APPLICATION NOTE

SWIR & NIR IMAGING IN AERIAL ELECTRO-OPTICAL SYSTEMS (EOS)

SWIR & NIR 25 – 250mm CONTINUOUS ZOOM LENS

INTRODUCTION

There is a debate as to whether innovative technology drives strategic operations or whether evolutionary operations drive strategic technological advances. Both are likely true and can be seen clearly in the use of short-wave infrared (SWIR) sensors in Aerial Electro-Optic Systems.

Image 1: unmanned aerial vehicle equipped with an EO system

Aerial EOS demands versatile optics capable of operating across the full range of operational wavelengths. Recent battlefield experiences are driving these systems to be much more comprehensive while requiring smaller payloads to maximize on-mission duration. From applications for high-speed and surveillance aircraft to large and small UAVs, these systems must navigate through challenging environments including poor visibility and detect, as well as decode, laser-pointers in the field.

SWIR sensors (typically defined in the 0.9-1.7mm wavelength regime) provide complementary capabilities to thermal (MWIR/LWIR) systems by excelling in low-light conditions while offering the ability to capture images during daylight as well. Moreover, SWIR has also emerged as a powerful tool for laser applications and it offers a range of unique characteristics that have opened up new possibilities in advanced Aerial EOS products.

PROBLEM

Aerial EO systems have historically included two imaging channels: visible and thermal. Using either MWIR or LWIR thermal sensors with small, light optics becomes easier with the introduction of smaller pixel size with larger sensor arrays. The visible channel often includes a near-infrared (NIR) capability that is inherent in the silicon arrays these systems employ. With use in actual scenarios, users define several areas where those two channels proved inadequate. SWIR became the answer to cover these applications. As with the earlier systems, technology companies had to develop, design and produce imaging systems to meet the challenges. While sensor technology improved with better efficiency, larger arrays and smaller pixel size, the optics were still a challenge with few options to integrate that met the unique mission requirements. Ophir has developed the 25 – 250mm continuous zoom lens to answer the need for small pixel detectors with advantages that contribute to improved EOS accuracy, precision, and efficiency, especially in applications where visibility may be limited.

Image 2: Helicopter equipped in its front with EO system. Credit: U. S. Navy Mass Communications Specialist 3rd class James Vasquez

There are six areas where the SWIR & NIR energy band has distinct advantages over visible and thermal imagers:

- Penetration of atmospheric obscurants
- Thermal interference resilience (thermal crossover)
- Use of natural ambient light
- Long-range daytime observation
- Glass transmission
- See-spot solutions for laser designators

Penetration of atmospheric obscurants

SWIR is a crucial element of aerial imaging with its inherent ability to penetrate haze, smoke, and maritime fog. The use of SWIR & NIR in aerial EOS allows for greatly improved visibility even in challenging conditions. The Ophir SWIR & NIR 25 – 250 mm continuous zoom lens provides the image clarity to cut through obscurants.

Thermal interference resilience

Thermal imagers rely on emitted energy and can experience difficulty imaging when background and target of interest become close in temperature. This term is referred to as thermal crossover. The addition of SWIR technology that uses reflected energy, it allows for improved contrast in challenging situation where aerial EOS operate in dynamic thermal environments. The Ophir SWIR & NIR 25 – 250 mm continuous zoom lens provides the image clarity to cut through obscurants.

Use of natural ambient light

SWIR sensors harness natural ambient light sources like sunlight, moonlight and man-made lighting, enabling reflected light image capture during daylight and low-light operations. Reflected light imaging when compared to emitted light imaging is key to human and artificial intelligence (AI) enhanced interpretation of the imagery. Many current uses of aerial EOS require positive identification as part of the rules of engagement. The Ophir SWIR & NIR 25 – 250 mm continuous zoom lens allows for reliable performance across diverse operational needs.

Image 3: Visible vs. SWIR imagery takensimultaneously.

Long-Range daytime observation

The SWIR wavelength proves invaluable for long-range day observation tasks. Unlike MWIR and LWIR regions, SWIR radiation is scattered from scene objects, akin to the visible (VIS) region. This makes SWIR particularly suitable for daytime observation, or when starlight and moonlight are significant factors. Additionally, SWIR wavelengths can penetrate through fog and water vapor, making it indispensable for operations in poor weather conditions when compared to even the best visible light imagery.

Image 4: (top to bottom) 25mm WFOV image scenery; 250mm NFOV image scenery approximately 1km distance.

Long-Range daytime observation

Unlike the MWIR and LWIR bands, SWIR wavelengths transmit through glass. This capability makes SWIR especially pertinent for specific surveillance applications. The Ophir SWIR 25 – 250 mm continuous zoom lens is particularly well suited to take advantage of this capability in aerial EOS missions.

See-spot solutions for laser designators

SWIR imagers with extended wavelength regime operate from the NIR to SWIR wavelengths (0.7 – 1.7µm). This allows them to image lasers commonly used in current military operations in the NIR wavelengths (850, 905, 1064, and 1550nm). The Ophir SWIR & NIR 25 – 250mm continuous zoom lens is best suited to take advantage of this capability and provide clear and accurate imaging of these lasers.

SOLUTION

The Ophir SWIR & NIR lens 25–250mm f/5.5 (NOFV) f/4 (WFOV) is a game-changing continuous zoom lens in a low SWaP package, engineered to seamlessly integrate with multiple SWIR sensors with pixel pitches of 5µm, 10µm, and 15µm, and array sizes of up to 1280 x 1024 (5µm and 10µm).

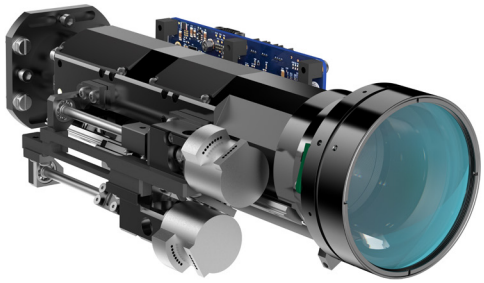


Image 5: Ophir SWIR & NIR 25-250mm

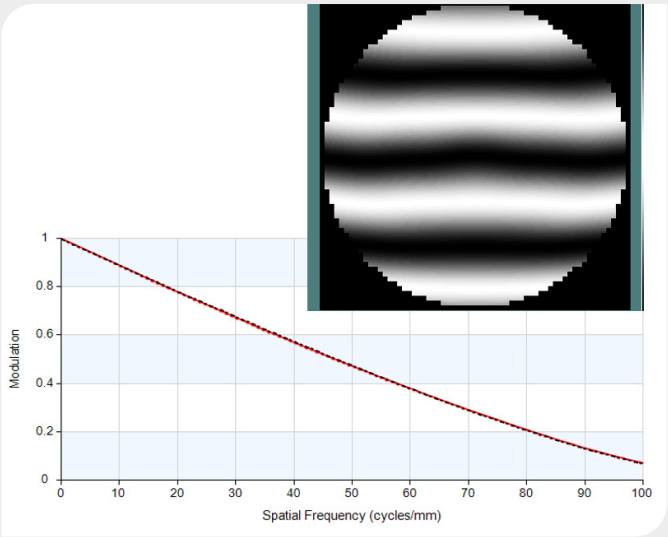
The Ophir SWIR & NIR zoom lens key features:

1. Optical Flexibility

This apochromatic lens redefines optical flexibility, offering maximum capability in a minimal package. This attribute proves indispensable for compact gimbal designs, ensuring superior performance in diverse operational scenarios. Additionally, using advanced algorithms, system designers can integrate the images captured with the Ophir lens into seamless multi-spectral content.

2. Optical Performance

MTF testing shows near diffraction limited performance in narrow field-of-view (FOV) for all field positions especially with SXGA 5µm detectors and extremely low distortion at all zoom positions. As with all of its lens designs, Ophir has conducted exhaustive testing of the lens to ensure that field performance meets all design criteria.



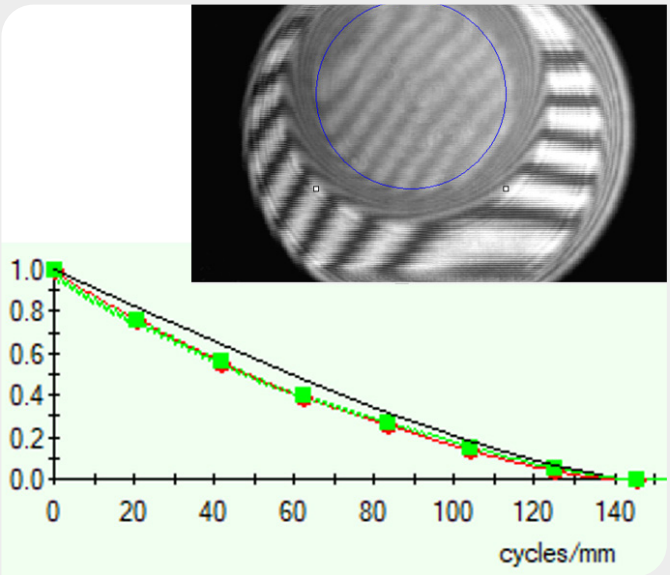


Figure 1 (top to bottom): theoretical (black) and measured (green – sag., red – tang.) MTF at NFoV (250mm EFL) vs. spatial frequency (cycles / mm) for light at 1.52µm and on-axis. Figures at the top right corners represents theoretical (top) and measured (bottom) wavefront distortion.

3. Broad Spectral Band Coverage

With a spectral range spanning from 700 to 1700 nm, this lens encompasses a wide-band NIR to SWIR range. This extensive coverage supports various sub-bands, guaranteeing compliance with a multitude of applications, including those necessitating “see spot” solutions for laser designators.

4. Low SWaP Design

Weighing a mere 860 grams and measuring just 224 mm in length, this lens defines new standards for lightweight, compact design. This characteristic makes it exceptionally well-suited for compact system designs, contributing to extended operational endurance and mission effectiveness.

5. Chromatic Correction

Achieving high-quality imaging across a broad spectrum presents challenges in chromatic correction. SWIR regions offer fewer available optical glass types compared to the VIS region, rendering chromatic aberration correction more demanding. Extensive glass selection work, along with the strategic placement of doublets, culminated in a well-corrected apochromatic behavior across the entire zoom range.

CONCLUSION

The SWIR & NIR 25-250mm continuous zoom lens represents a paradigm shift in long-range detection and integration within small airborne systems. Its superior performance ensures clear and precise imaging in all weather conditions. By designing in low SWaP characteristics, it perfectly aligns with the needs of compact gimbal designs integrated into UAVs, aircraft, or any other low SWaP application. The lens‘s apochromatic design, continuous zoom capability, and compatibility with various pixel pitches makes it the clear choice for high-performance SWIR imaging systems. Ophir‘s legacy of delivering quality optical solutions is exemplified by the 25 – 250 mm SWIR & NIR lens with new standard for versatility and performance in aerial EO applications.

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