sapphire (T-Sapphire).	Excitation Dichroic Emission	XF1008 XF2006 XF3003	405DF40 450DCLP 520DF40
Fluorescein (FITC) Cy2®, Alexa Fluor® 488 BODIPY® FL	XF25		Excitation Dichroic Emission	XF1015 XF2010 XF3018	485DF22 505DRLP OG530
Fluoro-Gold™ (high pH) Aniline Blue	XF09	Excellent for multiwavelength work in red.	Excitation Dichroic Emission	XF1005 XF2001 XF3007	365WB50 400DCLP 535DF35
TRITC, SpectrumOrange® Cy3®, Alexa Fluor® 555 MitoTracker® Orange	XF37	Similar set to XF145 but with a narrower excitation filter centered on the 546nm peak of the mercury lamp.	Excitation Dichroic Emission	XF1020 XF2062 XF3022	546DF10 555DRLP 580DF30
TRITC, SpectrumOrange® Cy3®, MitoTracker® Orange Alexa Fluor® 555	XF32	This TRITC set has a red shifted emission filter which gives compatible dyes a yellow fluorescence.	Excitation Dichroic Emission	XF1019 XF2015 XF3024	535DF35 570DRLP 590DF35
TRITC, Cy3®, SpectrumOrange® Alexa Fluor® 555 MitoTracker® Orange	XF38	Optimized for Hg Lamp.	Excitation Dichroic Emission	XF1020 XF2015 XF3016	546DF10 570DRLP OG590
Texas Red®/Texas Red®-X Alexa Fluor® 594	XF43	Narrow bandwidth excitation filter is specific for the 577nm output peak of the Mercury arc lamp. Good discrimination against green and yellow emitting fluors such as FITC/ eGFP and YFP.	Excitation Dichroic Emission	XF1044 XF2020 XF3028	575DF25 600DRLP 630DF30
Acridine orange (+RNA) Di-4 ANEPPS	XF21	This filter set is designed for imaging large Stoke's shift fluors with red emissions, such Rh414 and Di-4 ANEPPS.	Excitation Dichroic Emission	XF1014 XF2009 XF3015	480DF60 550DCLP 635DF55
Propidium Iodide Ethidium bromide Nile Red	XF35		Excitation Dichroic Emission	XF1019 XF2016 XF3015	535DF35 560DCLP 635DF55
Propidium Iodide (PI)	XF179	Filter set with narrowband excitation filter for PI which minimizes cross-excitation of Acridine Orange or other similar fluorophores.	Excitation Dichroic Emission	XF1077 XF2015 XF3012	540AF30 570DRLP 660DF50
APC (allophycocyanin) BODIPY® 630/650-X CryptoLight CF-2, SensiLight P-3	XF45	Narrow band filter set minimizes the excitation of spectrally close dyes such as Cy3 and TRITC.	Excitation Dichroic Emission	XF1025 XF2021 XF3030	610DF20 630DRLP 670DF40
Cy5® BODIPY® 630/650-X Alexa Fluor® 633/647	XF46	Excitation filter optimal for 633 HeNe laser line.	Excitation Dichroic Emission	XF1026 XF2022 XF3030	633NB3.0 640DRLP 670DF40
Cy5® BODIPY® 630/650-X Alexa Fluor® 660	XF47	Narrowband emission filter. Black and white camera typically needed to capture signal.	Excitation Dichroic Emission	XF1027 XF2035 XF3031	640DF20 650DRLP 682DF22

CUSTOM CONFIGURATIONS AVAILABLE UPON REQUEST

- Steep edges
- Exceptional transmission
- High throughput
- Single substrate construction

QUANTAMAX™ MULTI-BAND FILTERS

Multi-band interference filters and sets offer the ability to find, localize, and image two or more colors (fluorophores) with one filter set. This is accomplished by combining excitation and emission filters with two, three, or even four transmission regions with a dichroic mirror which reflects and transmits the appropriate excitation and emission passbands.

Complete multi-band sets can be used to screen multiple fusion protein constructs quickly for the presence of fluorescent protein without switching between single band filter sets. They can also be used in clinical diagnostic settings where simple screening for green/red colors in a genomic hybridization assay can reveal the presence of pathogenic organisms in patient samples.

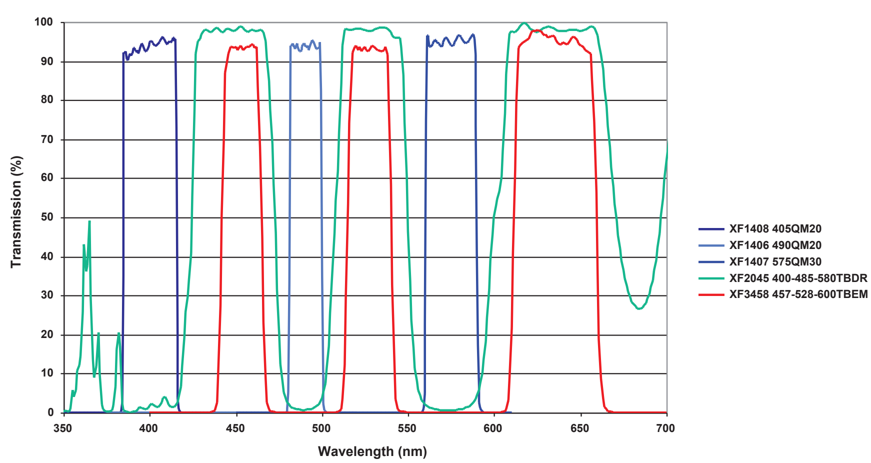
These filter sets are capable of capturing two or more colors in one image using a color camera (unless specified as being for visual identification only), but are not suitable for use with a black and white camera.

QuantaMAX™ Multi-band Filters

Arranged by fluorophores and emission wavelength.

Fluorophores	Filter Set SKU	Application	Components		
			Type	Product SKU	Description
FITC/ TRITC or eGFP/ DsRed2	XF452	Excellent contrast and high throughput filter set for green and orange emitting fluorophores such as FITC and TRITC. Can also be used with Alexa Fluor® 488, Cy2, and GFP-like fluorescent proteins, as well as Alexa Fluor®568 and tdTomato.	Excitation	XF1450	485-560DBEX
			Dichroic	XF2443	485-560DBDR
			Emission	XF3456	520-610DBEM
FITC/Texas Red® or eGFP/mCherry	XF453	XF453 is optimized for use with fluorescent proteins eGFP and mCherry. This high contrast filter set utilizes the 577nm Mercury peak for efficient excitation of red emitting fluorophores and is also compatible with many other common fluorophores such as FITC and Texas Red®.	Excitation	XF1451	484-575DBEX
			Dichroic	XF2044	490-575DBDR
			Emission	XF3457	525-637DBEM
FITC/ Cy5®	XF454	Due to their wavelength separation, FITC and Cy5 make a popular choice for dual labeling in a single sample as spectral bleedthrough is virtually non-existent. Also ideal for green and far red emitting fluorophores. Other compatible dyes are, Alexa Fluor®488, Hylite 488, Oregon Green, Cy2, and Alexa Fluor®647, Hylite 647.	Excitation	XF1420	475-625DBEX
			Dichroic	XF2401	475-625DBDR
			Emission	XF3470	535-710DBEM
DAPI/FITC/Texas Red(r) or BFP/eGFP/mCherry	XF467	This filter set is optimized for use with common blue, green, red emitting fluors such as DAPI/ FITC/Texas Red® or proteins BFP/eGFP/mCherry. The set can be used with visual detection, a CCD camera or color film for image capture.	Excitation	XF1458	390-486-577TBEX
			Dichroic	XF2045	400-485-580TBDR
			Emission	XF3458	457-528-600TBEM

XF467-1 Triple Band Set for DAPI/FITC/ Texas Red®



- Excitation and emission filters: 18, 20, 22, and 25 mm round
- Dichroic beamsplitters: 18 x 26, 20 x 28, 21 x 29, and 25.7 x 36 mm rectangular. Dichroics also available as 18, 20, 22, and 25 mm round
- Purchase as sets or as individual components

Multi-band Filters

Arranged by fluorophores and emission wavelength.

Fluorophores	Filter Set SKU	Application	Components Type	Product SKU	Description
DUAL BAND DAPI/FITC BFP/eGFP	XF50		Excitation	XF1048	400-500DBEX
			Dichroic	XF2041	385-502DBDR
			Emission	XF3054	460-550DBEM
CFP/YFP	XF135		Excitation	XF1078	436-510DBEX
			Dichroic	XF2065	436-510DBDR
			Emission	XF3099	475-550DBEM
FITC/TRITC eGFP/DsRed2	XF52		Excitation	XF1050	490-550DBEX
			Dichroic	XF2043	490-550DBDR
			Emission	XF3056	520-580DBEM
FITC/Texas Red®	XF53		Excitation	XF1051	490-577DBEX
			Dichroic	XF2044	490-575DBDR
			Emission	XF3057	528-633DBEM
Cy3®/Cy5®	XF92		Excitation	XF1062	550-640DBEX
			Dichroic	XF2053	555-640DBDR
			Emission	XF3066	595-700DBEM
TRIPLE BAND DAPI/FITC/Texas Red®	XF63	Real time visual detection.	Excitation	XF1055	400-477-580TBEX
			Dichroic	XF2048	400-477-575TBDR
			Emission	XF3061	445-525-650TBEM
DAPI/FITC/Texas Red®	XF56	Real time visual imaging with a CCD camera or color film.	Excitation	XF1052	390-486-577TBEX
			Dichroic	XF2045	400-485-580TBDR
			Emission	XF3058	457-528-633TBEM
DAPI/FITC/Texas Red®	XF67	Real time visual detection.	Excitation	XF1058	390-486-577TBEX
			Dichroic	XF2045	400-485-580TBDR
			Emission	XF3058	457-528-633TBEM
DAPI/FITC/TRITC	XF66	Real time visual imaging with a CCD camera or color film.	Excitation	XF1057	385-485-560TBEX
			Dichroic	XF2050	385-485-560TBDR
			Emission	XF3063	460-520-602TBEM
DAPI/FITC/TRITC	XF68	Real time visual detection.	Excitation	XF1059	386-485-560TBEX
			Dichroic	XF2050	385-485-560TBDR
			Emission	XF3063	460-520-602TBEM
DAPI/FITC/Propidium Iodide	XF69		Excitation	XF1098	400-495-575TBEX
			Dichroic	XF2051	400-495-575TBDR
			Emission	XF3116	470-530-620TBEM
FITC/Cy3®/Cy5®	XF93		Excitation	XF1063	485-555-650TBEX
			Dichroic	XF2054	485-555-650TBDR
			Emission	XF3067	515-600-730TBEM
QUAD BAND DAPI/FITC/TRITC/Cy5® DAPI/FITC/TRITC/ Alexa Fluor®647	XF57		Excitation	XF1053	405-490-555-650QBEX
			Dichroic	XF2046	400-485-558-640QBDR
			Emission	XF3059	460-520-603-710QBEM

CUSTOM CONFIGURATIONS AVAILABLE UPON REQUEST

NEW in 2012, Omega Optical has introduced filters and filters sets optimized for FISH and M-FISH imaging.

These new products offer the benefits of our high performance QuantaMAX™ coating technology such as minimized registration errors and outstanding transmission, along with high precise band placement to offer the consistency and sharpness of color required in this application.

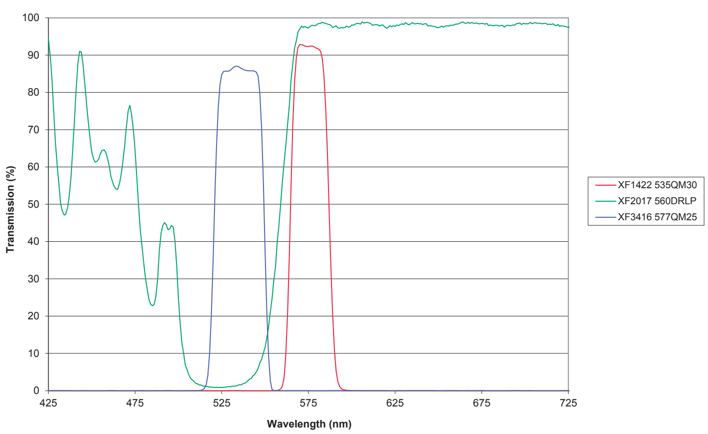
Please see also the Standard – FISH and M-FISH filters and sets on page 80.

QuantaMAX™ FISH and M-FISH Filters

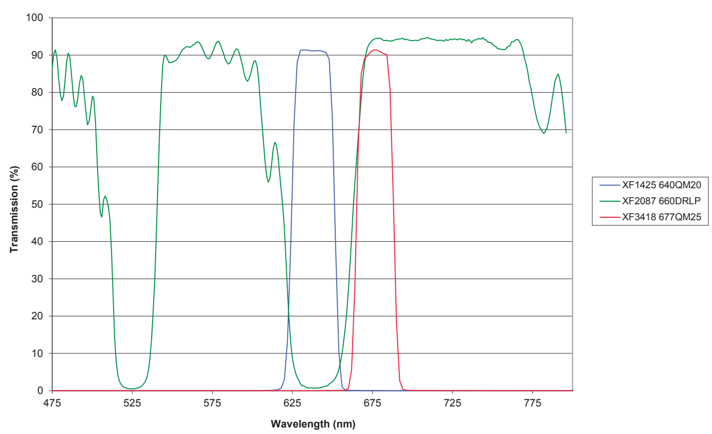
Arranged by fluorophores and emission wavelength.

Fluorophores	Filter Set SKU	Components		
		Type	Product SKU	Description
DAPI, Hoechst 33342 & 33258, AMCA/AMCA-X	XF408	Excitation	XF1409	365QM35
		Dichroic	XF2001	400DCLP
		Emission	XF3410	450QM60
DAPI, Hoechst 33342 & 33258, AMCA, BFP	XF403	Excitation	XF1415	380QM50
		Dichroic	XF2085	410DRLP
		Emission	XF3410	450QM60
Spectrum Aqua, CFP, Cerulean, CyPEt	XF401	Excitation	XF1402	440QM21
		Dichroic	XF2034	455DRLP
		Emission	XF3401	480QM30
Spectrum Green, FITC, Cy2	**NEW** XF421	Excitation	XF1406	490QM20
		Dichroic	XF2010	505DRLP
		Emission	XF3415	530QM20
Spectrum Gold	**NEW** XF422	Excitation	XF1422	535QM30
		Dichroic	XF2017	560DRLP
		Emission	XF3416	577QM25
Spectrum Red	**NEW** XF424	Excitation	XF1424	580QM30
		Dichroic	XF2029	595DRLP
		Emission	XF3418	630QM36
Spectrum Far Red	**NEW** XF425	Excitation	XF1425	640QM20
		Dichroic	XF2087	660DRLP
		Emission	XF3419	677QM25
DAPI/FITC/Texas Red®, or DAPI/Spectrum Green/Spectrum Red	XF467-1	Excitation #1	XF1408	405QM20
		Excitation #2	XF1406	490QM20
		Excitation #3	XF1407	575QM30
		Dichroic	XF2045	400-485-580TBDR
		Emission	XF3458	457-528-600TBEM

XF422 Filter Set for Spectrum Gold



XF425 Filter Set for Spectrum Far Red



- For maximizing multi-color labeling applications
- Steep edges and narrow bandwidth

FISH and M-FISH Filters

Arranged by fluorophores and emission wavelength.

Fluorophores	Filter Set SKU	Components		
		Type	Product SKU	Description
DAPI, AMCA, Cascade Blue® SpectrumBlue®	XF06	Excitation	XF1005	365WB50
		Dichroic	XF2001	400DCLP
		Emission	XF3002	450AF65
SpectrumAqua®, CFP, DEAC	XF201	Excitation	XF1201	436AF8
		Dichroic	XF2034	455DRLP
		Emission	XF3075	480AF30
SpectrumGreen®, FITC, EGFP, Cy2®, Alexa Fluor® 488, Oregon Green® 488, Rhodamine GreenTM	XF202	Excitation	XF1202	485AF20
		Dichroic	XF2010	505DRLP
		Emission	XF3017	530DF30
SpectrumGold®, Alexa Fluor® 532 YFP	XF203	Excitation	XF1203	520AF18
		Dichroic	XF2203	545DRLP
		Emission	XF3302	565DF20
Cy3®, TRITC, Alexa Fluor® 546 5-TAMRA, BODIPY® TMR/X SpectrumOrange®	XF204	Excitation	XF1204	546AF10
		Dichroic	XF2062	555DRLP
		Emission	XF3022	580DF30
Cy3.5®	XF206	Excitation	XF1206	572AF15
		Dichroic	XF2019	590DRLP
		Emission	XF3020	620DF35
SpectrumRed®, Texas Red® Alexa Fluor® 568, BODIPY® TR/X Alexa Fluor® 594	XF207	Excitation	XF1207	580AF20
		Dichroic	XF2020	600DRLP
		Emission	XF3028	630DF30
Cy5®, BODIPY® 650/665-X Alexa Fluor® 647	XF208	Excitation	XF1208	640AF20
		Dichroic	XF2035	650DRLP
		Emission	XF3031	682DF22

FISH and M-FISH Imaging

Application Note

Overview

The application of in situ hybridization (ISH) has advanced from short lived, non-specific isotopic methods, to very specific, long lived, and multi-color Fluorescent-ISH probe assays (FISH). Improvements in the optics, interference filter technology, microscopes, cameras, and data handling by software have allowed for a cost effective FISH setup to be within reach of most researchers. The application of mFISH (multiplex-FISH), coupled to the advances in digital imaging microscopy, have vastly improved the capabilities for non-isotopic detection and analysis of multiple nucleic acid sequences in chromosomes and genes.

Interference Filters and Fluorescence Imaging

In an upright microscope, the fluorescence illuminator follows an epi-fluorescent path (illumination from above) to the specimen. In the pathway is housed the filter blocks containing the dichroic mirror, excitation, and emission filters, which work to greatly improve the brightness and contrast of the imaged specimens, even when multiple fluorochromes are being used. Figure 1 illustrates the basic setup of the fluorescence illuminator on an upright microscope.

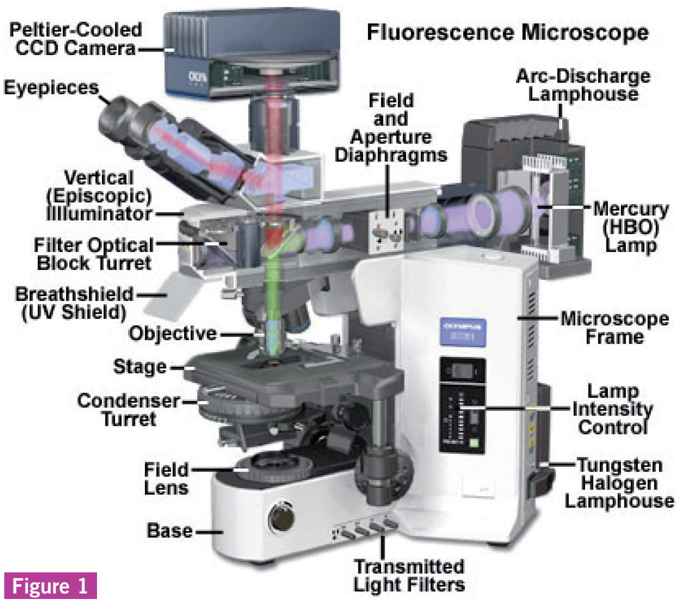


Figure 1

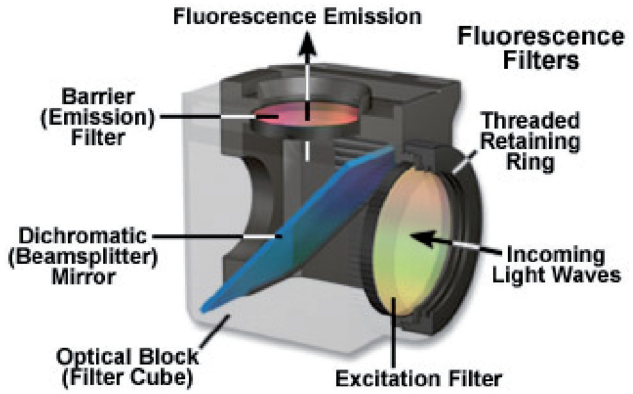


Figure 2

XF424	SpectrumRed® or TexasRed® filter set	
XF1424	Excitation	580QM30
XF2029	Dichroic	595DRLP
XF3418	Emission	63QM36

The principle components in the episcopic (reflected illumination) pathway consist of the light source (here depicted as a Mercury arc lamp), a series of lenses that serve to focus the light and correct for optical aberrations as the beam travels towards the filters, diaphragms which act to establish proper and even illumination of the specimen, and the filter turret which houses the filter sets. In the diagram it can be seen schematically how the broad band excitation light from the light source is selectively filtered to transmit only the green component by the excitation filter in the turret, which is in turn reflected by the dichroic mirror to the specimen. The red fluorescence emission is then transmitted back through the objective lens, through the mirror and is further filtered by the emission filter before visualization by eye or camera.

An expanded view of the filter cube is shown in Figure 2. The excitation filter is shown in yellow and the emission filter in red to describe a typical bandpass Texas Red filter set.

Optical Interference Filter Descriptions

Bandpass filters can be described in several ways. Most common is the Center Wavelength (CWL) and Full Width Half Maximum (FWHM) nomenclature, or alternatively, by nominal Cut-on and Cut-off wavelengths. In the former, the exciter in Fig. 2 is described as a 580AF20 or, a filter with nominal CWL of 580nm and a FWHM of 20nm. The half maximum value is taken at the transmission value where the filter has reached 50% of its maximum value (Figure 3). In the latter scheme, the filter would be described as having a Cut-on of 570nm and a Cut-off of 590nm, no CWL is declared. The Cut-on describes the transition from attenuation to transmission of the filter along an axis of increasing wavelengths. The Cut-off describes the transition from transmission back to attenuation. Both values indicate the 50% point of full transmission.

Cut-on and Cut-off values are also used to describe two types of filters known as Longpass filters (Figure 4) and Shortpass filters (Figure 5). A longpass filter is designed to reflect and/ or absorb light in a specific spectral region, to go into transmission at the Cut-on value (here 570mn) and transmit light above this over a broad wavelength range. A shortpass filter does the reverse, blocking the wavelengths of light longer than the Cut-off value for a specific distance, and transmitting the shorter wavelengths. It should be noted that these reflection and transmission zones do not continue indefinitely, but are limited by properties of the coating chemicals, coating design, and the physical properties of light.

Figure 3

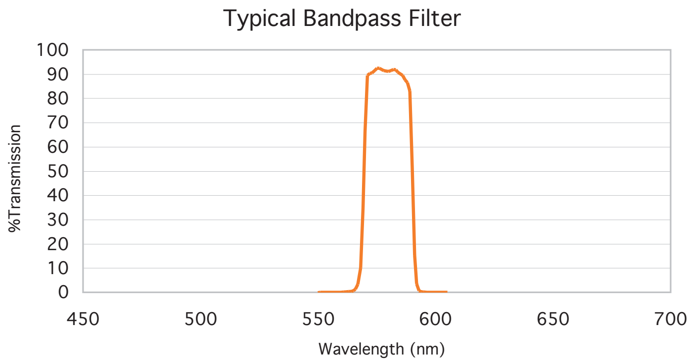


Figure 4

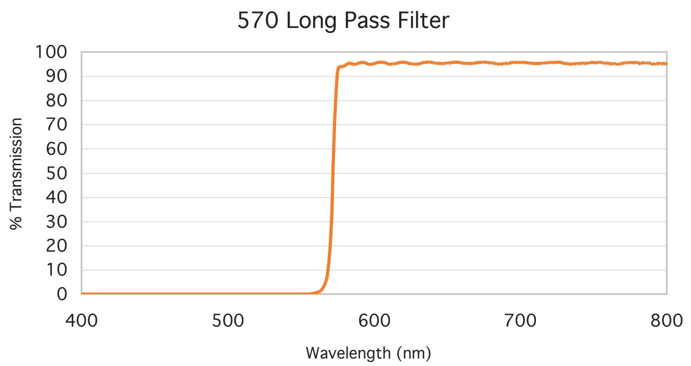
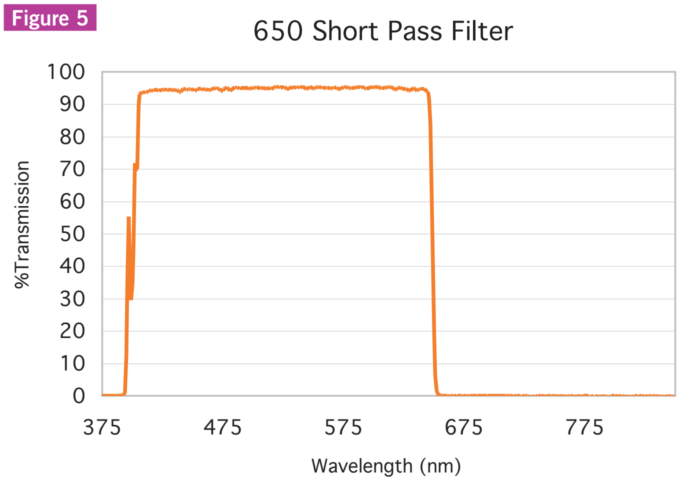


Figure 5



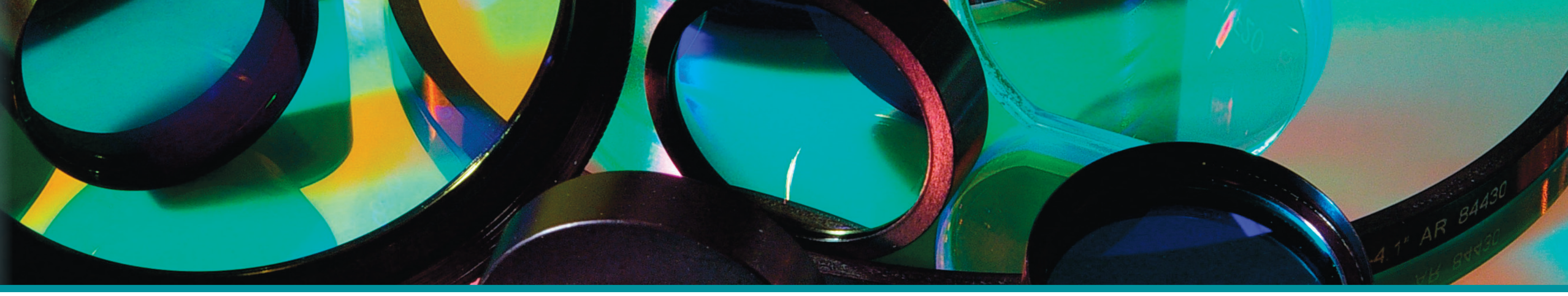
Specialized Filters for FISH and M-FISH

The imaging of multiple fluorescent probes requires special considerations towards the set-up of the interference filter blocks in the microscope turret. One strategy is to use individual filter cubes for each probe in the specimen. This is an effective strategy for 6-color viewing (six being the standard number of filter positions in most upright research microscopes), as good spectral isolation of the different probe species can be obtained through careful filter design. This setup also reduces the potential bleaching of the probes by illuminating only one fluorescent species at a time. A potential drawback to this setup is image registration shifts caused by slight misalignments of the filters, producing a minor beam deviation that can be detected when switching between several different filter cubes. The dichroic mirror and the emission filter are the imaging elements of the filter cube and are the two components which can contribute to this effect.

Another strategy is to utilize single multi-band dichroic mirrors and emission filters and separate excitation filters either in an external slider or filter wheel. This will preserve the image registration and reduce mechanical vibrations, but the trade offs are a reduced brightness of the fluorescence, limitations on how many different probes can be separated, and reduced dynamic range and sensitivity due to the required color CCD camera.

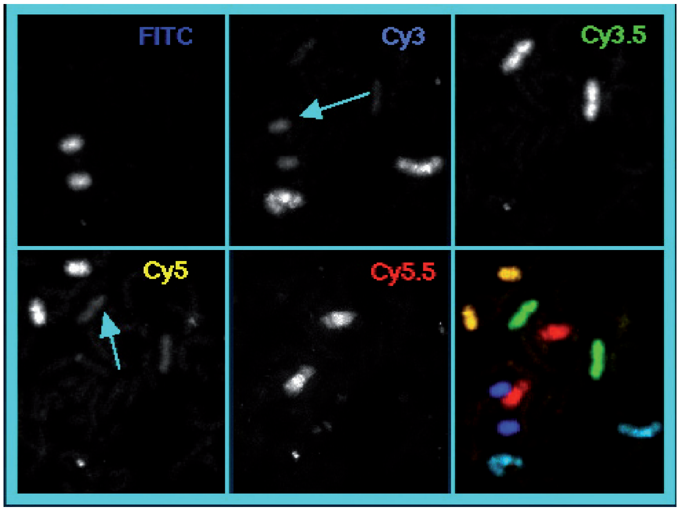
Fluorescence microscopes typically come equipped with standard interference filter sets for the common DAPI stain, FITC, TRITC, and Texas Red fluorophores. Standard filter sets typically have wideband excitation and emission filters (sometimes using longpass emission filters) in order to provide maximum brightness. When employing FISH, these standard sets can work well for 2, 3 and 4 color labeling, but spectral bleed-through can rapidly become a problem. For instance, FITC is partially visualized through the Cy3 filter, and Cy 3.5 can be seen through the Cy 5 filter.2

Figure 6 depicts five different labeled chromosome pairs, the crosstalk between channels is shown by the arrows in the top



middle and bottom left images. Bottom right panel is an overlaid pseudo-colored image of the series. In order to minimize the

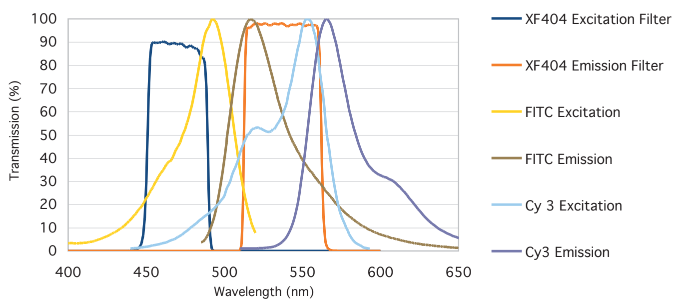
Figure 6



(Image courtesy of Octavian Henegariu, Yale University)

spectral bleed-through of very closely spaced fluorophores in multicolor labeling schemes, specialized narrow band filter sets are needed. Exciter filters of 10-20nm in bandwidth and emission filters of 20-40nm provided the specificity necessary to achieve the degree of sensitivity and spectral resolution required in mFISH. Figure 7 shows a typical wide band FITC filter set overlaid on the excitation and emission peaks of FITC and CY 3.

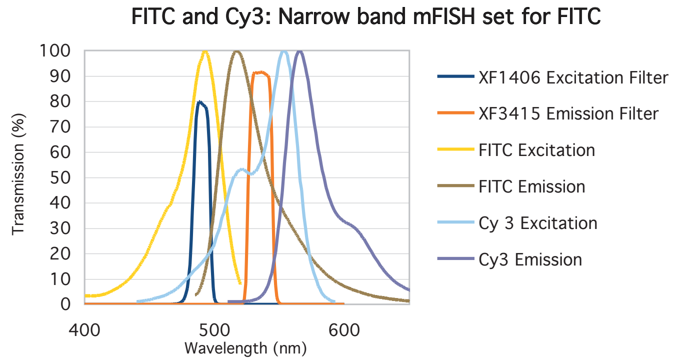
Figure 7



Although the filters are designed for covering a substantial area under the absorption and emission curves, there is a significant overlap with both the excitation and emission curves of Cy3, thus resulting in FITC channel contamination by Cy3. A solution is seen in Figure 8, where excitation and emission bands have been narrowed to improve the spectral resolution of FITC from Cy3, especially in the emission band. By limiting the red edge of the emission filter a reduction in the area under the emission curve of the Cy3 dye of about 4-fold is achieved.

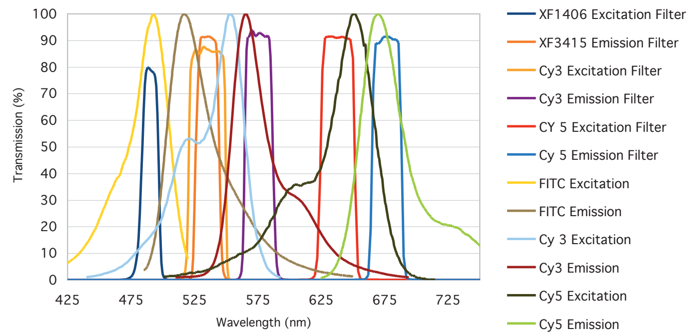
By incorporating the design strategy of narrow band, steep-edged filters, the spectral window for adding multiple fluorescent probes widens without the cost of adding emission bleed-though between fluorophores.

Figure 8



This can be seen in Figure 9 where three fluorophores are effectively separated within a spectral window of less than 300 nm. A fourth fluorophore such as Cy 3.5 could easily be incorporated in this scheme, as well in the 570-620nm region, but is omitted to reduce congestion.

Figure 9



The demands on the interference filters required for mFISH are such that it is necessary to provide a specific category of products which are matched together to make optimal use of the available bandwidth for each mFISH fluorophore. Product table on pages 79-80 shows the Omega Optical series of filter sets for the more prevalent fluorophores used in mFISH, along with excitation and emission filter bandwidths. Note: all are single fluorophore filter sets with the exception of and XF467-1 which use single excitation filters for each fluorophore and triple band dichroics and emission filters. This setup minimizes registration shift and stage movement by requiring only that an external filter slider or wheel be moved to excite the different dyes while the multi-band dichroics and emission filters are kept stationary in the microscope turret.

Conclusion

The techniques of FISH and mFISH used in conjunction with the resolving power and automated digital imaging capabilities of the fluorescence microscope offer a powerful combination of advantages that stand to benefit many areas of biology, from basic research to prenatal disease detection, cancer research, pathology, and cytogenetics.

In the fluorescence microscope, careful consideration of the sample and system components is necessary to specify the correct interference filters for probe detection. Use of multi-band dichroics and emission filters in a stationary turret with single excitation filters in an external slider or filter wheel can provide near simultaneous probe detection with no registration shift, but there are likely compromises in overall brightness, color balance difficulty, and reduced resolution of the color CCD camera. If sensitivity, spectral resolution, and minimal photo-bleaching are primary concerns, single narrow band filter sets with black and white CCD camera detection are the best option. Image registration shifts are minimized in today's filters by the use of polished glass substrates. The type and number of fluorescent probes also plays a role in the optimizing of the interference filters. For a small number of probes with adequate spectral separation it is possible to use traditional wide bandpass filter sets. In protocols where 5 or 6 probes are being used, it is necessary to use fluorophore-specific narrow band filter sets to reduce spectral bleed-through.

As methodologies in FISH and mFISH on the fluorescent microscope evolve, so must the software and hardware used to unravel the information contained in the specimen. A proper combination of interference filters, fluorophores, imaging hardware, and software is best for obtaining the resolution and contrast necessary for accurate image capture and analysis.

Troubleshooting

If there is no image:

- check that the fluorescence light source is on and the light path is clear. Light can usually be seen illuminating the sample unless it is below 400nm (DAPI excitation).
- image is being sent to correct port, camera or eyepiece.
- correct filter block is in place for the desired fluorophore.
- if desired fluorophore emission is > than approx. 670nm (Cy5) it is not visible by most eyes. If not visible by camera, check that there is no IR blocking filter in camera.

If image has high bleed-through from other fluorophores:

- make sure the filter set is correct for single dye usage, does not contain a longpass emission filter or is not a wide bandpass filter set.

References

- M. Brenner, T. Dunlay and M. Davidson (n.d.). Fluorescence in situ hybridization: Hardware and software implications in the research laboratory. October 7, 2008, Molecular Expressions Microscopy Primer Web **http://www.microscopyu.com/articles/fluorescence/insitu/brennerinsitu.html**
- O. Henegariu 2001. Multicolor FISH October 8, 2008 "Tavi' Page" **http://info.med.yale.edu/genetics/ward/tavi/fi12.html**
- R. Johnson D.Sc. 2006. Anti-reflection Coatings, Omega Optical

Omega Optical has been central to the development of practical applications of fluorescence in the life sciences since 1970. Innovators such as Brian Chance of the University of Pennsylvania worked closely with our technical staff to extend the state of the art influorescence interference filters. Following the University's development were early instruments for Becton Dickinson and Coulter that brought fluorescence detection to single cells and the advent of flow cytometry.

The ability of modern multicolor flow cytometers to simultaneously measure up to 20 distinct fluorophores and to collect forward and side scatter information from each cell allows more high quality data to be collected with fewer samples and in less time. The presence of multiple fluorescing dyes excited by an increasing number of lasers places high demands on the interference filters used to collect and differentiate the signals. These filters are typically a series of emission filters and dichroic mirrors designed to propagate the scattered excitation light and fluorescence signal through the system optics and deliver to the detectors.

EMISSION FILTERS

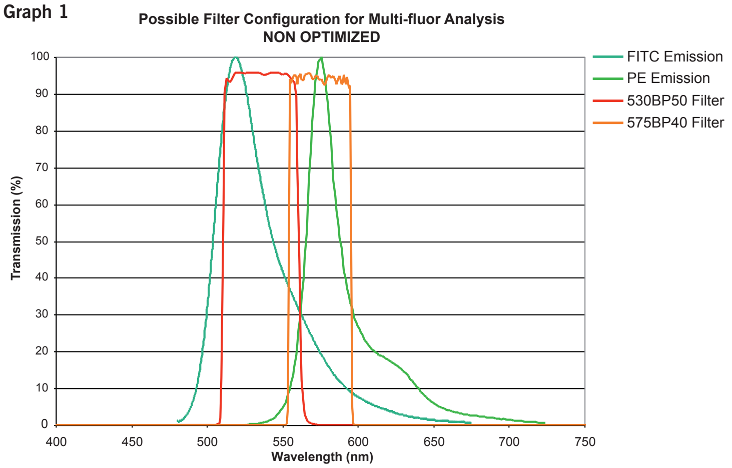
In multichannel systems, the emission filters' spectral bandwidths must be selected not only to optimize collection of the desired fluorescent signal, but also to avoid channel cross talk and to minimize the need for color compensation that inevitably results from overlapping dye emission spectra. For example, suppose a system is being configured to simultaneously count cells that have been tagged with a combination of FITC and PE. If either of these dyes were used alone, a good choice of emission filter would be a 530BP50 for FITC and a 575BP40 for PE. *see graph 1.*

These wide bands would very effectively collect the emission energy of each dye transmitting the peaks and much of each dye's red tail. There is a possibility of two problems if used simultaneously. First, there will be signifi cant channel cross talk since the red edge of the 530BP50 FITC filter would be coincident with the blue edge of the 575BP40 PE filter. Second, because the red tail of FITC overlaps with most of the PE emission, a high percentage of color correction will be needed to remove the input that the FITC tail will make to the signal recorded by the PE channel. A narrower FITC filter (XCY-525BP30) that cuts off at 535 nm would provide good channel separation. *see graph 2.*

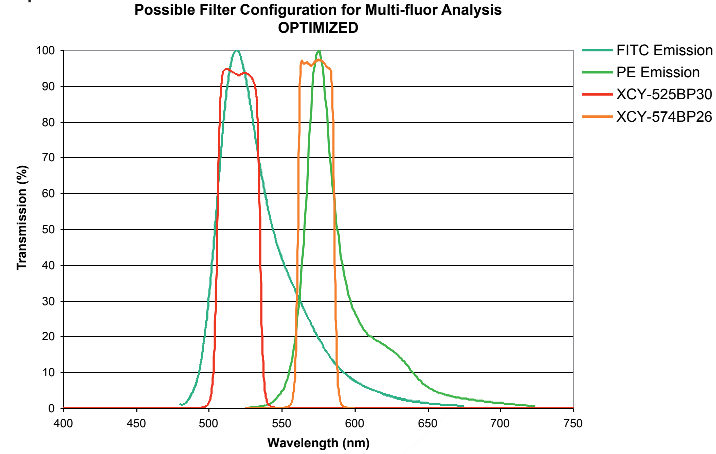
This will not however reduce the need for color compensation. To achieve this, a narrower PE filter is required. By moving the blue edge of the PE filter to 565 nm and the red edge to 585 nm, Omega Optical recommends the resulting XCY-574BP26 filter, which transmits the peak of the PE emission spectrum. Because it is more selective for PE, it transmits much less of the FITC red tail. The result is that the need for compensation due to FITC in the PE channel will be greatly reduced.

The selection of emission band placment and width is made more complicated by the presence of multiple excitation lasers. If all of the sources are on simultaneously, then in addition to cross talk and color compensation concerns, the interference filters will need to block all excitation wavelengths to OD5 or greater. If the lasers are fired sequentially, the complexity is reduced since each emission filter need only provide deep blocking for the laser that is on at the particular time a given channel is collecting energy.

Graph 1



Graph 2



QuantaMAX

Excitation Laser	Fluorophores	Product SKU	Description
	DAPI, AMCA, Hoechst 33342 and 32580, Alexa Fluor® 350, Marina Blue®	XCY-424DF44	424DF44
	Alexa Fluor® 405, Pacific Blue™	XCY-449BP38	449BP38
	Pacific Orange	XCY-545BP40	545BP40
405, 457 or 488	**Quantum Dot** Emission Filters The **405 laser** is optimal for excitation of Quantum Dots, but the **488 line laser** can also be used.		
	Qdot 525	XF3301	525WB20
	Qdot 565	XF3302	565WB20
	Qdot 585	XF3303	585WB20
	Qdot 605	XF3304	605WB20
	Qdot 625	XF3309	625DF20
	Qdot 655	XF3305	655WB20
	Qdot 705	XF3113	710AF40
	Qdot 800 for single color	XF3307	800WB80
	Qdot 800 for multiplexing with Qdot™ 705	XF3308	840WB80
488	GFP (for separation from YFP, also for separation from Qdots 545 and higher)	XCY-509BP21	509BP21
	GFP, FITC, Alexa Fluor® 488, Oregon Green® 488, Cy2®, ELF®-97, PKH2, PKH67, Fluo3/Fluo4, LIVE/DEAD Fixable Dead Cell Stain	XCY-525BP30	525BP30
	GFP, FITC, Alexa Fluor® 488, Oregon Green® 488, Cy2®, ELF-97, PKH2, PKH67, YFP	XCY-535DF45	535DF45
	YFP (for separation from GFP)	XCY-550DF30	550DF30
488 or 532	PE, PI, Cy3®, CF-3, CF-4, TRITC, PKH26	XCY-574BP26	574BP26
	PE, PI, Cy3®, CF-3, CF-4, TRITC, PKH26	XCY-585DF22	585DF22
	Lissamine Rhodamine B, Rhodamine Red™, Alexa Fluor® 568, RPE-Texas Red®, Live/Dead Fixable Red Stain	XCY-614BP21	614BP21
	Lissamine Rhodamine B, Rhodamine Red™, Alexa Fluor® 568, RPE-Texas Red®, Live/Dead Fixable Red Stain	XCY-610DF30	610DF30
	Lissamine Rhodamine B, Rhodamine Red™, Alexa Fluor® 568, RPE-Texas Red®, Live/Dead Fixable Red Stain	XCY-630DF22	630DF22
	PE-Cy5®	XCY-660DF35	660DF35
532	PE-Cy5.5®, PE-Alexa Fluor® 700	XCY-710DF40	710DF40
633	APC, Alexa Fluor® 633, CF-1, CF-2, PBXL-1, PBXL-3	XCY-660BP20	660BP20
	Cy5.5®, Alexa Fluor® 680, PE-Alexa Fluor® 680, APC-Alexa Fluor® 680, PE-Cy5.5®	XCY-710DF20	710DF20
	Cy7® (for separation from Cy5® and conjugates)	XCY-740ABLP	740ABLP
	PE-Cy7®, APC-Cy7®	XCY-748LP	748LP
	Cy7®, APC-Alexa Fluor® 750	XCY-787DF43	787DF43

- **Flow cytometry** filters are manufactured to fit all instruments including models by Accuri, Beckman Coulter, BD Biosciences, Bay Bio, ChemoMetec A/S, iCyt, Life Technologies, Molecular Devices, Partec and others. Our flow cytometry filters are manufactured with the features required to guarantee excellent performance in cytometry applications while keeping the price low.

CUSTOM CONFIGURATIONS AVAILABLE UPON REQUEST

For current product listings, specifications, and pricing:
www.omegafilters.com • sales@omegafilters.com
1.866.488.1064 (toll free within USA only) • **+1.802.254.2690** (outside USA)

Dichroic filters must exhibit very steep cut-on edges to split off fluorescent signals that are in close spectral proximity. Specifying the reflection and transmission ranges of each dichroic in a multichannel system requires complete knowledge of all of the emission bands in the system and of their physical layout. Most often, obtaining optimal performance requires flexibility in the placement of the individual channels and the order in which the various signals are split off.

Filter recommendations for a custom multicolor configuration require a complete understanding of the system. This includes the dyes that are to be detected, the laser sources that will be exciting the dyes, the simultaneity of laser firings, and the physical layout of the detection channels. With this information, optimum interference filters can be selected that will provide the highest channel signal, the lowest excitation background, channel cross talk and the need for color correction.

Since the emission spectra of fluorescent dyes tend to be spectrally wide, there is considerable spectral overlap between adjacent dyes. This becomes more the case as the number of channels is increased and the spectral distance between dyes is reduced. The result of this overlap is that the signal collected at a particular channel is a combination of the emission of the intended dye and emission contributions from adjacent dyes. Color compensation is required to subtract the unwanted signal contribution from adjacent dyes. Through our work with researchers in the flow cytometry community we have established specific band shape characteristics that minimize the need for color compensation. By creating narrower pass bands and placing them optimally on emission peaks, we have reduced the relative contribution of an adjacent dye to a channel's signal, thereby producing a purer signal with less need for color compensation.

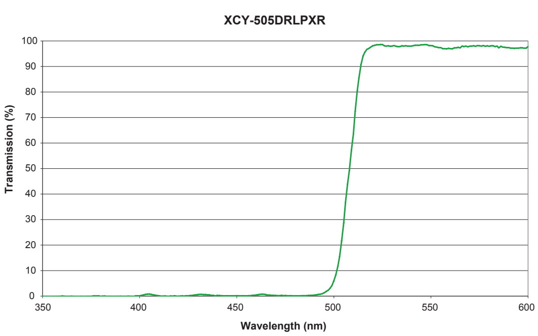
Polarization is an important parameter in signal detection. In an optical instrument that utilizes a highly polarized light source such as a laser to generate signal in the form of both scatter and fluorescence, there will be polarization bias at the detector. Many factors such as the instrument's light source, optical layout, detector, mirrors and interference filters affect the degree of polarization bias.

Dichroic mirrors are sensitive to polarization effects since they operate at off-normal angles of incidence. Omega Optical's dichroics are designed to optimize steep transition edges for the best separation of closely spaced fluorophores, while minimizing the sensitivity to the polarization state of the incident energy.

Note to Instrument Designers

With laser sources, all of the output is linearly polarized. The dichroics' performance will be different depending on the orientation of the lasers polarization. Omega Optical designs for minimum difference between polarization states, though it should be expected that the effective wavelength of the transition will vary by up to 10nm. Engineers at Omega Optical will gladly assist in discussing how to address this issue.

Product SKU	Application	Description
XCY-505DRLPXR	Extended reflection longpass; Reflects 451 nm, 457 nm, 477 nm, 488 nm and UV laser lines, Transmits > 525 nm.	505DRLPXR
XCY-560DRSP	Shortpass; Separation of FITC from PE.	560DRSP
XHC575DCLP	Separation of Mithramycin from Ethidium Bromide.	575DCLP
XCY-640DRLP	Separation of APC from dyes with shorter wavelength.	640DRLP
XCY-680DRLP	Separation of PE-Cy5® and PE-Cy5.5.	680DRLP
XCY-690DRLP	Separation of APC from APC-Cy5.5® or APC-Cy7®.	690DRLP
XCY-710DMLP	Separation of PE and Cy5® from PE-Cy5.5® or PE-Cy7®.	710DMLP
XCY-760DRLP	Separation of Cy5.5® from Cy7® and their conjugates.	760DRLP



Specifications

Physical	Size	12.5, 15.8 and 25 mm
	Thickness	< 6.7 mm
	Shape	Specify round and/or square
Angle of Incidence	Specify dichroic AOI 45° or 11.25°	

CUSTOM CONFIGURATIONS AVAILABLE UPON REQUEST

- Excitation and emission filters: 18, 20, 22, and 25 mm round
- Dichroic beamsplitters: 18 x 26, 20 x 28, 21 x 29, and 25.7 x 36 mm rectangular. Dichroics also available as 18, 20, 22, and 25 mm round
- Purchase as sets or as individual components

FRET Filters

Arranged by fluorophores and emission wavelength.

Fluorophores		Filter Set SKU	Components		
Donor	Acceptor		Type	Product SKU	Description
BFP	eGFP	XF89-2	Excitation	XF1005	365WB50
			Dichroic	XF2001	400DCLP
			Emission 1	XF3002	450AF65
			Emission 2	XF3084	535AF45
BFP	YFP	XF158	Excitation	XF1005	365WB50
			Dichroic	XF2001	400DCLP
			Emission 1	XF3002	450AF65
			Emission 2	XF3079	535AF26
BFP	DsRed2	XF159	Excitation	XF1005	365WB50
			Dichroic	XF2001	400DCLP
			Emission 1	XF3002	450AF65
			Emission 2	XF3019	605DF50
CFP	YFP	XF88-2	Excitation	XF1071	440AF21
			Dichroic	XF2034	455DRLP
			Emission 1	XF3075	480AF30
			Emission 2	XF3079	535AF26
CFP	DsRed2	XF152-2	Excitation	XF1071	440AF21
			Dichroic	XF2034	455DRLP
			Emission 1	XF3075	480AF30
			Emission 2	XF3022	580DF30
Midoriishi Cyan	Kusabira Orange	XF160	Excitation	XF1071	440AF21
			Dichroic	XF2027	485DRLP
			Emission 1	XF3005	495DF20
			Emission 2	XF3302	565WB20
eGFP	DsRed2 or Rhod-2	XF151-2	Excitation	XF1072	475AF20
			Dichroic	XF2077	500DRLP
			Emission 1	XF3080	510AF23
			Emission 2	XF3083	595AF60
FITC	TRITC	XF163	Excitation	XF1073	475AF40
			Dichroic	XF2010	505DRLP
			Emission 1	XF3017	530DF30
			Emission 2	XF3083	595AF60
FITC	Rhod-2 or Cy3	XF162	Excitation	XF1073	475AF40
			Dichroic	XF2010	505DRLP
			Emission 1	XF3007	535DF35
			Emission 2	XF3083	595AF60
Alexa 488	Alexa 546 or 555	XF164	Excitation	XF1087	470AF50
			Dichroic	XF2077	500DRLP
			Emission 1	XF3084	535AF45
			Emission 2	XF3083	595AF60
Alexa 488	Cy3	XF165	Excitation	XF1073	475AF40
			Dichroic	XF2010	505DRLP
			Emission 1	XF3084	535AF45
			Emission 2	XF3083	595AF60
YFP	TRITC or Cy3	XF166	Excitation	XF1068	500AF25
			Dichroic	XF2030	525DRLP
			Emission 1	XF3074	545AF35
			Emission 2	XF3083	595AF60
Cy3	Cy5 or Cy5.5	XF167	Excitation	XF1074	525AF45
			Dichroic	XF2017	560DRLP
			Emission 1	XF3083	595AF60
			Emission 2	XF3076	695AF55

Optimizing Filter Sets for FRET Applications

Application Note

Overview

FRET, or Forster Resonance Energy Transfer, is a phenomenon where closely matched pairs of fluorophores are used to determine spatial or temporal proximity and specificity in molecular, protein-protein interactions. More specifically, this energy transfer occurs when the emission energy of one fluorophore—the donor—is non-radiatively transferred to the second fluorophore—the acceptor—producing a secondary emission. When this occurs, donor fluorescence is quenched and acceptor fluorescence increases.

Biologically, in order for this transfer to occur, the cellular conditions need to be such that the distance between the molecules being measured is no more than 1-10nm. Spectrally, the fluorophores being used need to have a large overlap, which while creating the conditions for effective energy transfer, also results in spectral bleed through (SBT), defined as the overlap of the donor and acceptor emission spectra, and can be a problem in FRET measurements.

The development of SBT correction techniques have been critical to the evolution of FRET as a useful and more widely used application. These SBT correction techniques—which include software development, fluorescence lifetime imaging (FLIM) correlation, and photo bleaching techniques—have reached a degree of sophistication that improves the efficacy of FRET. Similarly, the development of microscopy techniques such as one-photon, two-photon (multi-photon), confocal, and TIRF are all contributing to the growing effectiveness and ease of FRET experiments.

While much has been written about the physical and biological aspects of FRET, as summarized above, this application note will review the best suited fluorophore pairs and summarize the considerations surrounding the hardware configuration and selection of optical filters required for successful capture, differentiation, and measurement of FRET.

Filters & Microscope Configurations

The filter components required for FRET experiments are not esoteric. As in any fluorescence microscopy application, an excitation filter is required for exciting the donor fluorophore, and a dichroic mirror is required for separating donor excitation energy from both donor and acceptor emission energy. Unlike other fluorescence applications, however, two emission filters are required, one for the acceptor fluorophore, or FRET emission, and one for the donor fluorophore in order to correct for single bleed thru. As for choosing specific filters, the same filter components and sets can be applicable for FRET as those which are matched to specific fluorophores and used in other single color, epifluorescence applications.

More important in the selection of filters is an understanding of the physical configuration of the microscope hardware to be used in the FRET experiment. At issue are critical experimental variables, such as time and image registration. While the ideal set-up may not be affordable or available to all researchers interested in FRET studies, it is nonetheless important to understand the pros and cons of the available hardware and filter set configurations.

1. Multi-View Configurations

Most ideal for the viewing and measurement of molecular, protein-protein interactions with critical spatial and temporal characteristic is a set-up which allows for simultaneous viewing of both donor and acceptor emission energy. This is only possible using a device which provides a simultaneous split-screen view of the sample. These multi-view accessories are mounted to the microscope in front of the detector and use filters integrated into the unit to split the donor and acceptor emission fluorescence into two images.

When FRET viewing is handled this way, the two critical variables—time and registration—are eliminated. The time of donor and acceptor imaging is simultaneous, and given a properly aligned unit, the image registration is identical, providing a duplicate view of the sample. The only difference between the two images is that one image is captured with an emission filter for donor emission while the other image uses an emission filter for acceptor emission.

2. Emission Filter Wheels

When multi-view accessories are not available, an automated emission filter wheel is the next best alternative. With this configuration, a filter cube/holder with a donor excitation filter and dichroic mirror are placed in the microscope. The emission filters for both the donor and acceptor fluorophores, in turn, are mounted in the emission filter wheel, which can be rapidly switched from one to the other.

Collecting donor and acceptor emission energy using this hardware configuration, while not simultaneous, can be accomplished with time delays of only 40-75msec (depending on make and model), given the state-of-the-art of automated filter wheels as well as camera and detector technology. Both temporal changes in the sample during live cell imaging and registration shift resulting from equipment movement, while almost negated, must still be considered when analyzing experimental results.

3. Separate Filter Cubes

Without a multi-view attachment or emission filter wheel, researchers must fall back on a third hardware configuration for FRET, which involves using a separate filter cube for both donor and acceptor fluorescence. In this configuration, while each cube has an exciter, dichroic and emitter, it is extremely important to remember that the exciter and dichroic in both sets are identical and are those filters that are typically used with the donor fluorophore.

While this third filter configuration allows for the discreet collection of donor and acceptor fluorescence, it is the configuration most susceptible to the time and image registration variables mentioned previously. The time variable can be minimized as a result of the automated turrets, which are a standard feature on many new microscopes but may not be typical on older, installed models. In addition, alignment of filters within cube tolerances allows more room for registration error than in the two other configurations. The time and resolution variables that are inherent with this configuration must be thoughtfully weighed when using a spatially and temporally sensitive technique such as FRET.

Fluorophore Pairs

While certain fluorophore pairs such as CFP/YFP, have dominated the scientific literature and provided the foundation for successful FRET studies to date, there has been continued development of new monomeric fluorescent proteins such as Midoriishi Cyan and Kusabira Orange, for FRET experiments. These fluorophore developments have been stimulated by the refinement of procedures and ratio correction techniques, as well as microscopy applications that are FRET friendly.

On the most basic level, the success of any given pair of fluorophores centers on their spectral characteristics. First, there must be sufficient separation of excitation spectra for selective stimulation of the donor. Second, there must be sufficient overlap (>30%) between the emission spectrum of the donor and the excitation spectrum of the acceptor in order to obtain efficient energy transfer. And third, there must be sufficient separation of the donor and the acceptor emission spectra so that the fluorescence of each fluorophore can be collected independently.

Development of new fluorescent proteins has centered on meeting these criteria, while producing new colors and fluorophores that bind to varied proteins and biological molecules. The newest developments are cited in the links and references to recent literature listed below:

Fluorophore References

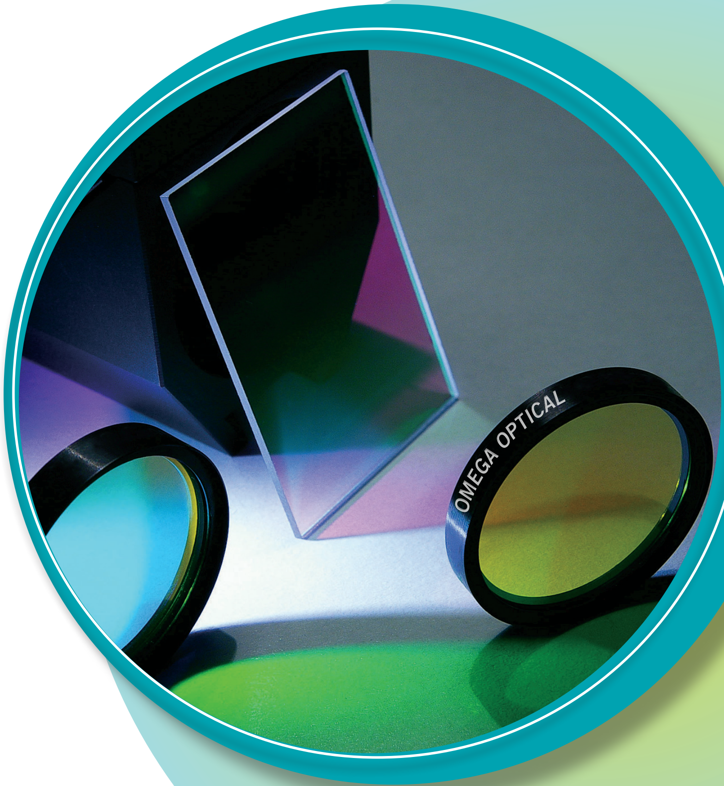
- Wallrabe, H., and Periasamy, A. (2005) FRET-FLIM microscopy and spectroscopy in the biomedical sciences. Current Opinion in Biotechnology. 16: 19-27.
- Karasawa, S., Araki, T., Nagai, T., Mizuno, H., Miyawaki, A. (2004) Cyan-emitting and orange-emitting fluorescent proteins as a donor/acceptor pair for fluorescence resonance energy transfer. Biochemical Journal, April 5.
- Shaner, N., Campbell, R., Steinbach, P., Giepmans, B., Palmer, A., Tsien, R. (2004) Improved monomeric red, orange, and yellow fluorescent proteins derived from Discosoma sp. red fluorescent protein. Nature Biotechnology, Vol. 22, Number 12, December. pp.1567-1572.

FRET Filter Sets

The products listed in the catalog include the most commonly used FRET fluorophore pairs, as well as those recently developed pairs that are worthy of attention. For each FRET fluorophore pair the chart lists a filter set that is useful in the emission filter wheel configuration. These sets are comprised of the exciter and dichroic for the donor fluorophore and emitters for both the donor and acceptor fluorophores.

Individual filter set part numbers for both donor and acceptor fluorophores are also listed so components can be purchased individually, dependent on the specifics of the hardware set-up. If purchasing filters individually, it is important to remember that the exciter and dichroic from the acceptor fluorophore set are never used.

It is important that you provide hardware details and related mounting instructions when ordering filters for FRET applications.



- For multi-color high discrimination applications
- Multiple excitation filters
- Must be mounted in a filter wheel or slider

Pinkel interference filter sets offer separate bandpass excitation filters used in conjunction with a multi-band dichroic filter and emission filter. This arrangement allows for selective excitation of individual fluorophores using an external filter wheel or slider without causing stage vibrations that can affect image quality. Pinkel sets offer improved signal to noise compared to complete multi-band sets, but should not be used with a black and white CCD camera.

Note: to achieve simultaneous multicolor images using a color CCD or the eye as detector, please see our complete multi-band filter sets on pages 77 -78.

QuantaMAX™ Pinkel Filters

Arranged by fluorophores and emission wavelength.

Fluorophores	Filter Set SKU	Application	Components		
			Type	Product SKU	Description
FITC/TRITC or eGFP/DsRed2	XF452-1	2 excitation filters, 1 multi-band dichroic beamsplitter and emission filter.	Excitation #1	XF1404	480QM20
			Excitation #2	XF1405	555QM25
			Dichroic	XF2443	485-560DBDR
			Emission	XF3456	520-610DBEM
FITC/Texas Red® or eGFP/mCherry	XF453-1	2 excitation filters, 1 multi-band dichroic beamsplitter and emission filter.	Excitation #1	XF1406	490QM20
			Excitation #2	XF1407	575QM30
			Dichroic	XF2044	490-575DBDR
			Emission	XF3457	525-637DBEM
FITC/ Cy5®	XF454-1	2 excitation filters, 1 multi-band dichroic beamsplitter and emission filter.	Excitation #1	XF1404	480QM20
			Excitation #2	XF1421	630QM40
			Dichroic	XF2401	475-625DBDR
			Emission	XF3470	535-710DBEM
DAPI/FITC/Texas Red® or DAPI/Spectrum Green/Spectrum Red	XF467-1	3 excitation filters, 1 multi-band dichroic beamsplitter and emission filter.	Excitation #1	XF1408	405QM20
			Excitation #2	XF1406	490QM20
			Excitation #3	XF1407	575QM30
			Dichroic	XF2045	400-485-580TBDR
			Emission	XF3458	457-528-600TBEM

Pinkel Filters

Arranged by fluorophores and emission wavelength.

Fluorophores	Filter Set SKU	Components		
		Type	Product SKU	Description
DUAL BAND				
DAPI/FITC BFP/eGFP	XF50-1	Excitation #1	XF1006	400DF15
		Excitation #2	XF1042	485DF15
		Dichroic	XF2041	385-502DBDR
		Emission	XF3054	460-550DBEM
FITC/TRITC Cy2®/Cy3® eGFP/DsRed2	XF52-1	Excitation #1	XF1042	485DF15
		Excitation #2	XF1043	555DF10
		Dichroic	XF2043	490-550DBDR
		Emission	XF3056	520-580DBEM
FITC/Texas Red®	XF53-1	Excitation #1	XF1042	485DF15
		Excitation #2	XF1044	575DF25
		Dichroic	XF2044	490-575DBDR
		Emission	XF3057	528-633DBEM
DAPI/TRITC	XF59-1	Excitation #1	XF1094	380AF15
		Excitation #2	XF1045	560DF15
		Dichroic	XF2047	395-540DBDR
		Emission	XF3060	470-590DBEM

- Excitation and emission filters: 18, 20, 22, and 25 mm round
- Dichroic beamsplitters: 18 x 26, 20 x 28, 21 x 29, and 25.7 x 36 mm rectangular. Dichroics also available as 18, 20, 22, and 25 mm round
- Purchase as sets or as individual components

Pinkel Filters *Continued*

Arranged by fluorophores and emission wavelength.

Fluorophores	Filter Set SKU	Components		
		Type	Product SKU	Description
CFP/YFP	XF135-1	Excitation #1	XF1079	436DF10
		Excitation #2	XF1080	510DF25
		Dichroic	XF2065	436-510DBDR
		Emission	XF3099	475-550DBEM
TRIPLE BAND				
DAPI/FITC/Texas Red®	XF63-1	Excitation #1	XF1006	400DF15
		Excitation #2	XF1042	485DF15
		Excitation #3	XF1044	575DF25
		Dichroic	XF2048	400-477-575TBDR
		Emission	XF3061	445-525-650TBEM
DAPI/FITC/Texas Red® **DAPI/Alexa Fluor® 488/546** **DAPI/Cy2®/Cy3®**	XF67-1	Excitation #1	XF1006	400DF15
		Excitation #2	XF1042	485DF15
		Excitation #3	XF1044	575DF25
		Dichroic	XF2045	400-485-580TBDR
		Emission	XF3058	457-528-633TBEM
DAPI/FITC/TRITC **DAPI/FITC/Cy3®**	XF68-1	Excitation #1	XF1006	400DF15
		Excitation #2	XF1042	485DF15
		Excitation #3	XF1045	560DF15
		Dichroic	XF2050	385-485-560TBDR
		Emission	XF3063	460-520-602TBEM
DAPI/FITC/MitoTracker Red	XF69-1	Excitation #1	XF1006	400DF15
		Excitation #2	XF1042	485DF15
		Excitation #3	XF1044	575DF25
		Dichroic	XF2051	400-495-575TBDR
		Emission	XF3116	470-530-620TBEM
FITC/Cy3®/Cy5® **FITC/TRITC/Cy5®**	XF93-1	Excitation #1	XF1042	485DF15
		Excitation #2	XF1043	555DF10
		Excitation #3	XF1046	655DF30
		Dichroic	XF2054	485-555-650TBDR
		Emission	XF3067	515-600-730TBEM
CFP/YFP/DsRed2	XF154-1	Excitation #1	XF1201	436AF8
		Excitation #2	XF1042	485DF15
		Excitation #3	XF1044	575DF25
		Dichroic	XF2090	455-510-600TBDR
		Emission	XF3118	465-535-640TBEM
QUAD BAND				
DAPI/FITC/TRITC/Cy5®	XF57-1	Excitation #1	XF1006	400DF15
		Excitation #2	XF1042	485DF15
		Excitation #3	XF1045	560DF15
		Excitation #4	XF1046	655DF30
		Dichroic	XF2046	400-485-558-640QBDR
		Emission	XF3059	460-520-603-710QBEM

- For imaging all UV-excited Qdot™ conjugates
- Sets include a choice of two excitation filters, a single dichroic, and emission filters optimized for each Qdot
- Designed to work in all applications using common energy sources including broadband arc lamps, LED, lasers and laser diodes

Quantum Dot (QDot) interference filter sets are designed around the center wavelength of each specified Qdot for capturing the maximum photon emission with a minimal bandwidth (20nm), thus allowing for multiplexing with other Qdot's without incurring spectral bleed-through.

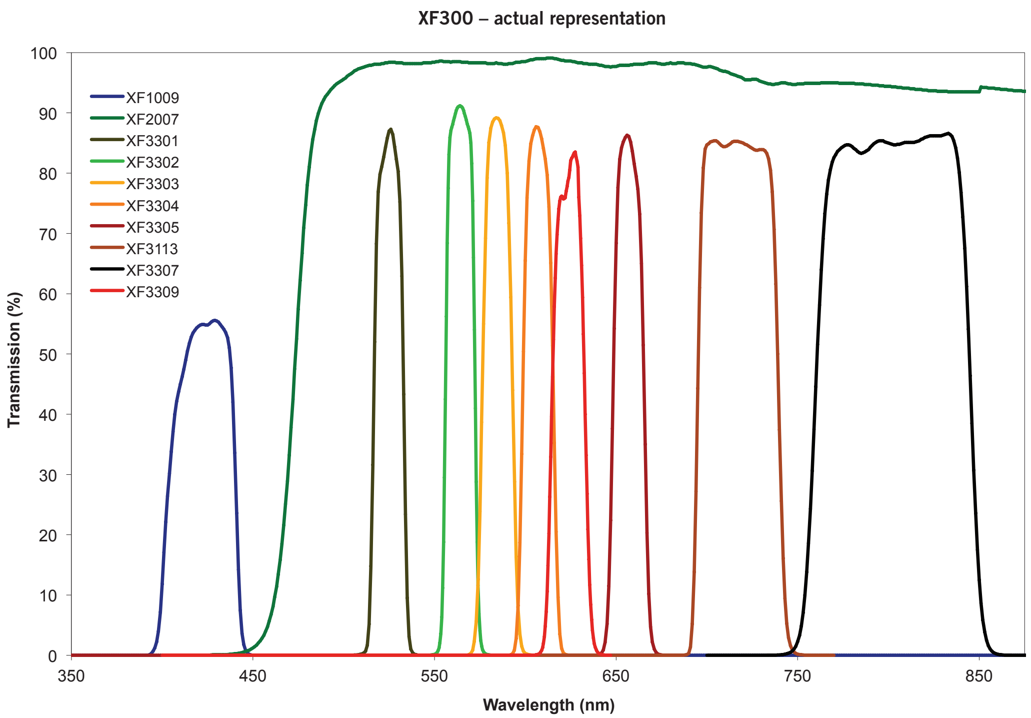
Each QDot set can be purchased with one of two excitation filters. The single excitation filter sets are equipped with a 425/45nm filter and the two excitation filter sets with a 100nm wide 405nm CWL filter. For most, the single excitation set is suitable as Quantum Dots are typically very bright so the wide excitation filter is unnecessary. The two excitation filter sets avoid transmitting potentially harmful UV light in live cell applications.

For a complete list of Quantum Dot filters, please go to page 94.

Quantum Dot (Qdot™) Filters

Fluorophores	Filter Set SKU	Components		
		Type	Product SKU	Description
For simultaneous multi-color viewing to minimize DAPI	XF320	Excitation	XF1009	425DF45
		Dichroic	XF2007	475DCLP
		Emission	XF3086	510ALP
For simultaneous multi-color viewing with Xenon excitation	XF02-2	Excitation	XF1001	330WB80
		Dichroic	XF2001	400DCLP
		Emission	XF3097	400ALP
For simultaneous multi-color viewing with Hg excitation	XF05-2	Excitation	XF1005	365WB50
		Dichroic	XF2001	400DCLP
		Emission	XF3097	400ALP

Note: Qdots are naturally bright and therefore do not require high levels of excitation light.



CUSTOM CONFIGURATIONS AVAILABLE UPON REQUEST

STANDARD – QUANTUM DOT FILTERS

- Excitation and emission filters: 18, 20, 22, and 25 mm round
- Dichroic beamsplitters: 18 x 26, 20 x 28, 21 x 29, and 25.7 x 36 mm rectangular. Dichroics also available as 18, 20, 22, and 25 mm round
- Purchase as sets or as individual components

Quantum Dot (Qdot™) Filters

Arranged by fluorophores and emission wavelength.

Fluorophores	Filter Set SKU	Components		
		Type	Product SKU	Description
Qdot™ All Conjugates	XF300	Excitation 1	XF1009	425DF45
		Excitation 2	XF1301	415WB100
		Dichroic	XF2007	475DCLP
		Emission 1	XF3301	525WB20
		Emission 2	XF3302	565WB20
		Emission 3	XF3303	585WB20
		Emission 4	XF3304	605WB20
		Emission 5	XF3305	655WB20
		Emission 6	XF3113	710AF40
		Emission 7	XF3307	800WB80
		Emission 8	XF3308	840WB80
		Emission 9	XF3309	625DF20
Qdot™ 525 Conjugate	XF301-1 or XF301-2 (Substitute Excitation 2 for Excitation 1)	Excitation 1	XF1009	425DF45
		Excitation 2	XF1301	415WB100
		Dichroic	XF2007	475DCLP
		Emission 1	XF3301	525WB20
Qdot™ 565 Conjugate	XF302-1 or XF302-2 (Substitute Excitation 2 for Excitation 1)	Excitation 1	XF1009	425DF45
		Excitation 2	XF1301	415WB100
		Dichroic	XF2007	475DCLP
		Emission 2	XF3302	565WB20
Qdot™ 585 Conjugate	XF303-1 or XF303-2 (Substitute Excitation 2 for Excitation 1)	Excitation 1	XF1009	425DF45
		Excitation 2	XF1301	415WB100
		Dichroic	XF2007	475DCLP
		Emission 3	XF3303	585WB20
Qdot™ 605 Conjugate	XF304-1 or XF304-2 (Substitute Excitation 2 for Excitation 1)	Excitation 1	XF1009	425DF45
		Excitation 2	XF1301	415WB100
		Dichroic	XF2007	475DCLP
		Emission 4	XF3304	605WB20
Qdot™ 625 Conjugate	XF309-1 or XF309-2 (Substitute Excitation 2 for Excitation 1)	Excitation 1	XF1009	425DF45
		Excitation 2	XF1301	415WB100
		Dichroic	XF2007	475DCLP
		Emission 9	XF3309	625DF20
Qdot™ 655 Conjugate	XF305-1 or XF305-2 (Substitute Excitation 2 for Excitation 1)	Excitation 1	XF1009	425DF45
		Excitation 2	XF1301	415WB100
		Dichroic	XF2007	475DCLP
		Emission 5	XF3305	655WB20
Qdot™ 705 Conjugate	XF306-1 or XF306-2 (Substitute Excitation 2 for Excitation 1)	Excitation 1	XF1009	425DF45
		Excitation 2	XF1301	415WB100
		Dichroic	XF2007	475DCLP
		Emission 6	XF3113	710AF40
Qdot™ 800 Conjugate For single color	XF307-1 or XF307-2 (Substitute Excitation 2 for Excitation 1)	Excitation 1	XF1009	425DF45
		Excitation 2	XF1301	415WB100
		Dichroic	XF2007	475DCLP
		Emission 7	XF3307	800WB80
Qdot™ 800 Conjugate For multiplexing with Qdot™ 705	XF308-1 or XF308-2 (Substitute Excitation 2 for Excitation 1)	Excitation 1	XF1009	425DF45
		Excitation 2	XF1301	415WB100
		Dichroic	XF2007	475DCLP
		Emission 8	XF3308	840WB80

- Excitation and emission filters: 18, 20, 22, and 25 mm round
- Dichroic beamsplitters: 18 x 26, 20 x 28, 21 x 29, and 25.7 x 36 mm rectangular. Dichroics also available as 18, 20, 22, and 25 mm round
- Purchase as sets or as individual components

Sedat interference filter sets offer the selectivity of single band filter sets and the microscope stage stability of a multi-band set.

Using a multi-band dichroic filter and independent excitation and emission filters mounted in an external slider or wheel, these filter sets allow for dye selective excitation and emission collection without requiring vibration-inducing rotation of the filter turret as the dichroic mirror is stationary during imaging.

The use of separate excitation and emission filters will typically offer a higher signal to noise ratio than either a complete multi-band set or Pinkel multi-band set. These sets may be used in conjunction with a monochrome CCD camera.

Note: to achieve simultaneous multicolor images using a color CCD or the eye as detector, please see our full multi-band filter sets on pages 77-78.

Sedat Filters

Arranged by fluorophores and emission wavelength.

Fluorophores	Filter Set SKU	Components		
		Type	Product SKU	Description
DUAL BAND FITC/ TRITC	XF156	Excitation 1	XF1042	485DF15
		Excitation 2	XF1043	555DF10
		Dichroic	XF2043	490-550DBDRLP
		Emission 1	XF3084	535AF45
		Emission 2	XF3024	590DF35
TRIPLE BAND DAPI/FITC/TRITC	XF157	Excitation 1	XF1006	400DF15
		Excitation 2	XF1011	490DF20
		Excitation 3	XF1045	560DF15
		Dichroic	XF2045	400-485-580TBDR
		Emission 1	XF3002	450AF65
		Emission 2	XF3084	535AF45
		Emission 3	XF3025	615DF45
QUAD BAND DAPI/FITC/TRITC/Cy5 DAPI/FITC/TRITC/ Alexa Fluor®647	XF155	Excitation 1	XF1005	365WB50
		Excitation 2	XF1006	400DF15
		Excitation 3	XF1042	485DF15
		Excitation 4	XF1045	560DF15
		Excitation 5	XF1208	640AF20
		Dichroic	XF2046	400-485-558-640QBDR
		Emission 1	XF3002	450AF65
		Emission 2	XF3084	535AF45
		Emission 3	XF3024	590DF35
		Emission 4	XF3076	695AF55

CUSTOM CONFIGURATIONS AVAILABLE UPON REQUEST

RATIO IMAGING FILTERS, IR BLOCKING, IR-DIC AND POLARIZING FILTERS

- Excitation and emission filters: 18, 20, 22, and 25 mm round
- Dichroic beamsplitters: 18 x 26, 20 x 28, 21 x 29, and 25.7 x 36 mm rectangular. Dichroics also available as 18, 20, 22, and 25 mm round
- Purchase as sets or as individual components

Interference filter sets for ratiometric imaging applications contain two excitation filters or two emission filters that are used in a filter slider or wheel to monitor changes in pH, ion concentration, or other intracellular dynamics.

Please note: if purchased with a filter cube the multiple excitation or emission filters will be supplied un-mounted unless otherwise instructed.

Ratio Imaging Filters

Arranged by fluorophores and emission wavelength.

Fluorophores	Filter Set SKU	Application	Components		
			Type	Product SKU	Description
SINGLE DYE EXCITATION SETS **Fura-2, Mag-Fura-2** **PBFI, SBFI**	XF04-2	UV excited ratiometric set for ion indicator probes. Note: some objectives pass 340nm light very poorly.	Excitation 1	XF1093	340AF15
			Excitation 2	XF1094	380AF15
			Dichroic	XF2002	415DCLP
			Emission	XF3043	510WB40
BCECF	XF16	Dual excitation filter set for ratiometric measurements of intracellular ph changes.	Excitation 1	XF1071	440AF21
			Excitation 2	XF1011	490DF20
			Dichroic	XF2058	515DRLPXR
			Emission	XF3011	535DF25
SINGLE DYE EMISSION SETS **SNARF®-1** Widefield	XF72	Widefield version of XF31. Filter 610DRLP splits the emission signal to 2 detectors.	Excitation	XF1080	510DF25
			Dichroic 1	XF2013	540DCLP
			Dichroic 2	XF2014	610DRLP
			Emission 1	XF3022	580DF30
			Emission 2	XF3023	640DF35

IR Blocking Filters

Used to reduce infrared energy from the light source in the excitation path (XF83) or in front of the detector in the emission path (XF85 and XF86).

Product SKU	Description	Application	Typical T%	Size
XF83	KG5	Blocks infrared energy at the light source	80% avg.	12, 18, 20, 22, 25, 32, 45, 50, 50 x 50 mm
XF85	550CFSP	99+% Near IR Attenuation, 600-1200 nm	>75%T	12, 18, 20, 22, 25, 32, 45, 50, 50 x 50 mm
XF86	700CFSP	99+% Near IR Attenuation, 750-1100 nm	>90%T	12, 18, 20, 22, 25, 32, 45, 50, 50 x 50 mm

IR-DIC Filters

Used for simultaneous capture of fluorescence and infrared DIC images.

Product SKU	Description	Application	Size
XF117	780DF35	Capture of fluorescence and infrared DIC images.	32, 45 mm

Polarizing Filters

Used to polarize incident light in both the excitation and emission path.

Product SKU	Description	Application	Size
XF120	Polarizing Filter	Polarize light in both the excitation and emission path.	10, 12.5, 22, 25, 32, 45, 50 x 50 mm

CUSTOM CONFIGURATIONS AVAILABLE UPON REQUEST

For current product listings, specifications, and pricing:
www.omegafilters.com • sales@omegafilters.com
1.866.488.1064 (toll free within USA only) • +1.802.254.2690 (outside USA)

Neutral density filters universally attenuate a broad spectral range using either an absorptive or reflective configuration. The purpose of these filters is to reduce a transmissive signal to a desired level in a given optical system. Various ND filters are available to accommodate individual requirements for signal reduction.

ND 0.05 = 90%	ND 0.20 = 63%	ND 0.40 = 40%	ND 0.60 = 25%	ND 0.80 = 16%	ND 2.0 = 1%
ND 0.10 = 80%	ND 0.30 = 50%	ND 0.50 = 32%	ND 0.70 = 20%	ND 1.0 = 10%	ND 3.0 = 0.1%

(values rounded to the nearest %)

Neutral Density Filters

For reducing excitation energy.

Sizes:	18Ø	25Ø	32Ø	45Ø	50Ø	50 x 50
Clear Aperture:	13Ø	20Ø	27Ø	40Ø	45Ø	45 x 45
Description	Product SKU					
ND 0.05	XND0.05/18	XND0.05/25	XND0.05/32	XND0.05/45	XND0.05/50	XND0.05/50x50
ND 0.1*	XND0.1/18	XND0.1/25	XND0.1/32	XND0.1/45	XND0.1/50	XND0.1/50x50
ND 0.2	XND0.2/18	XND0.2/25	XND0.2/32	XND0.2/45	XND0.2/50	XND0.2/50x50
ND 0.3*	XND0.3/18	XND0.3/25	XND0.3/32	XND0.3/45	XND0.3/50	XND0.3/50x50
ND 0.4	XND0.4/18	XND0.4/25	XND0.4/32	XND0.4/45	XND0.4/50	XND0.4/50x50
ND 0.5*	XND0.5/18	XND0.5/25	XND0.5/32	XND0.5/45	XND0.5/50	XND0.5/50x50
ND 0.6	XND0.6/18	XND0.6/25	XND0.6/32	XND0.6/45	XND0.6/50	XND0.6/50x50
ND 0.7	XND0.7/18	XND0.7/25	XND0.7/32	XND0.7/45	XND0.7/50	XND0.7/50x50
ND 0.8	XND0.8/18	XND0.8/25	XND0.8/32	XND0.8/45	XND0.8/50	XND0.8/50x50
ND 1.0*	XND1.0/18	XND1.0/25	XND1.0/32	XND1.0/45	XND1.0/50	XND1.0/50x50
ND 2.0*	XND2.0/18	XND2.0/25	XND2.0/32	XND2.0/45	XND2.0/50	XND2.0/50x50
ND 3.0*	XND3.0/18	XND3.0/25	XND3.0/32	XND3.0/45	XND3.0/50	XND3.0/50x50
Set of 6 - includes items with*	XND6PC/18	XND6PC/25	XND6PC/32	XND6PC/45	XND6PC/50	XND6PC/50x50
Set of 12	XND12PC/18	XND12PC/25	XND12PC/32	XND12PC/45	XND12PC/50	XND12PC/50x50

Multi-Photon Filters

Multiphoton filters are used in conjunction with two- and three-photon IR laser excitation of fluorophores for imaging deeper into samples with minimal photobleaching and photodamage to cells.

Type	Product SKU	Description
Dichroic	XF2033	675DCSPXR
Laser Blocking Filter	XF3100	710ASP

Beamsplitters & Mirrors

Available in standard dichroic sizes and designed to function at 45 degree angle of incidence from 400-700nm.

Product SKU	Description	Application	
XF121	50/50 Beamsplitter	50%T, 50%R	Standard dichroic
XF122	70/30 Beamsplitter	70%T, 30%R	Standard dichroic
XF123	30/70 Beamsplitter	30%T, 70%R	Standard dichroic
XF125	Reflecting Mirror	Opaque backing prevents transmission, ≥ 90% Reflection	Standard dichroic
EXTENDED REFLECTION DICHROIC ONLY			
XF2031	505DRLPXR	**FITC**	Extended Reflection Dichroic
XF2032	565DRLPXR	**TRITC**	Extended Reflection Dichroic
XF2039	485-555DBDR	**FITC/TRITC**	Dual Dichroic with UV Reflection

Fluorescence Reference Slides

This set of slides helps to: center and adjust the fluorescence illuminator; verify uniformity of fluorescence staining; monitor and adjust laser output and PMT settings; and avoid microspheres and photobleaching.

Product SKU	Set of 4 slides	Description
XF900	Blue emission	DAPI/Indo-1/Fura
	Green emission	FITC/GFP
	Yellow emission	Acridine Orange
	Red emission	Rhodamine/Texas Red®

MICROSCOPE FILTER HOLDERS

We offer interference filter holders for Olympus, Zeiss, Leica, and Nikon. This includes holders for single dye filter sets, stereo microscope holders, and multi position sliders.

When purchasing filters and filter holders together, you must specify if the filters should be installed in the holder. There is no extra cost for this service when purchased together.

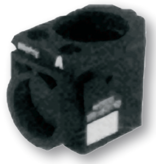
Please note: if ZPS (zero pixel shift) is required, emission filters will be aligned and care should be taken to not rotate them in the holder.

Nikon XC106

Nikon XC104

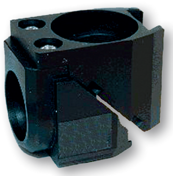
Olympus XC111

Olympus XC113



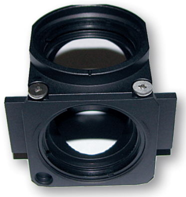
Leica XC121

Leica XC122

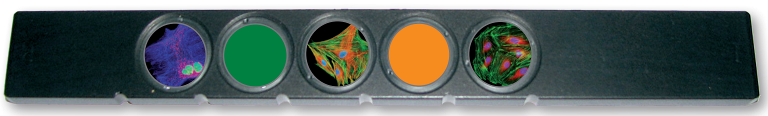


Leica XC123

Zeiss XC132



Zeiss XC136



Zeiss XC131

Microscope Filter Holders

		Type		
Product SKU	**Manufacturer & Model**	**Excitation**	**Dichroic**	**Emission**
	Nikon			
XC100	Original (Labophot, Diaphot, Optiphot, Microphot, TMD, FXA)	18 mm	18 x 26 mm	18 mm
XC101	Modified (Labophot, Diaphot, Optiphot, Microphot)	20 mm	18 x 26 mm	22 mm
XC102	Quadfluor, Eclipse (E Models; TE 200/300/800; LV 150/150A/100D, Diaphot 200 & 300, Labophot 2 and Alphaphot 2)	25 mm	25.7 x 36 mm	25 mm
XC104	TE2000, Eclipse 50i, 80i, LV- series	25 mm	25.7 x 36 mm	25 mm
XC105	Quadfluor plastic cube, Eclipse (E Models; TE200/300/800; LV 150/150A/100D, Diaphot 200 & 300, Labophot 2 and Alphaphot 2)	25 mm	25.7 x 36 mm	25 mm
XC106	TE2000 plastic cube, compatible with AZ100	25 mm	25.7 x 36 mm	25 mm
	Olympus			
XC110	IMT-2	22 mm	21 x 29 mm	20 mm
XC111	BH2 (cube style—not barrel, BHT, BHS, BHTU, AHBS 3, AHBT 3)	18 mm	18 x 26 mm	18 mm
XC113	BX2 (BX, IX, AX)	25 mm	25.7 x 36 mm	25 mm
XC114	CK-40 (CK Models 31/40/41, CB Models 40/41, CKX 31/41)	20 mm	21 x 29 mm	20 mm
XC117	BX3 illuminator (BX43, 53, 63)	25 mm	25.7 x 36 mm	25 mm
	Leica			
XC120	Ploemopak (DMIL, Diaplan, Dialux, Diavert, Fluovert, Labolux, Labovert, Orthoplan, Ortholux)	18 mm	18 x 26 mm	18 mm
XC121	DM (DML, DMR, DMLB, DMLM, DMLFS, DMLP)	22 mm	21 x 29 mm	22 mm
XC122	DMIRB (DMIL, DMRXA2, DMLS, DMICHB, DMLSP)	20 mm	18 x 26 mm	20 mm
XC123	DM2000, DM2500, DM3000, DM4000, DM5000, DM6000	22 mm	21 x 29 mm	22 mm
XC124	MZ FL III Stereo (Holds 2 emission filters)	18 mm	N/A	18 mm
	Zeiss			
XC131	Axio Excitation Slider (for exciters or ND filters, 5 ports)	18 mm	N/A	N/A
XC132	Axioskop 2 Cube (Axioplan 2, Axioskop 2, Axiovert 25, Axioskop 2FS)	25 mm	25.7 x 36 mm	25 mm
XC133	Axiovert 3FL Slider	25 mm	25.7 x 36 mm	25 mm
XC134	Axioskop 4FL Slider (Axiovert 100/135, Axioplan 1, Axioskop 1, Axioskop FS 1)	25 mm	25.7 x 36 mm	25 mm
XC135	Axioskop 6FL Slider (Axiovert 100/135, Axioplan 1, Axioskop 1, Axioskop FS 1)	25 mm	25.7 x 36 mm	25 mm
XC136	Axio 2 Push-and-Click	25 mm	25.7 x 36 mm	25 mm
XC137	Axioskop 5FL Slider (Axiovert 100/135, Axioplan 1, Axioskop 1, Axioskop FS 1)	25 mm	25.7 x 36 mm	25 mm
XC138	Axioskop 8FL Slider	25 mm	25.7 x 36 mm	25 mm
XC139	Standard 2FL Slider (Axiovert 100/135, Axioplan 1, Axioskop 1, Axioskop FS 1)	25 mm	25.7 x 36 mm	25 mm

Optimize Your System with the Right Filter Set

Application Note

Overview

The art of fluorescence imaging, requires you to know how to make the right interference filter selection. Filter sets are designed around a system and an application. The light source, fluorophore(s) and detector drive the spectral requirements of the filters, and the microscope make and model dictate the physical requirements.

– by Dan Osborn, Fluoresence Microscopy Product Manager, Omega Optical

Choosing a filter set for a fluorescence application can be difficult, but armed with knowledge of the microscope, light source, detector and fluorophore(s) can make the decision easier. The optical properties of filter sets correspond to a specific fluorophores excitation and emission spectra. The physical dimensions, size and thickness, are tailored to specific instrumentation hardware.

Filter Sets

A standard epi-fluorescence research microscope is configured to hold a number of "filter cubes" (interference filters mounted in a microscope's unique holder) in a rotating turret, or slider, where single or multi-color fluorescence imaging is achieved by moving one dye-specific filter cube at a time into the light pathway and collecting the image information from the sample at the detector, most often a scientific grade camera (CCD or CMOS), a PMT, or the eye. For successful imaging, the filter cube must be matched to the light source, the fluorophore being imaged, and the detector.

Each filter cube is designed to hold three interference filters, an excitation filter, a dichroic mirror, and an emission filter. The excitation filter, positioned normal to the incident light, has a bandpass design that transmits the wavelengths specific to the fluorophores absorption profile. The filtered excitation light reflects off a long-pass dichroic mirror placed at 45° and excites the fluorophore. The mirror has the unique ability to reflect more than 90 percent of the light within the reflection band, while passing more than 90% of the light in the transmission region. This directs excitation light and fluorescence emission appropriately within the optical setup.

Following excitation, the fluorophore emits radiation at some longer wavelength, which passes through the dichroic mirror and emission filter to a detector. The emission filter blocks all excitation light and transmits the desired fluorescence to produce a quality image with high signal-to-noise ratio (Figure 1).

Interference filters are manufactured to rigorous physical and spectral specifications and tolerances. For example, a filter set is designed so that the tolerances of the three filters are compatible. It is important to note that filters cannot be randomly interchanged without the possibility of compromising performance.

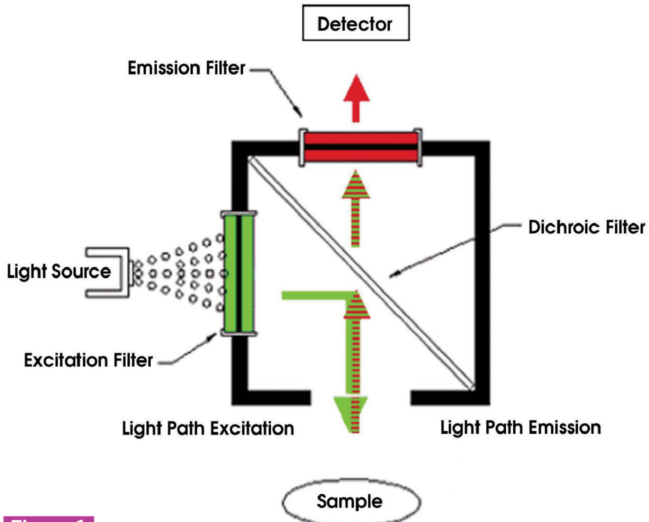


Figure 1

In a fluorescence filter cube, the incident light passes through the excitation filter. The filtered light reflects off a dichroic mirror, striking the fluorophore. The longer-wavelength fluorescence emission passes through the dichroic mirror and emission filter to the detector. The emission filter blocks stray excitation light, providing bright fluorescence against a dark background.

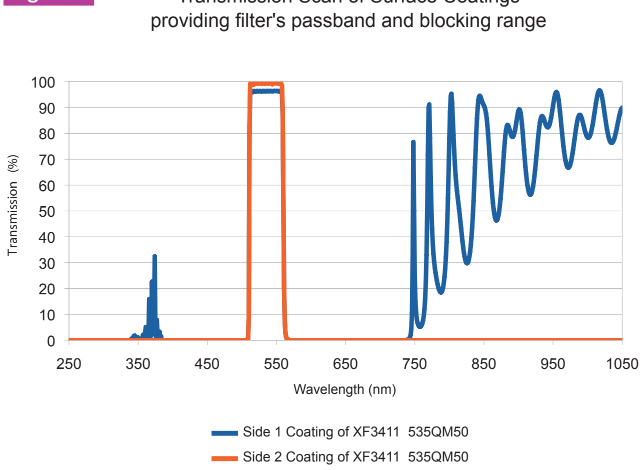
◗ Filter Set Design

The goal of every filter set is to achieve an appropriate level of contrast (signal over background) for a specific application. First and foremost in this regard is to ensure that the weak fluorescence emission is separated from the high intensity excitation light. This is primarily achieved through the blocking requirements imparted on the excitation filter and emission filter.

Optical density (OD), the degree of blocking, is calculated as -log T (transmission). For example, OD 1 = 10 percent transmission, OD 2 = 1 percent transmission and OD 3 = 0.1 percent transmission. Background "blackness" is controlled by attenuating excitation light through the emission filter. The degree of attenuation is determined by the total amount of excitation energy passed by the emission filter. Interference filters exhibit deep blocking of incoming energy at wavelengths near the passband, often achieving values of > OD 10 in theory. Therefore, it is this transition from the passband to the deep blocking region at the red edge of the excitation filter and the blue edge of the emission filter that determines much of the contrast enhancing properties of a filter set. The point at which the OD curves of the excitation and emission filter overlap is called the crossover point. For single band filter sets a crossover value of >/= OD 5 is typically specified to achieve a high degree of excitation light rejection, reducing the background and increasing contrast. Multi band filter sets, because they are most often used in visual identification applications, do not require such a degree of cross over blocking and values of approximately ≥4 ODs are sufficient to ensure good contrast.

Bandpass filters often consist of the combination of a short-pass design, which blocks longer wavelengths and transmits shorter ones to approximately 300 - 400nm, and a long-pass design, which blocks shorter wavelengths and transmits longer wavelengths. The steepness of the transition between the transmission and near-

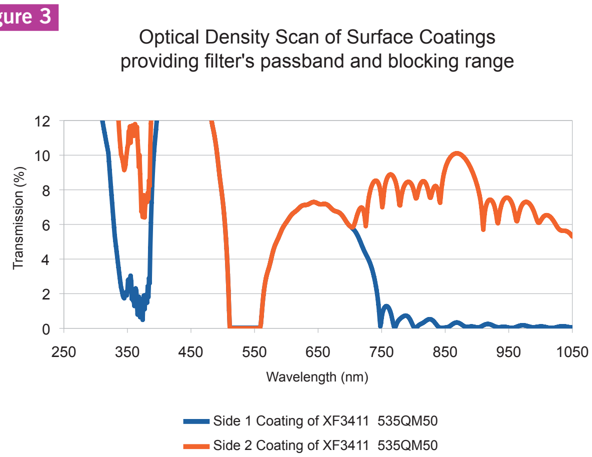
Figure 2



band blocking – important design and performance features – depends on the filter design and phase thickness. The phase thickness is determined by both the number of interference coating layers and their physical thickness. This combination filter design can be coated on one surface of a monolithic substrate. Additional coating can be applied to the second surface to extend blocking to the UV and/or the IR.

Filter coatings with a high phase thickness produce the steepest transition regions, characterized by a ≥1%, five-decade slope factor. This means, for a 1% slope factor a 500nm long-pass filter

Figure 3



(the wavelength at 50 percent transmission) will achieve OD5 blocking (0.001 percent transmission) at 495nm, or 500nm minus 1 percent. Less demanding and less expensive designs have five-decade slope factors of 3 to 5 percent. In fluorescence imaging the use of steep-edged filter designs is most often exploited where the excitation and emission maxima are spectrally very close to each other, such as fluorophores with small Stokes shifts. E-GFP, a widely used fluorescent protein, has an excitation absorption maximum at 488nm and an emission maximum at 509nm. With a Stokes shift of only 21nm it becomes imperative that the filters used to separate out the excitation source light from the fluorescence emission achieve a very high level of blocking in a short spectral distance. If the excitation and emission filter edges are not very steep they should be placed spectrally further apart to gain deep blocking. This will reduce the filters ability to deliver and capture photons at the fluorophores absorption and emission maximums.

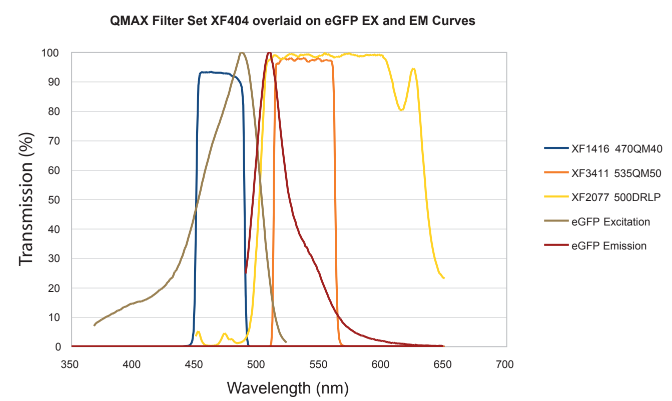


Figure 4

System-Based Needs

Epi-fluorescence systems are the most common in fluorescence microscopy. Standard filter sets have transmission and blocking optimized for the application's fluorophore(s) and the white light used for excitation, usually a mercury arc or xenon arc lamp. The mercury arc lamp is most commonly used because of its brightness. Its five energy peaks, 365, 405, 436, 546 and 577 nm, affect application performance and are considered in the filter set designs. The xenon lamp, though not as bright, irradiates uniformly between 300 and 800 nm with energy peaks beginning at ~820 nm. This is recommended for ratio imaging.

The Nipkow disc scanning confocal microscope contains optics similar to those in the epi-fluorescence system and therefore requires similar filters. However, laser scanning confocal microscopes require filters designed for the specific laser used for excitation. The secondary lines and other unwanted background signals caused by the lasers demand customized excitation filters. Emission filters must have greater than OD5 blocking and antireflection coatings on both sides to minimize skew rays reflecting off secondary surfaces. As in epi-fluorescence systems, dichroic mirrors must efficiently reflect specific laser wavelengths and transmit the desired fluorescence. Multiphoton microscopy, another laser-based fluorescence technique, requires a tunable pulsed Ti:sapphire infrared laser. This light source excites shorter-wavelength fluorophores, contrary to conventional fluorescence systems.

At the focal point, a fluorophore absorbs two photons simultaneously. The combined energy elevates the fluorophores electrons to a higher energy level, causing it to emit a photon of lower energy when the electrons return to the ground state. For example, a 900nm laser pulse will excite at 450nm and yield fluorescence emission at ~500nm, depending on the fluorophore. This technique generally uses a combination of a shortpass dichroic mirror and an emission filter with deep blocking at the laser line. An all-purpose multiphoton short-pass dichroic mirror reflects radiation between 700 and 1000nm — the range of Ti:sapphire lasers — and transmits visible light. The emission filter must transmit fluorescence and block the laser light to more than OD6.

Application Relevance

A number of applications have been developed around epi-fluorescence in the research laboratory, and some are being extended to confocal and multiphoton. Example, ratio imaging can be used to quantify environmental parameters such as calcium-ion concentration, pH and molecular interactions, and it demands a unique set of filters. For example, Fura-2, a calcium dependent fluorophore, has excitation peaks at 340 and 380nm requiring excitation filters that coincide with the peaks and a dichroic mirror that reflects them. The xenon arc lamp is an ideal excitation source for epifluorescence because of its uniform intensity over the excitation range. A mercury arc source may require additional balancing filters to attenuate the effects of the energy peaks.

In fluorescence resonance energy transfer (FRET), energy is transferred via dipole-dipole interaction from a donor fluorophore to a nearby acceptor fluorophore. The donor emission and acceptor excitation must spectrally overlap for the transfer to happen. A standard FRET filter set consists of a donor excitation filter, a dichroic mirror and an acceptor emission filter. Separate filter sets for the donor and acceptor are recommended to verify dye presence, but most importantly, single-dye controls are needed because donor bleed-through into the acceptor emission filter is unavoidable.

Recently, fluorescence detection has found an expanded role in the clinical laboratory as well. Tests for the presence of the malaria causing parasite, Plasmodium, are traditionally performed using a thin film blood stain and observed under the microscope. Although an experienced histologist can identify the specific species of Plasmodium given a quality stained slide, the need for rapid field identification of potential pathogens is not met using this method, particularly in resource poor third world countries. The use of the nucleic acid binding dye Acridine Orange together with a simple portable fluorescence microscope, equipped with the proper filter set, can significantly reduce assay time and provide a more sensitive detection method.

In another test using fluorophore tagged PNA (peptide nucleic acids) as ribosomal RNA (rRNA) probes specific for pathogenic yeasts and bacterium's such as C. albicans and S. aureus, clinicians can make accurate positive or negative determinations in fewer than two hours. The sensitivity and reduced processing time of the assay greatly enhances positive patient outcomes compared to previously used cell culture methods.

In both techniques, the filters must provide specific excitation light to the sample in order to generate the required fluorescence, and more importantly, reproducibly provide the desired signal level and color rendition to allow for accurate scoring. For this to occur, the filter manufacturer must apply stringent tolerances to each component in the filter set to ensure its proper functioning in the clinical laboratory.

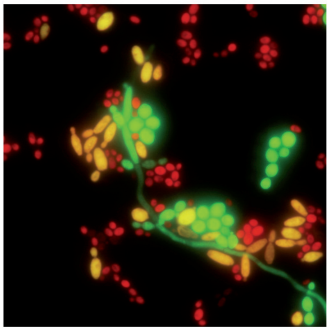


Figure 5

Using fluorescence detection as a visual test for determining the presence of pathogenic organisms requires precise band placement for accurate color determinations. Photo courtesy Advandx Corp.

Multicolor imaging is extending to 800nm and beyond, with far-red fluorophores readily available and CCD camera quantum efficiencies being pushed to 1200 nm. There are a multitude of filter combinations from which to choose, depending on the application, each with its own advantages and disadvantages. A standard multi-band filter set allows simultaneous color detection by eye and is designed for conventional fluorophores such as DAPI (blue), fluorescein (green) and rhodamine/Texas red (orange/red). Two and three-color sets are most common, while the fourth color in a four-color set includes a fluorophore in the 650 to 800nm range. Multiple passbands limit the deep blocking achieved in single-band filter sets, resulting in a lower signal-to noise ratio from multi-band sets.

For an increased signal-to-noise ratio and better fluorophore-to-fluorophore discrimination, Pinkel filter sets for the camera consist of single- and multi-band filters. For microscopes that are equipped with an excitation slider or filter wheel, changing single-band excitation filters allows single-color imaging of multi-labeled samples. The Pinkel filter holder and sample slide remain fixed, minimizing registration errors.

A Sedat set hybrid combines a similar suite of single-band excitation filters in a filter wheel; a set of single-band emission filters, along with an emission filter slider or wheel; and a multi-band dichroic housed in a filter holder. Such a hybrid setup will increase the signal-to-noise ratio and discrimination even more than a traditional Pinkel set. The disadvantages of Pinkel and Sedat sets to multi-band sets include increased filter cost and the inability to image multiple colors simultaneously. Instead, commercially available imaging software can be used to merge separate images.

Fluorescence in situ hybridization (FISH) applications attempt to image as many colors as possible in a single sample. For example, multiple fluorescent labeled DNA probes can identify genes colorimetrically on a single chromosome. Optimized signal-to-noise ratio and color discrimination require narrowband single- dye filter sets. The filters must conform to tighter spectral tolerances than standard bandpass filter sets to minimize excitation/emission overlap of spectrally close fluorophores. Minor passband edge shifts may significantly compromise fluorophore discrimination. In addition, these narrowband filters must be optimized for transmission to provide adequate signal.

Choosing optical filter sets for fluorescence microscopy can be confusing. Proper bandwidths, degree and extent of blocking, and the type of filter design for your application are important considerations. We can help with your decision-making. Please feel free to contact us for assistance.

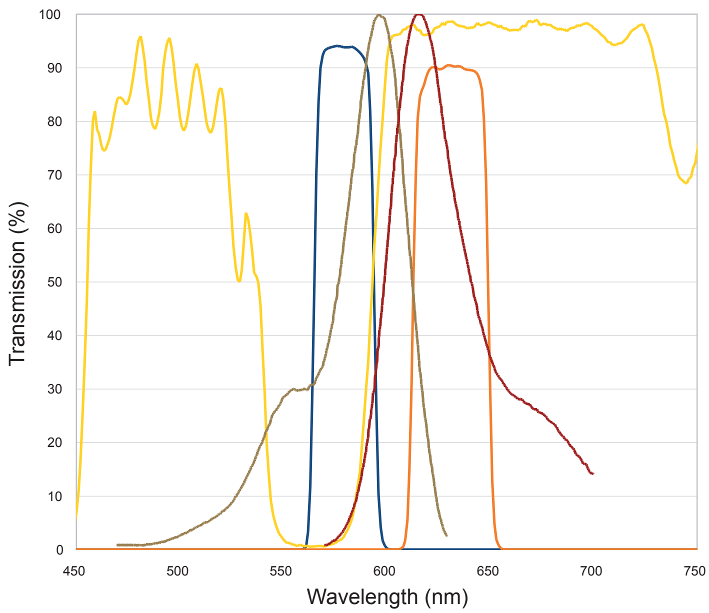


Figure 6

Filter sets used in mFISH assays exhibit narrow filter bandwidths for minimizing spectral bleedthrough of non-specfic fluorophores and accurate color reperesentation. Reperesented here is Omega filter set XF424 for Spectrum Red, Texas Red, and similar fluors.

CHOOSING the OPTIMAL FILTER SET

Please consult our Fluorophore Reference Table (pages 105-107) for excitation and emission peaks, as well as for recommended filter sets, or visit curvomatic on our website.

What is most important in your application – bright signal, dark background, color discrimination, or high signal-to-noise? While no single design can optimize for all dimensions, many designs provide a solution that gives good overall performance.

- Does your application require customized reflection and transmission specifications for your dichroic? Call us for assistance.
- Does your application require "imaging quality" filters? All 3RD Millennium and QuantaMAX™ fluorescence filters in this catalog are suitable for imaging applications.

What is your light source – halogen, laser, LED, mercury, xenon? Filters are designed to optimize performance for different light sources.

Specify your detector – CCD, PMT, CMOS, film, eye. Filter blocking strategies are designed to optimize performance for different detectors.

Zero Pixel Shift

ZPS is recommended for multi-color applications and results in better discrimination. ZPS is also recommended for applications such as FISH (fluorescence in-situ hybridization), CGH (comparative genomic hybridization), SKY (spectral karyotyping), and co-localization studies.

Please specify when ZPS is required. An additional charge may be added to the price of some sets.

Figure of Merit - NEW Feature on Curvomatic

Our new Figure of Merit calculator allows you to obtain the relative value of a single filter set effectiveness when combined with a light source and a single fluorophore to capture the spectral absorption and emission probability curves.

When considering the merit of two or more filter sets independently, against the same fluorophore, the set with higher value will offer a greater ability to capture the fluorescence signal. The number returned by the Figure of Merit is a single benchmark by which to gauge if your filter set selection is best for a given application, or to compare two or more sets effectiveness against a particular fluorophore. It does not give a measure of the relative brightness that will be seen in the microscope as it does not consider the quantum yield or absorption coefficients of the selected fluorophore, the sample labeling density, or other experimental variables. Factors such as detector sensitivity at a given wavelength, the presence of other fluorophores, slight shifts in the absorption or emission peaks of the fluorophore, and the sample background all contribute to the overall system efficiency and are not considered here.

◗ Understanding the Results

A few examples of returned results can help demonstrate how the Figure of Merit can help you decide which filter set is optimal in your set of conditions.

◗ Q: The results of filter set "X" and fluorophore "Y" = 0. Why the results are zero:

A: The filter set is incompatible with the fluorophore or the light source (if selected).

Check to make sure the fluorophores absorbance and emission profiles overlap the filter set's excitation and emission passbands. Verify that the excitation filter transmits the light source efficiently.

◗ Q: The results of filter set "X" and fluorophore "Y" is 425. Using the same fluorophore ("Y") with a different filter set ("Z") the result is 577. Is filter set "Z" the one I want?

A: Figure of Merit is but one benchmark to use in making this decision. If filter set "Z" contains a long pass emission filter it will collect more signal (if the excitation filter is equivalent) than a bandpass filter and return a higher number, but it may also collect more background photons or signal from other fluorophores in the sample. If sample background and spectral bleed-through are not issues, then Set "Z" is the best choice.

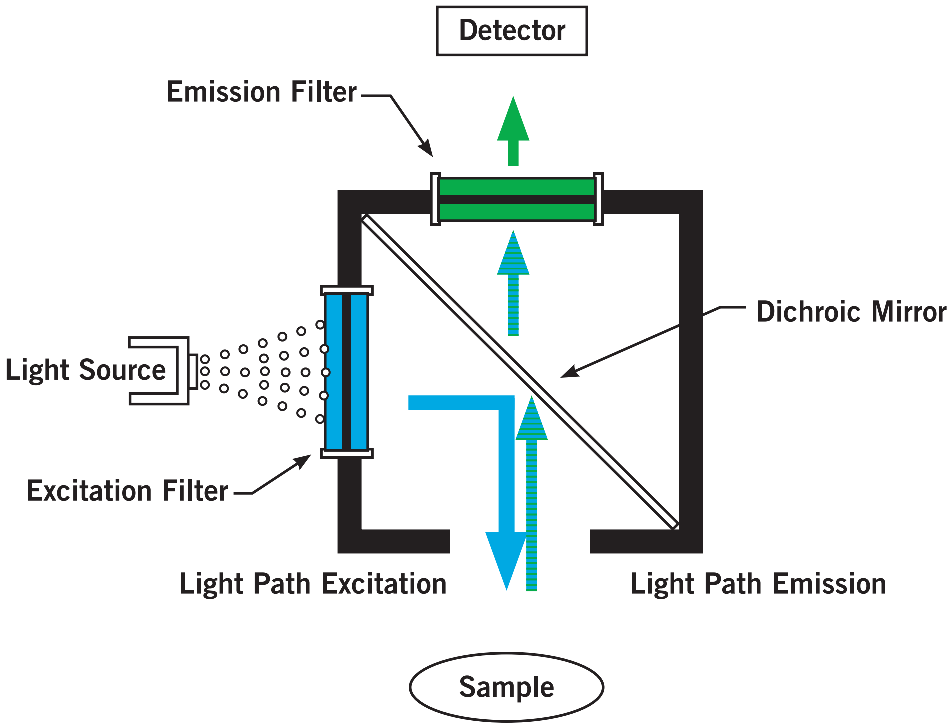
◗ Q: I compared a narrow band filter (mFISH set XF202) to a wider band set (XF404 for Cy 2) and the returned values were 130.5 and 535.1 respectively. I am doing a multi-color assay and am worried about spectral bleed-through. Is the value too low for this set to be useful?

A: No. A number that comes in several fold lower than another set, using the same fluorophore and light source, may indicate that in an ideal situation the higher value set will provide a much stronger signal, but it does not account for any noise factors. If you are doing a multicolor assay and do not efficiently reject bleed-through from other fluorophores, you may increase the total signal using the higher scoring filter set , but reduce the signal-to-noise because of the spectral bleed-through. You can actually use the tool to estimate the spectral bleed-through by placing another fluorophore on the graph and seeing the returned value of the two filter sets. In this case, if the other fluorophore was Cy3, the returned values for the XF202 and XF404 are 1.8 and 18.6 respectively.

TYPICAL EPI-FLUORESCENCE CONFIGURATION

Successful fluorescence imaging requires three filters mounted as a single unit in a filter cube or holder, secured in a fluorescence microscope with the proper lightsource and detector. The excitation filter, positioned normal to the incident light, has a bandpass design that transmits the wavelengths. The filtered excitation light reflects off a long-pass dichroic mirror placed at 45° and excites the fluorophore. The mirror has the unique ability to reflect more than 90 percent of the light within the reflection band while passing more than 90 percent of the light in the transmission region. This directs excitation light and fluorescence emission appropriately within the optical setup.

Following excitation, the fluorophore emits radiation at some longer wavelength, which passes through the dichroic mirror and emission filter into a detector. The emission filter blocks all excitation light and transmits the desired fluorescence to produce a quality image with high signal-to-noise ratio (See below).



In a fluorescence filter cube, the incident light passes through the excitation filter. The filtered light reflects off a dichroic mirror, striking the fluorophore. The longer-wavelength fluorescence emission passes through the dichroic mirror and emission filter to the detector. The emission filter blocks stray excitation light, providing bright fluorescence against a dark background.

FLUOROPHORE REFERENCE CHART

Fluorophores (A-B)

Fluorophore	EX	EM	Best Set	Page #
AcGFP1	475	505	XF404	72
Acridine Yellow	470	550	XF23	74
Acridine orange (+DNA)	500	526	XF412	72
Acridine orange (+RNA)	460	650	XF403	72
Alexa Fluor® 350	347	442	XF403	72
Alexa Fluor® 405	401	421	**Visit website**	
Alexa Fluor® 430	434	540	XF14-2	73
Alexa Fluor® 488	495	519	XF404	72
Alexa Fluor® 500	503	525	XF412	72
Alexa Fluor® 532	531	554	XF412	72
Alexa Fluor® 546	556	573	XF402	72
Alexa Fluor® 555	553	568	XF402	72
Alexa Fluor® 568	579	604	XF414	72
Alexa Fluor® 594	591	618	XF414	72
Alexa Fluor® 610	612	628	XF414	72
Alexa Fluor® 633	632	647	XF140-2	75
Alexa Fluor® 647	653	669	XF110-2	75
Alexa Fluor® 660	663	690	XF141-2	75
Alexa Fluor® 680	679	702	XF141-2	75
Alexa Fluor® 700	702	723	XF142-2	75
Alexa Fluor® 750	749	775	**Visit website**	
Alexa Fluor® 488/546 FRET	495	573	XF164	88
Alexa Fluor® 488/555 FRET	495	568	XF164	88
Alexa Fluor® 488/Cy3® FRET	495	570	XF165	88
Allophycocyanin (APC)	650	660	XF416	72
AMCA/AMCA-X	345	445	XF408	72
AmCyan1	458	489	**Visit website**	
7-Aminoactinomycin D (7-AAD)	546	647	XF103-2	74
7-Amino-4-methylcoumarin	351	430	XF408	72
Aniline Blue	370	509	XF09	76
ANS	372	455	XF05-2	73
AsRed2	578	592	XF405	72
ATTO-TAG™ CBQCA	465	560	XF18-2	73
ATTO-TAG™ FQ	486	591	XF409	72
Auramine O-Feulgen	460	550	**Visit website**	
Azami Green	493	505	XF404	72
BCECF	503	528	XF16	96
BFP (Blue Fluorescent Protein)	382	448	XF403	72
BFP/DsRed2 FRET	382	583	XF159	88
BFP/eGFP FRET	382	508	XF89-2	88
BFP/YFP FRET	382	527	XF158	88
BOBO™-1, BO-PRO™-1	462	481	XF401	72
BOBO™-3, BO-PRO™-3	570	604	XF414	72
BODIPY® FL - Ceramide	505	513	XF404	72
BODIPY® TMR	542	574	XF402	72
BODIPY® TR-X	589	617	XF414	72
BODIPY® 492/515	490	515	XF404	72
BODIPY® 493/ 503	500	506	XF404	72
BODIPY® 500/ 510	509	515	XF412	72

Fluorophores (B-C)

Fluorophore	EX	EM	Best Set	Page #
BODIPY® 505/515	502	510	XF404	72
BODIPY® 530/550	533	550	XF402	72
BODIPY® 558/568	558	568	XF402	72
BODIPY® 564/570	564	570	XF402	72
BODIPY® 581/591	582	590	XF414	72
BODIPY® 630/650-X	630	650	XF45	76
BODIPY® 650/665-X	650	665	XF416	72
BODIPY® 665/676	665	676	XF416	72
BTC	401/464	529	**Visit website**	
Calcein	494	517	XF404	72
Calcein Blue	375	420	XF408	72
Calcium Crimson™	590	615	XF414	72
Calcium Green-1™	506	531	XF412	72
Calcium Orange™	549	576	XF402	72
Calcofluor® White	350	440	XF408	72
5-Carboxyfluorescein (5-FAM)	492	518	XF404	72
5-Carboxynaphthofluorescein (5-CNF)	598	668	XF414	72
6-Carboxyrhodamine 6G	525	555	XF412	72
5-Carboxytetramethylrhodamine (5-TAMRA)	522	576	XF402	72
Carboxy-X-rhodamine (5-ROX)	574	602	XF414	72
Cascade Blue®	400	420	XF408	72
Cascade Yellow™	402	545	XF106	73
GeneBLAzer™ (CCF2)	402	520	XF106	73
Cell Tracker Blue	353	466	XF408	72
Cerulean	433	475	XF401	72
CFP (Cyan Fluorescent Protein)	434	477	XF412	72
CFP/DsRed2 FRET	434	583	XF152	88
CFP/YFP FRET	434	527	XF88	88
Chromomycin A3	450	470	XF114-2	73
Cl-NERF (low pH)	504	540	XF104-2	74
CoralHue Azami Green	492	505	**Visit website**	
CoralHue Dronpa Green	503	518	CALL	—
CoralHue Kaede Green	508	518	**Visit website**	
CoralHue Kaede Red	572	580	**Visit website**	
CoralHue Keima Red	440	620	CALL	—
CoralHue Kusabira Orange (mKO)	552	559	XF402	72
CoralHue Midoriishi-Cyan (MiCy)	472	492	XF410	72
CPM	385	471	**Visit website**	
6-CR 6G	518	543	XF412	72
CryptoLight CF-2	584/642	657	**Visit website**	
CryptoLight CF-5	566	597	**Visit website**	
CryptoLight CF-6	566	615	XF414	72
CTC Formazan	450	630	XF21	76
Cy2®	489	506	XF404	72
Cy3®	550	570	XF402	72
Cy3.5®	581	596	XF414	72
Cy5®	649	670	XF407	72
Cy5.5®	675	694	XF141-2	75
Cy7®	743	767	**Visit website**	

FLUOROPHORE REFERENCE CHART

Fluorophores
(C-G)

Fluorophore	EX	EM	Best Set	Page #
Cy3®/Cy5.5® FRET	550	694	XF167	88
Cy Pet	435	477	XF401	72
Cycle 3 GFP	395/478	507	XF76	76
Dansyl cadaverine	335	518	XF02-2	73
Dansylchloride	380	475	**Visit website**	
DAPI	358	461	XF403	72
Dapoxyl®	373	574	XF05-2	73
DiA (4-Di-16-ASP)	491	613	XF21	76
DiD (DilC18(5))	644	665	XF416	72
DIDS	341	414	XF408	72
DiL (DiLC18(3))	549	565	XF405	72
DiO (DiOC18(3))	484	501	XF404	72
DiR (DilC18(7))	750	779	**Visit website**	
Di-4 ANEPPS	488	605	XF21	76
Di-8 ANEPPS	468	635	XF21	76
DM-NERF (4.5–6.5 pH)	510	536	XF412	72
DsRed2 (Red Fluorescent Protein)	558	583	XF405	72
DsRed-Express	557	579	XF405	72
DsRed Monomer	556	586	XF405	72
ELF® -97 alcohol	345	530	XF09	76
Emerald	487	509	XF404	72
EmGFP	487	509	XF404	72
Eosin	524	544	XF404	72
Erythrosin	529	554	XF104-2	74
Ethidium bromide	518	605	XF103-2	74
Ethidium homodimer-1 (EthD-1)	528	617	XF103-2	74
Europium (III) Chloride	337	613	XF02-2	73
5-FAM (5-Carboxyfluorescein)	492	518	XF404	72
Fast Blue	365	420	XF408	72
Fluorescein (FITC)	494	518	XF404	72
FITC/Cy3® FRET	494	570	XF162	88
FITC/Rhod 2 FRET	494	571	XF162	88
FITC/TRITC FRET	494	580	XF163	88
Fluo-3	506	526	XF412	72
Fluo-4	494	516	XF404	72
FluorX®	494	519	XF404	72
Fluoro-Gold™ (high pH)	368	565	XF09	76
Fluoro-Gold™ (low pH)	323	408	XF05-2	73
Fluoro-Jade	475	525	XF404	72
FM® 1-43	479	598	XF409	72
Fura-2	335	505	XF04-2	96
Fura-2/BCECF	335/503	505/528	**Visit website**	
Fura Red™	436	637	**Visit website**	
Fura Red™/Fluo-3	472/506	672/527	**Visit website**	
GeneBLAzer™ (CCF2)	402	520	**Visit website**	
GFP wt	395/ 475	509	**Visit website**	
eGFP	488	508	XF404	72
GFP (sapphire)	395	508	XF76	76
eGFP/DsRed FRET	470	585	XF151-2	88

Fluorophores
(G-M)

Fluorophore	EX	EM	Best Set	Page #
eGFP/Rhod-2 FRET	488	571	XF151-2	88
HcRed	591	613	XF414	72
HiLyte Fluor™ 488	497	525	XF401	72
HiLyte Fluor™ 555	550	566	XF402	72
HiLyte Fluor™ 647	649	672	XF140-2	75
HiLyte Fluor™ 680	688	700	XF141-2	75
HiLyte Fluor™ 750	750	782	**Visit website**	
Hoechst 33342 & 33258	352	461	XF403	72
7-Hydroxy-4-methylcoumarin (pH 9)	360	449	XF408	72
1,5 IAEDANS	336	482	XF02-2	73
Indo-1	330	401	**Visit website**	
ICG (Indocyanine Green)	785/805	835	XF148	75
JC-1	498/593	525/595	XF409	72
6-JOE	525	555	XF412	72
JOJO™-1, JO-PRO™-1	529	545	XF412	72
JRed	584	610	XF406	72
Keima Red	440	620	**Visit website**	
Kusabira Orange	548	559	XF405	72
Lissamine rhodamine B	570	590	XF414	72
LOLO™-1, LO-PRO™-1	565	579	**Visit website**	
Lucifer Yellow	428	536	XF14-2	73
LysoSensor™ Blue (pH 5)	374	424	XF131	73
LysoSensor™ Green (pH 5)	442	505	XF404	72
LysoSensor™ Yellow/Blue (pH 4.2)	384	540	**Visit website**	
LysoTracker® Green	504	511	XF412	72
LysoTracker® Red	577	592	XF406	72
LysoTracker® Yellow	465	535	XF18-2	73
Mag-Fura-2	330	491	XF04-2	96
Mag-Indo-1	330	417	**Visit website**	
Magnesium Green™	506	531	XF412	72
Marina Blue®	365	460	XF408	72
mBanana	540	553	CALL	—
mCherry	587	610	XF406	72
mCitrine	516	529	XF412	72
4-Methylumbelliferone	360	449	XF408	72
mHoneydew	487	537	CALL	—
Midorishii Cyan	472	495	XF410	72
Mithramycin	395	535	XF14-2	73
Mitofluor Far Red	680	650-773	XF142-2	75
Mitofluor Green	490	516	XF404	72
Mitofluor Red 589	588	622	XF414	72
Mitofluor Red 594	598	630	XF414	72
MitoTracker® Green	490	516	XF404	72
MitoTracker® Orange	551	576	XF402	72
MitoTracker® Red	578	599	XF414	72
MitoTracker® Deep Red	644	655	XF416	72
mOrange	548	562	XF402	72
mPlum	590	649	XF416	72
mRaspberry	598	625	XF414	72
mRFP	584	607	XF407	72

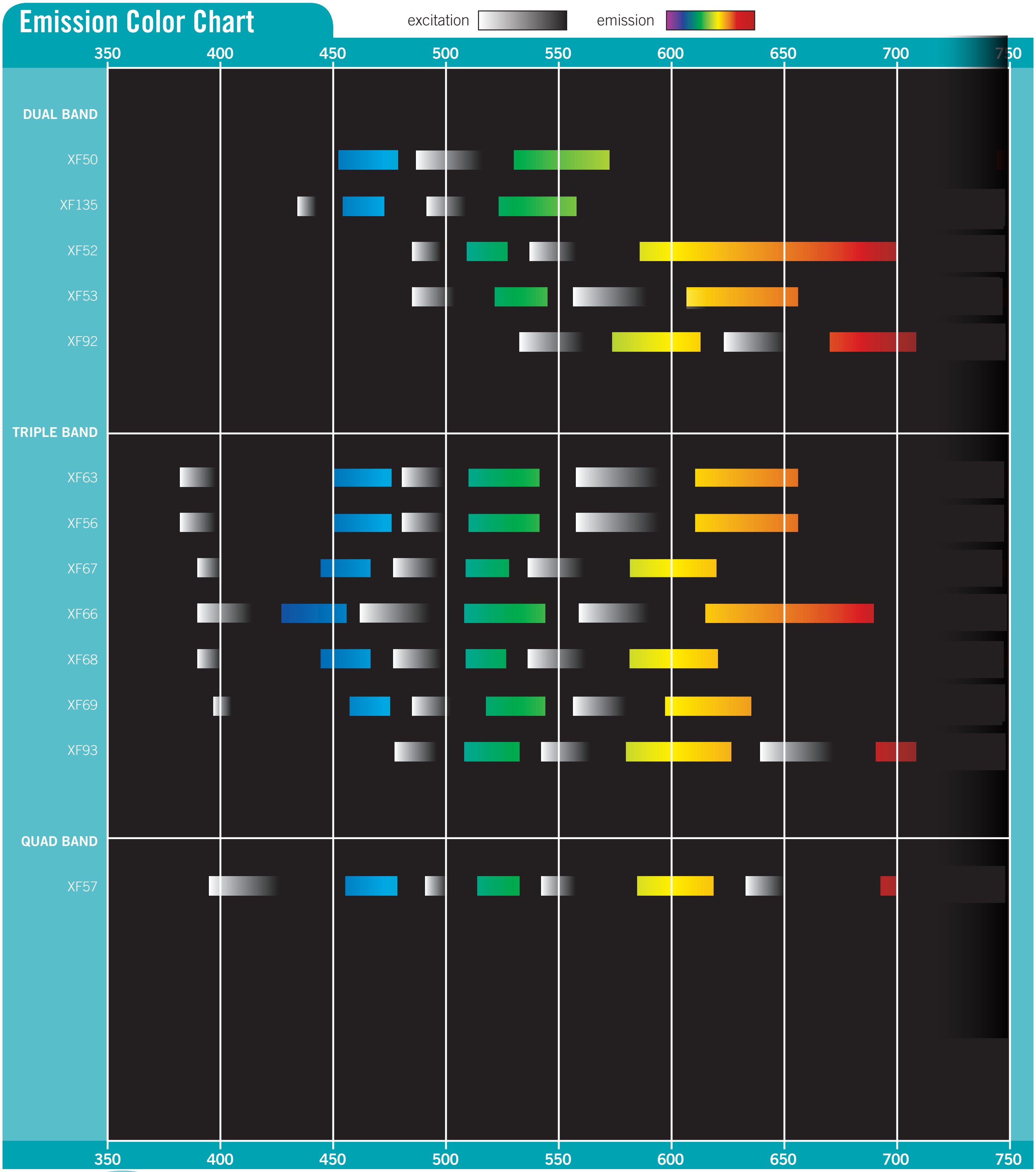
Fluorophores
(M-S)

Fluorophore	EX	EM	Best Set	Page #
mStrawberry	574	596	**Visit website**	
mTangerine	568	585	XF402	72
mTFP	462	492	**Visit website**	
NBD	465	535	XF18-2	73
Nile Red	549	628	XF103-2	74
Oregon Green® 488	496	524	XF404	72
Oregon Green® 500	503	522	XF412	72
Oregon Green® 514	511	530	XF412	72
Pacific Blue™	410	455	XF119-2	73
PBF1	334	504	XF04-2	96
C-phycocyanin	620	648	XF45	76
R-phycocyanin	618	642	XF414	72
R-phycoerythrin (PE)	565	575	XF402	72
Phi YFP	525	537	XF412	72
PKH26	551	567	XF402	72
POPO™-1, PO-PRO™-1	434	456	XF401	72
POPO™-3, PO-PRO™-3	534	572	XF402	72
Propidium Iodide (PI)	536	617	XF103-2	74
PyMPO	415	570	**Visit website**	
Pyrene	345	378	XF02-2	73
Pyronin Y	555	580	XF402	72
Qdot™ 525 Conjugate	UV	525	XF301-1	93
Qdot™ 565 Conjugate	UV	565	XF302-1	93
Qdot™ 585 Conjugate	UV	585	XF303-1	93
Qdot™ 605 Conjugate	UV	605	XF304-1	93
Qdot™ 625 Conjugate	UV	625	**Visit website**	
Qdot™ 655 Conjugate	UV	655	XF305-1	93
Qdot™ 705 Conjugate	UV	705	XF306-1	93
Qdot™ 800 Conjugate	UV	800	**Visit website**	
Quinacrine Mustard	423	503	XF14-2	73
Resorufin	570	585	XF414	72
Red Fluorescent Protein (DsRed2)	561	585	XF402	72
RH 414	500	635	XF103-2	74
Rhod-2	550	571	XF402	72
Rhodamine B	555	580	XF402	72
Rhodamine Green™	502	527	XF412	72
Rhodamine Red™	570	590	XF414	72
Rhodamine Phalloidin	542	565	XF402	72
Rhodamine 110	496	520	XF404	72
Rhodamine 123	507	529	XF412	72
5-ROX (carboxy-X-rhodamine)	574	602	XF414	72
SBFI	334	525	XF04-2	96
SensiLight P-1	550	664	**Visit website**	
SensiLight P-3	609	661	XF45	76
Sirius	360	420	XF149	73
SITS	337	436	XF408	72
SNAFL®-1	576	635	**Visit website**	
SNAFL®-2	525	546	**Visit website**	
SNARF®-1	575	635	XF72	96

Fluorophores
(S-Z)

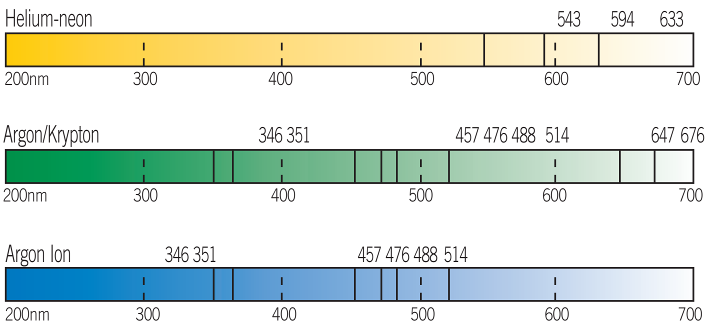
Fluorophore	EX	EM	Best Set	Page #
Sodium Green™	507	535	XF412	72
SpectrumAqua®	433	480	XF201	80
SpectrumBlue®	400	450	XF408	72
SpectrumGold®	530	555	XF203	80
SpectrumGreen®	497	524	XF202	80
SpectrumOrange®	559	588	XF204	80
SpectrumRed®	587	612	XF207	80
SpectrumFRed®	655	675	XF208	80
SYTO® 11	508	527	XF412	72
SYTO® 13	488	509	XF404	72
SYTO® 17	621	634	**Visit website**	
SYTO® 45	452	484	XF401	72
SYTOX® Blue	445	470	XF401	72
SYTOX® Green	504	523	XF412	72
SYTOX® Orange	547	570	XF402	72
5-TAMRA (5-Carboxytetramethylrhodamine)	542	568	XF402	72
tdTomato	554	581	XF173	74
Tetramethylrhodamine (TRITC)	555	580	XF402	72
Texas Red®/Texas Red®-X	595	615	XF414	72
Thiadicarbocyanine	651	671	XF47	76
Thiazine Red R	510	580	**Visit website**	
Thiazole Orange	453	480	XF401	72
Topaz	514	527	XF412	72
T-Sapphire	399	511	XF76	76
TOTO®-1, TO-PRO®-1	514	533	XF412	72
TOTO®-3, TO-PRO®-3	642	660	XF416	72
TO-PRO®-5	748	768	**Visit website**	
Turbo RFP	553	574	XF402	72
Turbo YFP	525	538	XF412	72
Venus	515	528	XF412	72
WW 781	605	639	XF45	76
X-Rhodamine (XRITC)	580	605	XF414	72
YFP (Yellow Fluorescent Protein)	513	527	XF412	72
YFP/Cy3® FRET	513	570	XF167	88
YFP/TRITC FRET	513	580	XF166	88
YOYO®-1, YO-PRO®-1	491	509	XF404	72
YOYO®-3, YO-PRO®-3	612	631	XF414	72
Ypet	517	530	XF412	72
ZsGreen1	493	505	XF404	72
ZsYellow1	529	539	XF412	72

EMISSION COLOR CHART

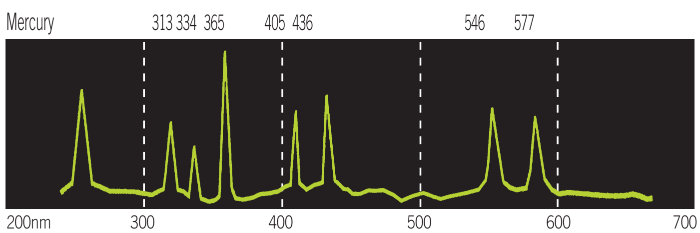


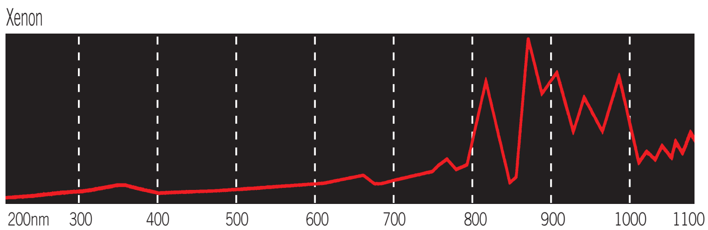
LIGHT SOURCE and DETECTOR REFERENCE CHARTS

Lasers

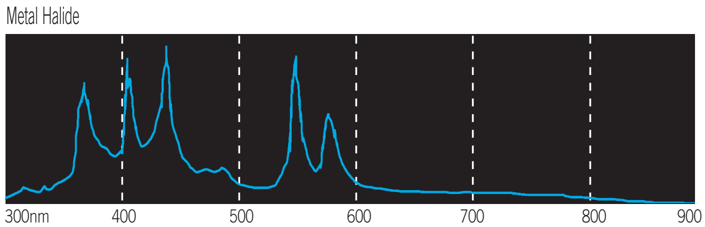


Arc Lamps

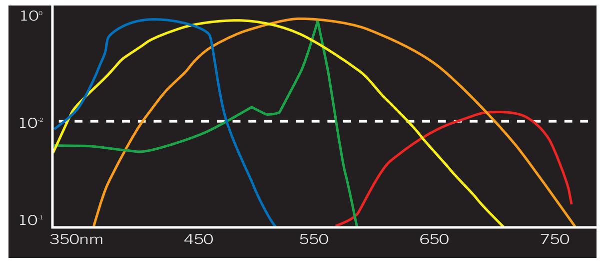




Exfo™

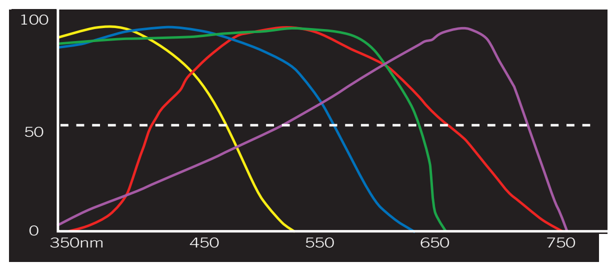


Detectors



Relative spectral response of the commonly used detectors: photopic human eye, scotopic human eye and color film.

- Yellow Dye
- Scotopic Eye Response
- Magenta Dye
- Photopic Eye Response
- Cyan Dye

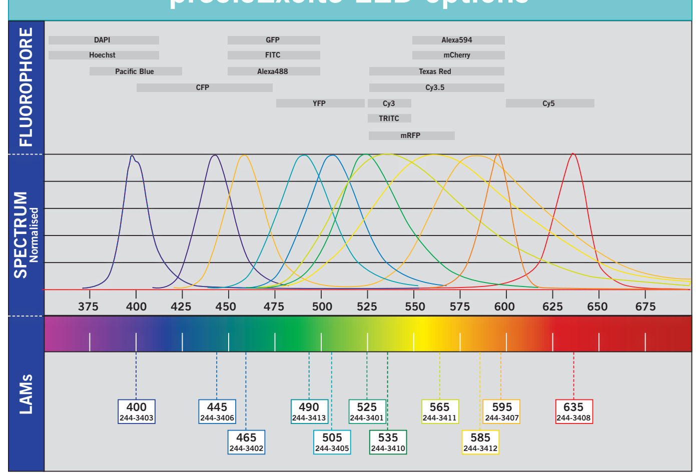


Normalized response of bi-alkali PMT detector, extended red PMT detector, silicon detector, S20 PMT and CCD.

- Bi-alkali PMT
- S20 PMT
- Extended Red PMT
- CCD
- Si Photodiode

LED

precisExcite LED options



GLOSSARY

A

- **Angle of Incidence (AOI):** The angle formed by an incident ray of light and an imaginary line perpendicular to the plane of the component's surface. When the ray is said to be "normal" to the surface, the angle is 0°.
- **Anti-Reflective Coating (AR):** An optical thin-film interference coating designed to minimize reflection that occurs when light travels from one medium into another, typically air and glass.

B

- **Bandpass:** The range (or band) of wavelengths passed by a wavelength-selective optic.
- **Bandpass Filter:** Transmits a band of color, the center of which is the center wavelength (CWL). The width of the band is indicated by the full width at half maximum transmission (FWHM), also known as the half band width (HBW). It attenuates the light of wavelengths both longer and shorter than the passband.
- **Bandwidth (HBW, FWHM):** Width of the passband: specifically, the difference between the two wavelengths at which the transmittance is half the peak value.
- **Blocking:** Attenuation of light, usually accomplished by reflection or absorption, outside the passband. Blocking requirements are specified by wavelength range and amount of attenuation.
- **Broadband AR Coating:** A coating designed to reduce reflectance over a very wide (broad) band of wavelengths.

C

- **Cavity:** Sometimes called "period". The basic component of a thin-film filter consists of two quarter-wave stack reflectors separated by a solid dielectric spacer. As the reflectivity of each of the quarter wave stack reflectors increases, the FWHM decreases; as the number of cavities increases, the depth of the blocking outside the passband increases and the shape of the passband becomes increasingly rectangular.
- **Center Wavelength (CWL):** The arithmetic center of the passband of a bandpass filter. It is not necessarily the same as the peak wavelength.
- **Clear Aperture (CA):** The central, useable area of a filter through which radiation can be transmitted.
- **Cut-on or Cut-off Slope:** A measure of the steepness of the transmittance curve x 100% where $\lambda_{80\%}$ and $\lambda_{5\%}$ correspond to 80% and 5% to absolute transmittance points.
- **Cut-on or Cut-off Wavelength (λ_c):** The cut-on is the wavelength of transition from attenuation to transmission, along a continuum of increasing wavelength. The cut-off is the wavelength of transition from transmission to reflection. The cut-on is the wavelength of transition from attenuation to transmission generally specified as the point at which the transition slope achieves 50% of peak transmission. The cut-off is the wavelength of transition from transmission to attenuation and again specified as the 50% point of peak transmission.

D

- **Dual Magnetron Reactive Sputtering:** A thin film coating method utilizing an energetic plasma in a controlled magnetic field and vacuum environment to precisely deposit alternating layers of high and low refractive index materials yielding a desired spectral response.

E

- **Evaporated Coating:** Precisely controlled thin layers of solid material(s) deposited on a substrate after vaporization under high-vacuum conditions.

F

- **Fabry-Perot Etalon:** A non-absorbing, multi reflecting device, similar in design to the Fabry-Perot interferometer, which serves as a multilayer, narrow bandpass filter.

H

- **Half Bandwidth (HBW):** The wavelength interval of the passband measured at the half power points (50% of peak transmittance). Expressed as half bandwidth (HBW), full width half maximum (FWHM) or half power bandwidth (HPBW).

I

- **Intensity Crosstalk:** Intensity crosstalk occurs between channels and is a result of non-ideal optical filtering, where light from neighboring channels can leak through and be detected along with the filtered signal of interest. When the leakage level of a neighboring channel is higher than the noise floor that is associated with the channel of interest, it becomes the dominant noise factor in the SNR. As a rule of thumb, the intensity crosstalk of neighboring channels must be at least 20 dB below the target signal level. This type of crosstalk can be dealt with by using a high quality optical filter to eliminate all unwanted signals outside of the target channel bandwidth.
- **Interference Filter:** An optical filter consisting of multiple layers of evaporated coatings on a substrate, whose spectral properties are the result of wavelength interference rather than absorption.
- **Ion-assisted Deposition:** A technique for improving the structure density of thin-film coatings by bombarding the growing film with accelerated ions of oxygen and argon. The kinetic energy then dissipates in the film, causing the condensed molecules to rearrange at greater density.

O

- **Optical Density (OD):** Units measuring transmission usually in blocking regions. Conversion: $-\log^1 T = OD$. For example, 1% transmission is .01 absolute, so $-\log^1 (0.01) = OD\ 2.0$.
- **Optimized Blocking:** To conserve the most energy in the transmission band by controlling only the out-of-band region of detector sensitivity.

P

- **Peak Transmission (Tpk):** The maximum percentage transmission within the passband.
- **Polarization:** At non-normal AOI, an interference filter's spectral performance in p-polarized light will differ from its performance in s-polarized light.
- **Protected Coatings:** The process by which two or more substrates, coated with thin film depositions, are assembled together using an index-matching optical epoxy.

Q

- **QMAX or QuantaMAX™:** Surface coated single substrate designs with steep edges, very high transmission and no registration shift.

R

- **Reflection (R):** The return of light from a surface with no change in its wavelength(s).

S

- **Signal to Noise Ratio (S/N):** The system ratio of the integrated energy within the passband envelope to the energy outside this envelope and within the free spectral range.
- **Slope:** The rate of transition from attenuation (defined as 5% of peak transmission) to transmission (defined as 80% of peak transmission). Slope = (lambda 0.80 - lambda 0.05) divided by lambda 0.05.
- **SP:** Shortpass filters transmit wavelengths shorter than the cut-off and reflect a range of wavelengths longer the cut-off.
- **Surface Quality:** Allowable cosmetic flaws in an optical surface by comparison to reference standards of quality; usually made up of two types of standards defining long defects (such as scratches) and round defects (such as digs & pits).
- **System Speed:** When filtering a converging rather than collimated beam of light, the spectrum results from the integration of the rays at all of the angles within the cone. The peak wavelength shifts about one-half the value that it would shift in collimated light at the cone's most off angle.

T

- **Temperature Effects:** The performance of an interference filter shifts with temperature changes due to the expansion and contraction of the coating materials.
- **Thin Film:** A thick layer of a substance deposited on an insulating base in a vacuum by a microelectronic process. Thin films are most commonly used for antireflection, achromatic beamsplitters, color filters, narrow passband filters, semitransparent mirrors, heat control filters, high reflectivity mirrors, polarizer's and reflection filters.
- **Transmission:** The fraction of energy incident upon the filter at any particular wavelength that passes through the filter. Expressed as either percent (95%) or a fraction of 1 (0.85).
- **Transmittance (T):** The guaranteed minimum value of the peak transmittance of the filter (not necessarily occurring at the centre wavelength).

FREQUENTLY ASKED QUESTIONS and ANSWERS

◗ Q: What's a safe Angle of Incidence (AOI) range for an interference filter?

A: AOI is a critical parameter to consider when purchasing an interference filter. The primary effect of an increase in the AOI on an interference coating is a shift in spectral performance toward shorter wavelengths. That is, the principle wavelength of the filter decreases as the AOI increases. A typical interference filter will exhibit only minor changes in performance with a tilt of up to 10°. However, for certain narrowband filters and transition edges of dichroics, this slight shift may cause dramatic performance changes. For advice on how tilt affects performance please call one of our engineers.

◗ Q: Would a dichroic have better reflection/transmission in S or P?

A: Simply put, reflection is better in S polarized light and transmission is better in P. This characteristic is most pronounced at the transition edge, where the dichroic is going from high reflection to high transmission.

◗ Q: Why are blocking specs so critical?

A: Most people know where their signal of interest lies, but sometimes do not consider potential sources of "noise". This "noise" could be autofluorescence from the sample, or the signal from another fluorophore, or even energy from their light source. Blocking is the feature of a filter that attenuates this unwanted energy and permits the energy from the signal of interest to pass through. Using filters designed to block unwanted signals can improve signal-to-noise and robustness of the data.

◗ Q: I want sharp edges, are the 3rd Millennium filters suitable?

A: 3RD Millenium filters are manufactured using Omega Optical's ALPHA technology , which produces very steep edges, capable of handling most application needs.

Standard 3RD Millenium filters utilize an ALPHA Gamma edge that has a 3% slope factor. This means that the filter's cut-on or cut-off edge will go from 50% peak height to OD 5 by the value: 50% peak height wavelength x (0.03).

3RD Millenium filters can also be manufactured with an ALPHA Epsilon edge. This filter has a 1% edge factor and thus will go from 50% peak height to OD 5 by the value: 50% peak height wavelength x (0.01).

◗ Q: Do my excitation and emission filters need to transmit at the peaks of a fluorophore's absorption/ emission probability curve?

A: Not necessarily. Although it is usually best to encompass as much of the probability peaks of a fluorophore as possible, sometimes other limiting factors preclude this solution. One example is a sample with multiple labels that have significant overlap of their emission peaks. In this case, moving the emission filter off the longer wavelength fluorophore's emission peak can improve signal discrimination.

◗ Q: How do I clean my filters?

A: If dust and debris are the primary contaminants, filters can usually be sufficiently cleaned by using dry air (such as a puff from a pipet bulb) or compressed air (not canned air). If the filters have oily substances that cannot be easily removed, either acetone or isopropanol can be used with a soft, lint free applicator, such as a Q-Tip or soft lens paper.

◗ Q: What does the arrow on the side of a filter indicate?

A: Omega Optical filters should be oriented with the arrow pointing in the direction of the light path. In other words, the arrow points away from the light source and towards the detector.

◗ Q: Can I use an excitation filter as an emission filter and vice versa?

A: Though generally not recommended, Omega's QuantaMAX™ product line is manufactured on single glass substrates with extended blocking on both excitation and emission filters, thus allowing for an excitation filter to be used as an emission filter, and vice versa.

Note: QuantaMAX™ fluorescence filters are designed to function optimally as part of a filter set. Using a specific filter outside of the intended set may provide acceptable, though not optimal, performance.

◗ Q: Can I use a dichroic from my microscope in a flow cytometer for the same dye?

A: Generally, no. Flow cytometers are designed to use dichroic beamsplitters which have different specifications than a fluorescence microscopy dichroic beamsplitter. When inquiring about a particular dichroic not sold as part of a filter set, you should always specify its desired application.

◗ Q: I'm using a filter set to image Cy5®, but I don't see any image on the screen and I know I have enough dye loaded. Is the filter working properly?

A: Probably, yes. Cy5® is a fluorophore which emits at the far end of the visible spectrum (peak at 670nm), this can make viewing it through the eyepiece of the microscope very difficult and typically a B/W CCD camera or PMT is needed to detect it. Many CCD cameras come with IR blocking filters housed in front of the chip and attenuate light from 650 nm upwards. This effectively blocks signal from Cy5® and similar dyes from reaching the detector. Consult your camera's manual to see if the filter can be switched off line or removed.

◗ Q: How thin can my filter be?

A: 1 mm (in limited cases 0.5 mm), and when reflection is not a requirement. Filter coatings can "bend" substrate materials, so the thinner the substrate, the greater the chance for bending, which will distort images.

CLEANING OPTICAL INTERFERENCE FILTERS

Omega Optical interference filters are manufactured using state of the art technology for robustness and durability. As with all optical filters, care should be given to proper handling and cleaning.

Directions:

1. Avoid depositing oil from your hands onto filters by using finger cots. Hold filters from the edges only. For smaller filters use tweezers to help with handling.
2. Blow loose dirt and particles from the surface of the filter using a puffer. Do not blow air from your mouth. Food and drink particles can be deposited.
3. Apply isopropyl alcohol to a lint-free cotton swab and rub the filters surface in a circular motion, working from the center to edge. Gently apply pressure. Avoid rapid side-to-side motions.
4. Use a puffer to evaporate excess alcohol from filter surfaces.
5. Repeat steps 3 & 4 above using a clean, lint-free cotton swab with each cleaning until all surface contamination is removed.
6. To complete the cleaning process wipe filter surfaces using lens paper gently applying pressure.
7. Return your filter to the original plastic case or envelope provided.

Note: We do not recommend the use of water, detergents or any other non-optical cleaning materials for this process.

For an Omega Optical cleaning kit that includes the materials necessary to properly clean interference filters, please purchase from our website.

ONLINE TOOLS

eCommerce

Order from our website: www.omegafilters.com

- ✓ Choose “Shop Products”. There is a large selection of overstock products at very reasonable prices.
- ✓ Search by selecting one or more options from the 5 major criteria, or search by Product SKU or Description.
- ✓ Click “Add to Cart” and check out using our secure online store.

Build-A-Filter

A unique tool for finding the right filter

buildafilter

- ✓ Select your instrument or filter type.
- ✓ We search our database of custom, semi-custom, and off-the-shelf filters. Pricing comparable to catalog filters.
- ✓ You will receive a response in less than 24 hours.
- ✓ Order online. We ship your filters in 5 business days or less (Dependant on specifications. Expedited shipment available upon request)

curvomatic

Curv-o-matic

for stock and standard filters

- ✓ Select a fluorophore or filter using Curv-o-matic, our interactive spectral database.
- ✓ Choose a filter or filter set.
- ✓ Order online.

GENERAL INFORMATION

Specifications

Unless indicated otherwise, our products are manufactured to our standard in-house specifications and tolerances. We reserve the right to modify or change without notice.

Customer supplied materials

We will handle all of customer supplied materials with the greatest care. Omega Optical accepts no liability for loss or damage to any materials furnished for processing.

Quotations

For a competitive quote, please contact us at **1.802.254.2690** (press 2 for sales) OR **sales@omegafilters.com**

Quotations are valid for a period of 90 days.

Pricing

We value our relationship with you, our customer. We will strive to produce the best product at the most competitive price and meet your critical need for performance, quality, and service. Please contact us to discuss.

Ordering

- **Order from our website: www.omegafilters.com**
- **Order by phone: 1.866.488.1064** (toll free within USA only) • **+1.802.254.2690** (outside USA)
- **Order by e-mail: sales@omegafilters.com**
- **Order from our agents:** Our extensive line of filters can be purchased directly from Omega Optical or from our worldwide network of agents. Please visit our website for a complete listing.

Payment terms

Terms are N30 and N45 with pre-established accounts. VISA, MASTERCARD, AMERICAN EXPRESS and PayPal are accepted.

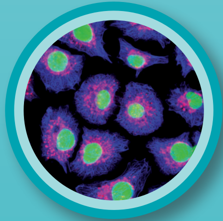
Shipments

All shipments are FOB Brattleboro Vermont USA. Shipping and handling charges will be invoiced or charged to your specified carrier account.

Warranty

All of the products listed in this catalog are backed by a warranty of satisfaction. It is important that our customers are pleased with every optical filter we ship. If at any time you are not 100%satisfied, please contact us.

Warranty does not cover obvious misuse of the product and is limited to repair or replacement of the product purchased. Omega Optical accepts no liability for consequential or incidental damage caused by use of the product.



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