Advanced IR Zoom Lenses for Next Generation Thermal Imaging Applications

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Abstract: In this paper we review recent advances in the development of infrared zoom lenses that meet challenging requirements for reduced Size, Weight, and Power (SWaP) while enabling high-resolution vision and identification in harsh environmental conditions and constrained platforms such as airborne and portable systems. The design considerations and performance of advanced folded-optics and lightweight zoom lenses optimized for next generation infrared thermal imaging systems and applications are described.

1. INTRODUCTION

Infrared imaging applications are evolving at a rapid pace and continue to drive challenging requirements for reduced Size, Weight, and Power (SWaP). In particular, applications like Hand Held Thermal Imagers (HHTI), UAV, and small gimbals present a growing need for advanced, high-performance, IR thermal imaging systems with reduced size and weight. While advances in detector resolution should improve imaging performance, this is impossible without an accompanying improvement in the quality of the IR optical lens assembly. Specifically, in optics-limited systems, lens quality is playing a major role in determining the imaging performance, even with the best detector. The challenge falls on lens providers to design and produce compact, lightweight lenses with a crisp clean image over the entire zoom range and an MTF close to the diffraction limit. In this vein, various technologies are being used to meet these optical needs, including innovative opto-mechanical designs[1], exotic materials[2,3], and free-form optics[4]. In this paper we demonstrate advanced designs of two continuous IR zoom lenses with reduced SWaP based on unique folded-optic and lightweight opto-mechanical concepts, respectively, suitable for next generation IR cooled detector and thermal imaging applications with constrained platforms.

2. CONTINUOUS ZOOM LENS SWAP DESIGNS

Two examples of SWaP zoom lenses for cooled MWIR IR sensors are described. The first is a 16-180mm f/3.6 continuous zoom lens in a folded-optic configuration suitable for compact gimbaled payloads with 10µm pixel cooled detectors. The second SWaP example is a 20-275mm f/5.5 continuous zoom lens with a unique light-weight opto-mechanical design suitable for UAVs, drones, and HHTI applications.

2.1. Folded-Optic 16-180mm f/3.6 Zoom Lens Design

Figures 1(a) demonstrates the opto-mechanical layout and picture of the 16-180mm f/3.6 zoom lens optimized for MWIR 10µm pixel detectors. The design is based on a standard relay and objective configuration with two moving groups that allow for the change in the focal length. The materials were selected using best practices, as well as the athermalization and achromatization concepts.

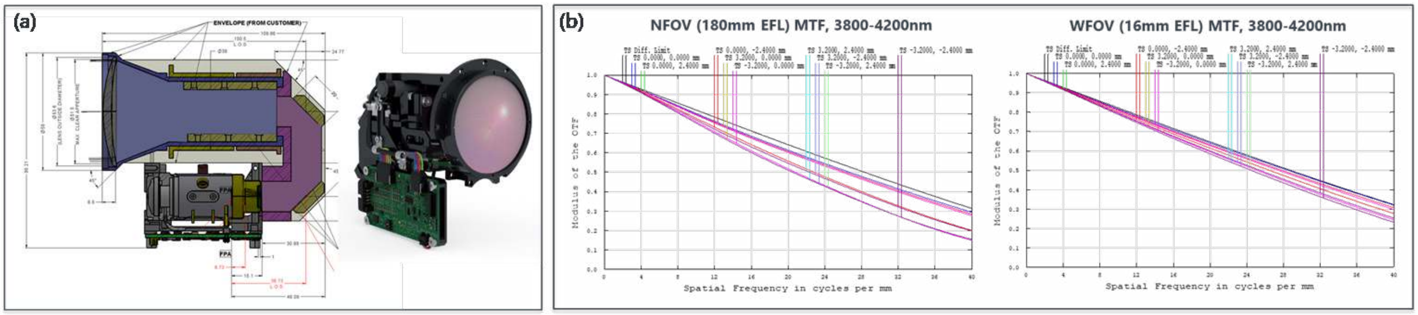

Fig. 1. Folded-optic 16-180mm f/3.6 zoom lens – (a) Opto-mechanical layout and picture, (b) MTF characteristics

The folded-optic design was implemented with long optical lengths for reduced sensitivity to tolerances in a compact configuration while addressing the various challenges of such a concept, including line-of-sight (LOS) stabilization and reduced number of optical elements based our capabilities for producing aspheric and diffractive surfaces with exceptional levels of accuracy and quality.

Figure 1(b) shows the MTF results as a function of spatial frequency of the 16-180mm folded design for the WFOV and NFOV, illustrating the capabilities of the design to obtain near diffraction limit performance. As can be seen, the high MTF performance of this design is maintained across the entire field and, even at the corners, the performance is more than reasonable.

2.2. Lightweight 20-275mm f/5.5 Zoom Lens Design

The 20-275mm f/5.5 lightweight zoom lens opto-mechanical layout and picture are presented in Fig. 2(a). The innovative opto-mechanical design resulted in only 264 gr, which is ~40% reduction compared to our legacy 19-275mm lens. Despite the challenging SWaP restrictions, the advanced lightweight design resulted in high level of MTF values across the entire field, as shown in Fig. 2(b). Moreover, the selection of advanced materials enabled unique athermalization properties maintaining the highest performance over a wide operating temperature range of -35°C to +65°C.

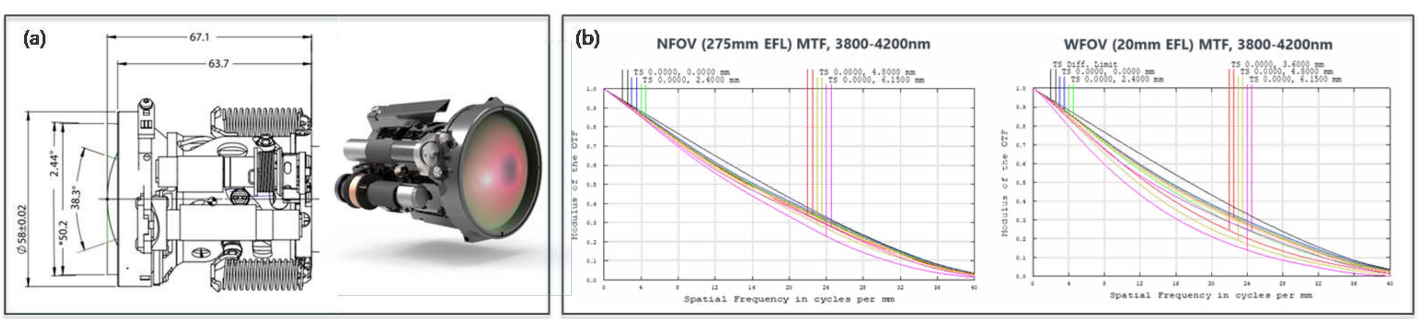

Fig. 2. Lightweight 20-275mm f/5.5 zoom lens – (a) Opto-mechanical layout and picture, (b) MTF characteristics

The characteristics of this lens lead to long operational ranges relative to the lens size and weight. For example, the detection range of a 2.3m vehicle would be around 15km(!) when integrated with a 23mK NETD, 15µm pixel detector (based on FLIR92 model calculations). To the best of our knowledge, this is the smallest and lightest continuous zoom lens on the market today enabling such high-performance capabilities of advanced IR thermal imaging systems in harsh environmental conditions and constrained platforms.

3. SUMMARY

We have successfully designed and implemented advanced IR zoom lenses with reduced SWaP which are based unique folded-optic design suitable for 10µm pixel size, as well as lightweight opto-mechanical concept that enabled over 40% weight reduction. In both lenses we have demonstrated MTF performance close to the diffraction limit and capabilities for high-resolution vision and identification in harsh environmental conditions and constrained platforms. Such zoom lenses open-up new opportunities in next generation UAV, HHTI, and small gimbals thermal imaging applications.

REFERENCES

1. J.L. Ramsey et al., “Experimental verification of a MWIR/LWIR 3x continuous zoom lens”, Proc. SPIE 10998, 109980M1-6 (2019).
2. G. Beadie et al., “Temperature-dependent dispersion fitting for a recent infrared glass catalog”, Proc. SPIE 10998, 10998041-6 (2019).
3. D. Gibson et al., “Multispectral IR optics and GRIN”, Proc. SPIE 10998, 109980D1-10 (2019).
4. S. Szapiel et al., “Freeform based lateral-shift compact zoom system: theory and computer simulations”, Proc. SPIE 10627, Advanced Optics for Defense Applications: UV through LWIR III, 1062707 (May 2018).

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