TAMRON

Designing Lenses for Near-Infrared and Fluorescence Endoscopy

Fluorescence endoscopy is becoming increasingly important in many medical diagnostic tests. Based on the molecular absorption of light, this technique works by revealing tissue abnormalities that are hidden from view under normal white light. Already, fluorescence endoscopy can improve the endoscopic detection of non-visible malignant lesions or tumors, for example. Sensitizers, which accumulate in these lesions, induce tissue fluorescence in response to light of certain wavelengths. In the field of gastroenterology, this ability to reveal and visualize lesions holds promise for the early detection of dysplasia and cancers. Similarly, near-infrared (NIR) fluorescence rigid endoscopic imaging systems are emerging as a critical tool in some brain surgeries.

Fluorescence endoscopy, which is gaining ground in these and other medical applications compared to traditional white light endoscopic techniques, places some unique requirements on optical lenses. For example, a lens with the right combination of high resolution, anti-reflective coatings and minimal focus shift can enable better fluorescence imaging across the visible and NIR range, which includes wavelengths between 400 and 850 nanometers.

To explore this topic further, this white paper will discuss various lens design considerations, including optical filters and anti-reflective coatings, that can further optimize the performance of NIR fluorescence endoscopy in medical and life science applications.

Current NIR Fluorescence Imaging Applications

Compared to visible light fluorescence imaging, NIR fluorescence imaging exhibits superior tissue penetration and causes less autofluorescence in adjacent tissue. For these reasons, the technique is becoming increasingly important in many medical applications:

Cancer detection. Both nonspecific and specific cancer-targeted fluorescent agents are currently being used for in vivo cancer detection.

Lymphatic imaging. ICG, a blood flow tracer, can visualize lymphatic flow from cancer lesions. Separate visualizations of different lymphatic drainages are also possible using fluorescent agents with multiple colors.

Surgical guidance. NIR fluorescence imaging systems are playing a growing role in applications requiring surgical or endoscopic guidance.

Anti-Refractive Lens Coating Technologies

Recent advancements in coating and thin-filter optical technologies are finding more uses in the medical and life science industries and can optimize NIR fluorescence endoscopic techniques. One such advancement, called the Extended Bandwidth and Angular Dependency (eBAND) lens coating, deploys a nano-structured layer with an ultra-low refractive index, the dimensions of which are smaller than the wavelengths of visible light. This nano-structured layer, coupled with the sophisticated multi-layer coatings underneath, yields significant anti-reflection properties. By suppressing tangential reflection, this coating also reduces undesired flare and ghosting to deliver sharp, crisp images even in very poor lighting conditions.

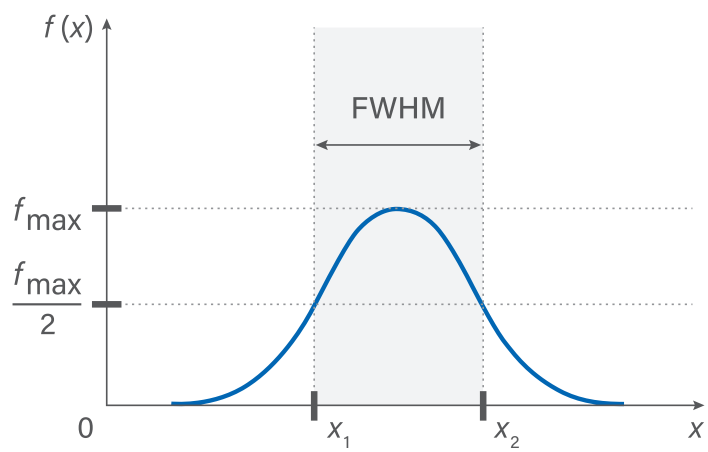
Compared to other anti-reflective coatings, eBAND is suitable for wavelengths from 400 to 1,700 nanometers, which includes the visible to near-infrared range. Thanks to this capability, eBAND enables deeper examinations using indocyanine green (ICG), a medical dye frequently used in tests that involve the heart and liver, as well as certain parts of the eye. Another coating technology is the Broad-Band Anti-Reflective (BBAR) coating. Like eBAND, this coating suppresses the surface reflections that lead to ghosting and flare to deliver clearer images.

High Optical Density

In addition to anti-reflective coatings, fluorescence endoscopy relies on lenses with highly precise optical filters, as well as lenses with a high optical density (OD). The purpose of these filters is to selectively transmit only certain wavelengths on the optical spectrum and reject others, while OD describes the amount of energy blocked by the filter. A high optical density indicates low energy transmission, while a low optical density indicates high transmission. Optical densities of six or greater are typically used in applications, like fluorescence endoscopy, that require extreme blocking.

In addition to high precision, fluorescence endoscopy requires optical filters that enable strict control of both the laser beam incident angle and Full Width at Half Maximum (FWHM) value. The laser beam incident angle indicates the degree at which a laser beam hits the filter, while FWHM measures the optical bandwidth of a light source. FWHM is the distance between the points on a curve at which the function reaches half its maximum value — in other words, the width of the curve's "bump." When applied to optics, it refers to the width of an optical signal at half its maximum intensity and provides the bandwidth of a light source operating at 50-percent capacity.

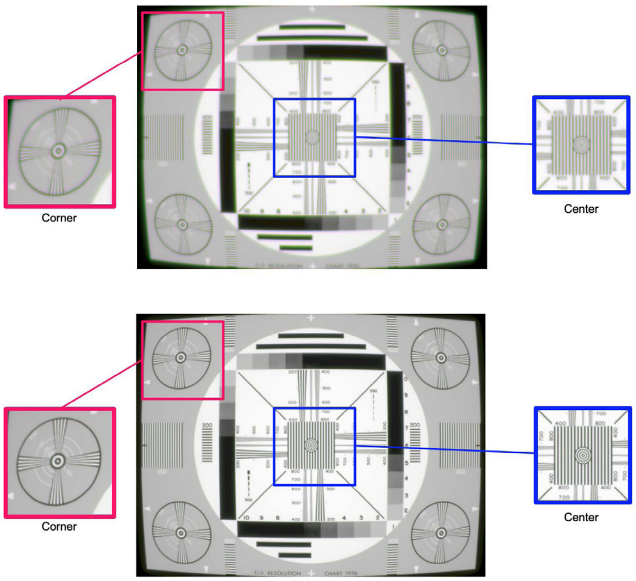
The ability to control both the laser beam incident angle and FWHM translates to highly precise, accurate control of a light source, enabling affected areas in fluorescence endoscopy procedures to be seen more clearly.



The Full Width at Half Maximum (FWHM).

Minimal Focus Shift

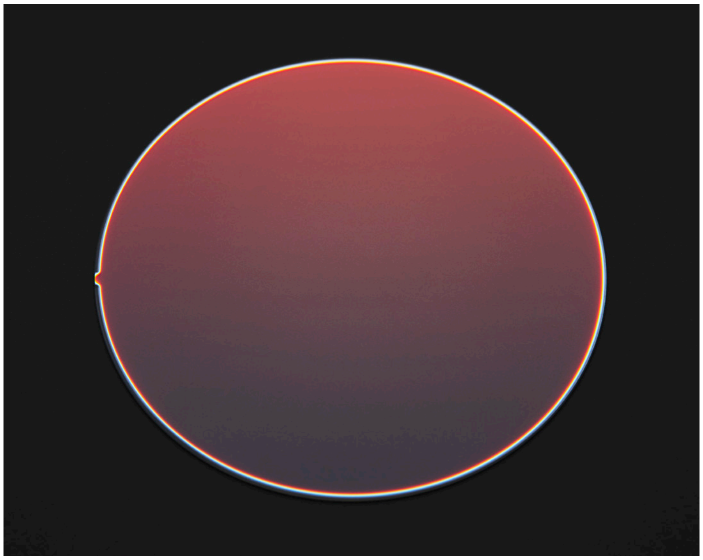
Lenses for fluorescence endoscopy should feature an optimized optical design that maintains image quality across a broad spectrum of wavelengths, all while minimizing the focus shift between the visible, near-infrared and even short-wave infrared ranges. For example, during testing, one Tamron lens eliminated the need to refocus between the visible light range and the NIR range (400 to 850 nanometers), as well as between the visible light range and the short-wave infrared range (400 to 1,700 nanometers). We are able to minimize the focus shift thanks to our optical design solution, which enables us to select the right materials and spherical and aspherical lenses to meet the demands of various markets.



Comparing the focus shift between conventional and Tamron lens designs across the visible and NIR light range.

Extra Low Dispersion Glass

In imaging, chromatic aberration occurs when a lens element refracts different wavelengths at slightly different angles, causing "color fringing" and reducing the sharpness of an image. Low dispersion (LD) lens elements, which are made out of a special optical glass with extremely low dispersion indices, can combat this effect. In other words, for this type of glass, the refraction of a ray of light into its rainbow colors is extremely narrow. As a result, these lens elements compensate for chromatic aberrations at the center of the field. They also compensate for lateral chromatic aberrations that can occur at short focal lengths toward the edges of the field.



OD6-level filters with low-film thickness.

Tamron Optical Technology

At Tamron, we produce spherical and aspherical lenses and optical assemblies to the highest level of precision with diameters from 1 to 300 millimeters. Our product range includes optical, spherical, aspherical, micro and cemented prism lenses with thicknesses up to 0.1 millimeter. Our optical technologies also achieve high transmission blocking levels, as well as tight wavelength control. Together, these qualities can block lasers and other light sources without sacrificing the quality of target signals. Other notable qualities of our optical technologies include:

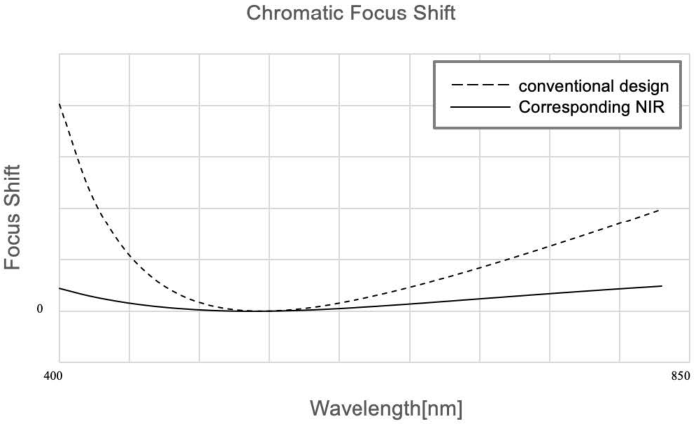
- OD6-level filters with low-film thicknesses
- Up to 99-percent transmission blocking
- High steep edges and low ripple effect
- Ideal for wavelengths up to 1,700 nanometers

In addition, we produce not only single lens elements, but the optical filters, mechanical tooling and production fixtures as well. And, we handle all optical design and mechanical simulation processes in-house, giving us precise, end-to-end control of lens quality and making us a cost-effective, one-stop shop for all optical technologies.

To learn more, please visit www.tamron-usa.com.

Optical lenses, spherical, aspherical, micro lens and micro multiple cemented prisms.

Similarly, anomalous dispersion (AD) optical glass offers even greater, more precise control of chromatic aberrations to enhance overall imaging performance. This type of glass provides an abnormally large partial dispersion ratio for specific wavelengths within the visible spectrum. Thus, combining AD glass with normal glass makes it possible to control the dispersion factors of specific wavelengths. Optical lenses used in fluorescence endoscopy should avoid chromatic aberrations, maintaining focus shift consistency across extended wavelengths.



Comparing chromatic focus shifts between Tamron and conventional lens designs across visible and NIR ranges.

The Modulation Transfer Function

Modulation transfer function (MTF) is a reference value that enables optical designers to quantify the overall imaging performance of a system in terms of its resolution and contrast. Designers often refer to MTF data in applications like fluorescence endoscopy that depend on imaging accuracy for success. Although a helpful value to know, MTF does not always reflect the real-world performance of the lens. Nonetheless, understanding the MTF curves of the lens and other parts within an optical system allows designers to select and optimize the components for a particular resolution. To this end, one of our strengths at Tamron is our ability to manufacture optical products with real-world values that very closely resemble their design values.

To learn more, please visit www.tamron-usa.com.

Certificated at Tamron Head Office and Aomori Factory Hirosaki site, Aomori Factory Namioka site, JAPAN

Detailed scope of certification: Design and manufacture of lens parts for endoscope.