Lower-Cost And Faster Time-To-Market MWIR Equipment – The Right Optical Filter Is Key

Source: Iridian Spectral Technologies
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Utilization of midwave, infrared (MWIR) light is critical in many areas, including thermal monitoring of equipment and homes; military enhanced-vision systems for imaging vehicles, people, and terrain; industrial process monitoring and control; and environmental sensing and detection of gases. Even diagnosis of pregnancy in dairy cows can be carried out using light in the MWIR range.

As in many types of infrared (IR) optical system, optical filters are critical to MWIR hardware success. They enable the transmission of the desired signal wavelengths and blockage of other extraneous wavelengths providing more signal with less background to the applications employing them. It is important to identify the ideal filter performance to provide the simplest filter solution needed to meet the application requirement without requesting more stringent filter specifications than necessary. It helps to consider what function truly needs to be provided by the filter and what functions other parts of the optical system may already fulfill. If this approach is not used, filter designs often become more difficult to implement, take longer to bring to market, and involve unnecessarily greater expense.

By obtaining informed advice at the outset and making some easily accommodated changes to the design process, while focusing on the functionality that the filter needs to provide, companies can save time and money while achieving their goals.

MWIR Filters

MWIR optical filters operate in the wavelength range from 3 to 6 microns. The filters comprise substrates coated with robust multi-layer thin film structures that transmit desired IR wavelengths while blocking others. MWIR filters are typically bandpass or edge pass filters whose wavelength selectivity improves the signal-to-noise ratio for the detectors in an MWIR imaging or detection system.

A filter enables an application to receive the signal wavelengths it needs to correctly operate while blocking out background wavelengths that degrade signal-to-noise ratio. Critical performance characteristics that affect the filter's ability to provide what the application needs include surface quality, transmitted and blocked wavelengths, and ability to retain these characteristics under the application's operating conditions. To tightly control filter characteristics, manufacturers must correctly match filter specifications and manufacture to the functional specifications of the application design.

Surface quality

Surface quality and the influence of defects can affect image quality. Sometimes the impact of defects is less important, such as in a sensing application that only needs to measure the amount of a specific band of MWIR light present or absent. Occasionally the impact is more important. In an imaging application that renders a MWIR scene into an image visible to the human eye, defects might matter more because the quality of the image itself is critical.

However, designers often, out of habit or assumption, apply surface quality specifications that are more stringent than necessary. MWIR wavelengths are much longer than those in the visible light spectrum. Effectively, defects that might be visible to the naked eye in ambient lighting would be invisible under MWIR light, where the wavelengths are too long to resolve the defects. Even when the application involves imaging, surface quality is often over-specified due to specifications inherited from the more familiar visible wavelength range. When filter surface quality is over-specified, yields can drop significantly, driving up the cost of the final filters.

Transmission characteristics

The wavelengths the filter transmits and blocks are at the heart of its intended function. Depending on the application design, bandpass filters might be needed to transmit a band of contiguous wavelengths within the MWIR range. Other applications could require longwave (transmitting light above a specified wavelength) or shortwave (transmitting light below a specified wavelength) filtering, multi-band filters transmitting more than one spectral region, or notch filters blocking a specific wavelength region within a broad transmission band.

However, as the wavelength range narrows, the amount of transmitted light drops. Manufacturers frequently must balance the specific wavelength transmission bands of the filter with the total amount of IR energy that will travel through the filter to satisfy a given design. A sensor, for example, needs to receive a certain amount of energy to react. If the filter cannot transmit enough IR energy to meet the specifications of the sensor, the design will not work.

Restricting the breadth of the transmission band, while providing more wavelength selectivity, also reduces the total potential light that can pass through sometimes compromising the functionality of the detector. Conversely a filter that is much wider than the functional wavelength region of interest may allow MWIR background light into the detector, degrading the signal-to-noise ratio. It is a delicate balance that must be struck.

Environmental factors

Filters must also work within the application environment. A coating that is stable at temperatures or humidity levels in a manufacturing facility might perform differently in the conditions of actual use.

Filter construction

The choice of production method to coat filters has a major influence on the ability to control the filter performance. The most common approach for coating MWIR filters is evaporation. In this process, the coating material is heated to a vapor state and then allowed to condense on the substrate. An alternate approach, which Iridian employs, is energetic sputtering. Although this technology is common in other wavelength ranges such as within the visible or near-infrared (NIR), it has been used less often to address needs in the MWIR range due to the necessity to use coating materials that transmit in the MWIR. Sputtering offers some strong advantages over evaporation. The resultant filters are environmentally robust, and manufacturers can apply high degrees of control over final spectral characteristics.

Common filter issues

Beyond trade-offs in performance characteristics, design choices can have unintended consequences. Although MWIR filters are common in multiple industries, even experienced designers can create unnecessary manufacturing challenges with their designs and filter specifications.

At a high level, designers may think more like scientists than engineers. They consider what would be perfect in theory and forget that real-world conditions might be tolerant of less-than-perfect choices. The result can be overly tight specifications and unnecessary costs. Additionally, filter characteristics tend to be requested rather than the functionality that the filters are intended to provide.

For example, designers often ask for a tight defect specification on the filter surface. If an application involves sensing and not full imaging, the surface quality specification may be unwarranted if enough IR light can still fall on the detector and the signal-to-noise ratio is not compromised. The right design depends on the application and its required functionality. In an imaging system for military use, where someone will have to discern and react to objects on a display, the integrity of the image may be more important. In many other applications, such as MWIR gas sensing, it may not matter.

Another way lack of communication at the design stage can create issues is through the assumption that specifying and requesting a large filter to be delivered and then subsequently cutting this into multiple smaller filters is less expensive than requesting filters of the correct final size. This can result in undue requirements for uniform performance on a large part and can be a substantial cost driver. While correctly sizing filters for the device design during the manufacturing process does add processing costs, these costs can be substantially less than the costs associated with yielding fully compliant larger parts. Even with custom processing, the total cost is usually significantly lower.

Other aspects of the system hardware can have implications for filter design and requirements. An IR detector has a specific range over which it operates. Light that falls outside that range will not register on the detector. Such limitations often become a positive feature in the filter design. If, for example, the detector will not respond to wavelengths below 2 microns, it is a waste of money to engineer the filter so it blocks anything below 2 microns.

Considering the filter early in the design process can result in redesigned optical path layouts that can greatly influence the complexity, cost, and achievable performance of the filter. Modifying the size and placement of the filter within the optical path, and in some cases reengineering the placement of detectors and thus the beam path, can affect the entire industrial design and also how the device operates. A shift in detection techniques can sometimes result in a more effective final product.

Understanding the actual functional needs and working with a filter manufacturer to design filter solutions that balance both technical and commercial requirements can head off issues that can arise in filter manufacturing. The manufacturing process can positively or negatively affect the difficulty of filling design specifications and also have a large impact on the turnaround time on custom designs. Iridian has a typical turnaround time from order to delivered of MWIR filters of six to eight weeks. Filter manufacturers that do not work closely with system designers and fail to consider complexities of manufacturing can encounter unexpected delays in completing a successful filter build. The result can delay an entire project, in some cases by many months, increasing time to market.

Filter design solutions

Small changes or additions to the design process can help eliminate many of these issues.

Optical systems designers should consider filter requirements as early in the design process as possible. The hardware should not be an amalgam of black boxes that operate independently. Use a systems-engineering approach to consider how the interactions of separate elements affect the entire project. There may be advantages to gain, like using a detector's specifications to help limit the wavelengths the filter must block.

Next, consider alternative application designs. A modification of layout, a different detector, or another change can improve performance and lower costs.

Most importantly, look at a filter vendor as a collaborator and partner, and start consultations at the onset of the design process. Experts in filter design and manufacture can raise important questions based on past experience and knowledge of what filters can and cannot do. It is better to head off issues before they arise, thus saving time and money.

Any design will still have its own challenges. But elimination of the unnecessary ones frees resources to focus on those that remain.