Application Note

IR Zoom Lenses for Long-Range Security and Surveillance Applications

BACKGROUND In the security and surveillance markets, long range, infrared (IR) imaging plays an increasingly important role for monitoring, tracking, and targeting. The worldwide market for IR systems for commercial and dual-use security and surveillance applications is estimated to grow rapidly and reach a total of $243 million dollars by 2025,[1] with a CAGR of 6.1% (2019-2025).

Harnessing the technologies of IR imaging, long-range IR cameras can capture imagery of people and vehicles at extreme ranges vital to today's long-range security and surveillance challenges. These IR cameras must be equipped with high performance IR lenses that can effectively capture the emitted IR radiation and focus it onto a detector array.

The production of optical components, such as IR lenses, for long-range security and surveillance, has been influenced by the following recent market trends:

Fig. 1. IR Imaging in Security and Surveillance cameras

- **Development of optics-limited IR systems** advances have led to sensors with smaller pixels, increased camera resolution and high definition format, resulting in requirements for optics-limited IR systems with advanced, high-precision IR optical components and lens assemblies.
- **Growing use of UAVs and drones for security and surveillance**
  UAVs and drones have strict SWaP (size, weight and power) restraints, necessitating new, innovative opto-mechanical designs.
- **Demand for multi-spectral capabilities**
  An increased demand for systems with multi-spectral capabilities, covering SWIR+MWIR, MWIR+LWIR, as well as VIS and NIR bands, leads to new specifications for IR components and assemblies.
- **Constant operation in a wide range of environmental conditions**
  Security and surveillance missions are carried out both day and night, and under harsh visibility conditions such as rain or fog. Therefore, optical components must be durable, and retain high performance in all environmental conditions.

PROBLEM In light of the aforementioned trends, optical manufacturers are tasked with the challenge of producing optical components that provide high performance capabilities within the constraints and demands of a modern security and surveillance imaging system.

The following key considerations should be addressed for this purpose:

- Detection, Recognition and Identification (DRI) requirements with long range capabilities
- Camera's choice of sensor, either uncooled LWIR or cooled MWIR
- Detector resolution and type
- Focal length and F#
- Size and weight limitations (SWaP constraints, especially relevant for UAV and drone systems)
- Modulation Transfer Function (MTF) requirements for optical performance
- Environmental requirements

To take these considerations into account, Ophir uses new innovative designs and manufacturing technologies.

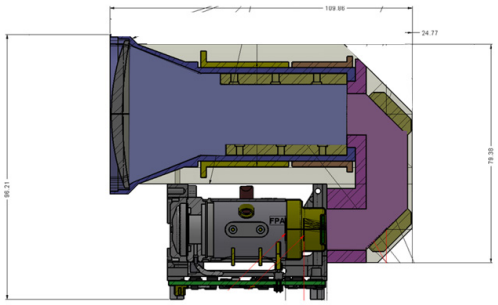

Fig. 2. Folded optics zoom lens design

SOLUTION Ophir uses the following approaches to create IR optics that meet the rigorous challenges of long-range security and surveillance systems:

Continuous zoom lens design

A continuous zoom lens design allows high performance with reduced size and weight, as it contains just one zoom lens, compared to multiple, single FOV lenses. For security and surveillance mission flexibility, operators can easily change the magnification during operation.

Innovative optical design

- Advanced IR materials allow for a reduction in the number of elements, which addresses athermalization, achromatization, size, and weight considerations.
- Folded optics designs also allow a reduction in size and weight (see fig.2).
- Diffraction-limited designs allow for the highest performance possible.

Innovative mechanical design

Mechanical design ensures durability in harsh environmental conditions, as well as high accuracy and stability in varying operational situations, utilizing the following components:

- High-precision, high-grade mechanical components
- High accuracy and stability ground and hard-coated parts
- Advanced materials to ensure athermalization and low-SWaP design
- Durability to harsh environmental conditions

Ophir optimizes lens assemblies for weight and rigidity to withstand shock and vibration. Engineers design and test moving parts for long life without maintenance in extreme environmental conditions. Lens assemblies meet or exceed IP67 environmental standard.

Advanced production capabilities

With cutting-edge, in-house capabilities for **component production**, components can be made in many shapes and materials, suited to their specific application. Moreover, large optics with high precision are crucial for obtaining small fields of view (FOV) and our advanced high-end lens production capabilities is one of the key contributors to addressing the challenges.

Optical coatings are also vital for optical performance. Ophir uses high durability (HD) and low reflection hard carbon (LRHC) AR coatings to maximize both performance and toughness for operability in extreme environmental conditions. These coatings are suitable for multispectral applications as well.

Product Capabilities

Ophir offers a broad range of products for security and surveillance applications with the following key characteristics, meeting the application's demands:

- Maintaining boresight through the full zoom range
- Maintaining fixed F# through the full zoom range
- Maintaining focus through the full zoom range
- Operating in low temperatures and harsh environmental conditions
- Maintaining high image quality
- Providing fast FOV change with continuous optical zoom position adjustability
- Providing compatibility with major MWIR & LWIR detectors

To demonstrate our capabilities, we present the following three long EFL zoom lenses that provide state-of-the-art capabilities for long-range security & surveillance applications:

Fig. 3. Ophir's longest FL's long-range continuous zoom lenses. L > R: The SupIR 28-850mm f/5.5, SupIR 45-900mm f/4.0, and SupIR 50-1350mm f/5.5

SupIR® 28-850mm f/5.5

The main features of this lens are:

- MWIR spectral range – 3µ to 5µ wavelength
- Compatible with High Definition detector format (1280 x1024) with 15µ pixel pitch
- 30x zoom ratio
- Folded design
- Tight boresight retention
- Extremely long operational range (over 20 km detection, see figure 7 for details)

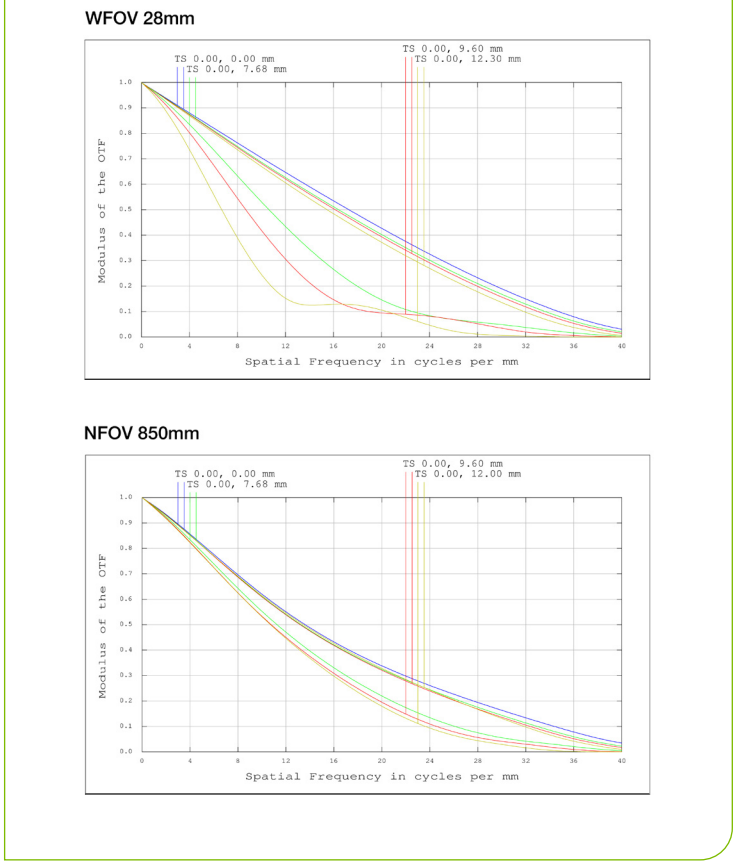

Fig. 4. SupIR 28-850mm f/5.5 MFT performance

Fig. 4 describes the MTF charts of this lens at both NFOV and WFOV. These charts show the Sagittal (S) and Tangential (T) components of the MTF as a function of the spatial frequency at different field positions across the

focal plane for both WFOV and NFOV. As can be seen, the Sagittal MTF at both the WFOV and NFOV is close to the diffraction limit over the whole focal plane, while the Tangential component is lower, especially at the WFOV.

SupIR® 45-900mm f/4

This lens is a combination of the 15-300mm f/4 lens and a 3x optical extender. Together they form a zoom lens with a long EFL of 900mm, a 20x zoom ratio, and fixed F# of 4 along the entire zoom range.

Fig. 5 describes the MTF charts of this lens at both NFOV and WFOV. For this lens, both Sagittal and Tangential MTF components are close to the diffraction limit at both the WFOV and NFOV with some degradation towards the focal plane corners.

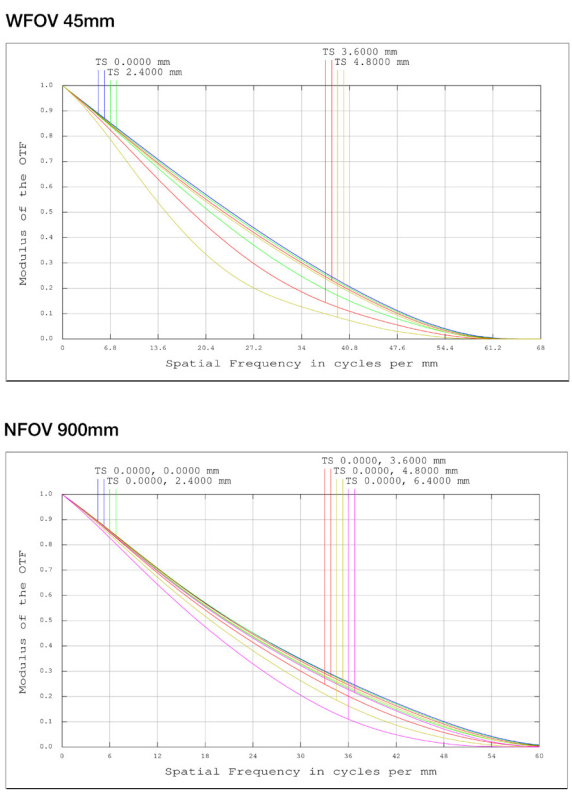

Fig. 5. SupIR 45-900mm f/4 MFT performance

SupIR® 50-1350mm f/5.5

The third lens in this family is the 50-1350mm f/5.5 zoom lens, which is based on the 28-850mm lens with an extender. Similar to the 28-850mm zoom lens, this product supports the SXGA 1280 x 1024, 15µ FPA format, with close to diffraction limit performance. Being the longest focal length lens currently available in our portfolio, this product fits the most demanding requirements of long-range thermal imaging optics for aerial & surveillance applications, with detection ranges of **more than 26km**.

Fig. 6 presents the MTF graphs of the 50-1350mm f/5.5 lens at both NFOV and WFOV. Its MTF performance follows to the 28-850mm zoom lens from which it is composed. Consequently, the Sagittal MTF at both the WFOV and NFOV is close to the diffraction limit over the whole focal plane, while the Tangential component is lower.

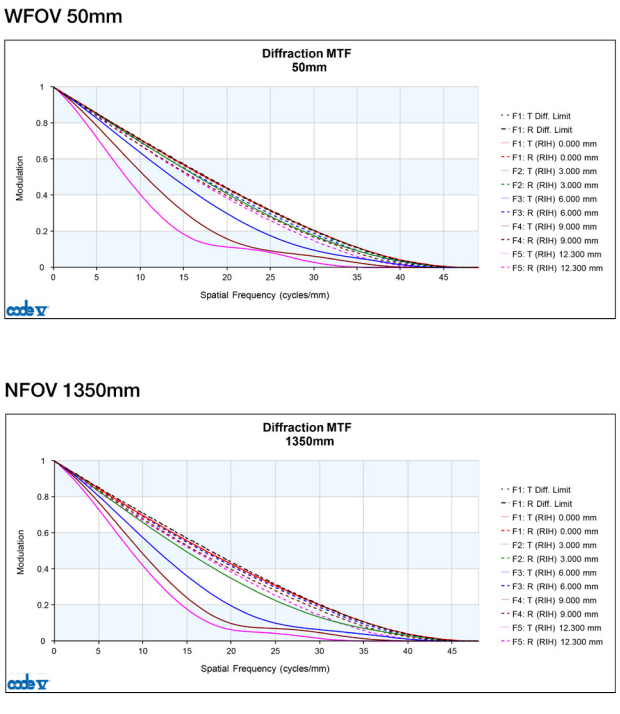

Fig. 6. SupIR 50-1350mm f/5.5 MTF performance

The DRI performance values for these lenses are described in figure 7, where the ranges reach up to an impressive >26km, achieved by the SupIR 50-1350mm f/5.5. We calculated the DRI ranges by using the U.S Army Night Vision Lab's FLIR92 model, assuming a value of 0.2 km-1 for the atmospheric attenuation coefficient. The long DRI values are obtained thanks to the long EFL values and the high NFOV MTF values, as shown in figures 4-6.

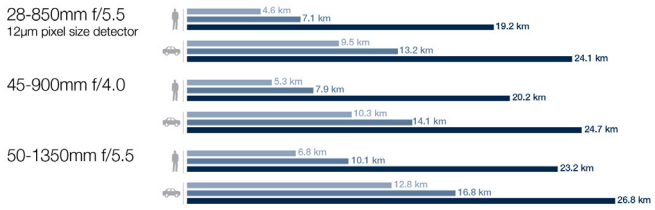

Fig. 7. Detection, recognition, identification ranges for each of the lenses.

CONCLUSION

Optical, mechanical and zoom designs for configurations and components are key to ensuring high performance for small pixel sensors and long-range detection optical systems.

When it comes to constrained platforms, such as UAVs and drones, lightweight designs with high optical performance over the entire zoom range are a must.

For high resolution imaging in harsh environmental conditions, lenses must be manufactured with the longest focal length and zoom ratio capabilities, as well as with high durability coatings to ensure continued performance and an extended product lifetime.

Using this unparalleled combination of the latest designs and production capabilities, Ophir is ready to meet the needs of next-generation, long-range thermal imaging applications in the security and surveillance market with high image quality, high resolution, continuous zoom, and long-range operational distances in harsh environmental conditions.

REFERENCES

1. Maxtech International Inc.: "The world market for commercial and dual use infrared imaging and infrared thermometry equipment", 2020.

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