

Large-Aperture Multilevel Diffractive Lenses for MWIR and LWIR Imaging

Tina M. Hayward^{1,*}, Syed N. Quadri², Apratim Majumder¹, Nicole Brimhall³, and Rajesh Menon^{1,3}

¹*Department of Electrical and Computer Engineering, University of Utah, SLC, UT 84112 USA*

²*US Naval Research Laboratory, Washington, DC 20036, USA*

³*Oblate Optics, Inc., San Diego CA 92130*

* tinahayward4@gmail.com

Optics made for the mid-wave infrared (MWIR) and long-wave infrared (LWIR) bands are generally heavy, thick, and expensive. An MDL, which is many times lighter and thinner than traditional optics, that operates in MWIR or LWIR would be invaluable^{1,2}. Imaging in the MWIR and LWIR bands (3 to 5 μm and 8 to 12 μm) is useful for molecular fingerprinting, low light level night vision, tracking missiles, surveillance, emergency response, biomedical imaging, astronomy, non-destructive testing of integrated circuits, and environmental monitoring^{2,3}. Many of these applications would benefit from thinner, lighter optics, especially any application where weight is a limiting factor, such as on a satellite, drone, or headset.

MWIR systems also provide exceptional clarity in various weather conditions, making it well-suited to long range imaging applications as well. Metalenses have been developed for the MWIR band; however, their aperture diameters are typically under 1 mm and their fabrication in silicon is relatively complex, requiring minimum feature widths of 0.36 μm and aspect ratios reaching up to 12.6³⁻⁵. Fabricating these devices remains so complex that, despite the success of advanced inverse design algorithms in producing achromatic MWIR metalenses in silicon, experimental realization has yet to be achieved due to persistent fabrication constraints.

We have designed several MDLs with large apertures ranging from 25 mm to 150 mm using inverse design methods^{4,5}. We fabricated each design, shown in Fig. 1, with grayscale lithography on both silicon and sapphire wafers using the Heidelberg 66+ pattern generator on a positive-tone photoresist (ma-P1275, Microresist Technology GmbH).

Additionally, we optically characterized the optical properties of our lenses, and, in some cases, incorporated the lenses into hybrid telescopes to demonstrate field performance, as shown in Fig. 2.

¹C. L. Tan and H. Mohseni, "Emerging technologies for high-performance infrared detectors," *Nanophotonics*, vol. 7, no. 1, pp. 169–197, 2018.

²A. Karim and J. Y. Andersson, "Infrared detectors: Advances, challenges and new technologies," *IOP Conf. Ser.: Mater. Sci. Eng.*, vol. 51, p. 012001, 2013.

³K. Ou et al., "Broadband achromatic metalens in MWIR," *Laser Photon. Rev.*, vol. 15, no. 9, p. 2100020, 2021.

⁴T. M. Hayward et al., "Inverse-designed 50-mm f/1 MWIR flat lens," *Opt. Lett.*, vol. 49, no. 18, p. 5015, 2024.

⁵T. M. Hayward et al., "MWIR multilevel diffractive lens with extended DOF," *Opt. Express*, vol. 31, no. 10, p. 15384, 2023.

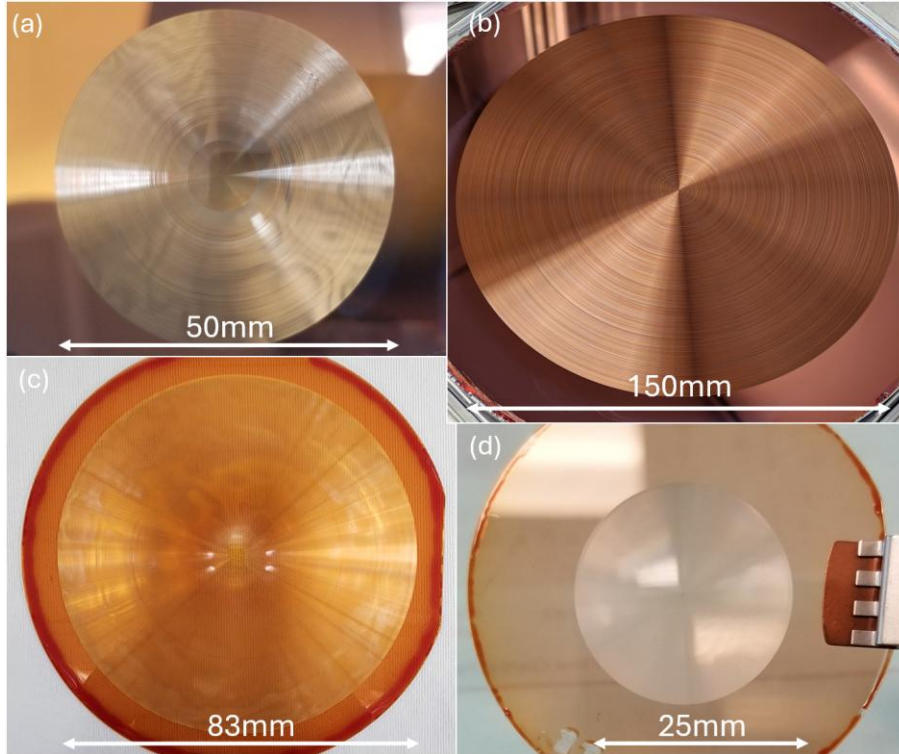


Fig. 1: Fabricated MWIR device with diameters of (a) 50 mm, (c) 83mm, and (d) 25 mm. (d) Fabricated LWIR device with diameter of 150 mm.

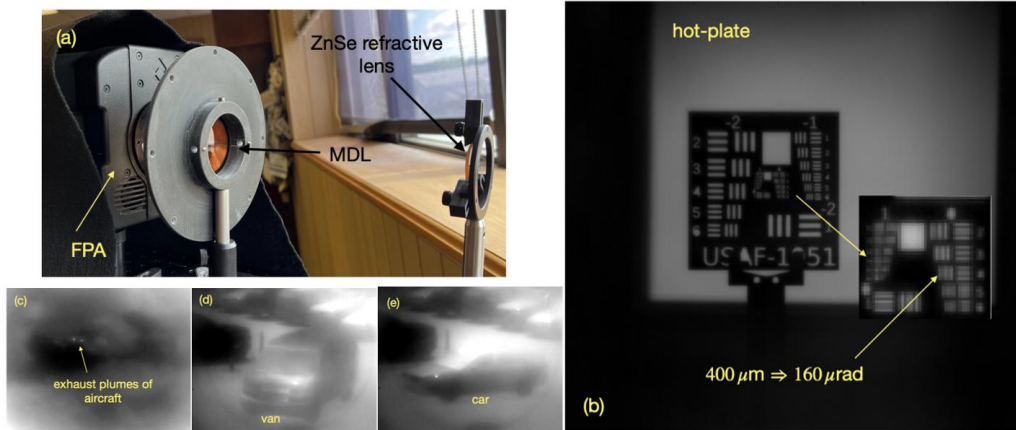


Fig. 2: Imaging with a refractive-MDL hybrid telescope. (a) Photograph of telescope comprised of the MDL as the fast eyepiece and a ZnSe refractive (focal length = 150 mm) as the primary lens. (b) Image of an AF target, demonstrating angular resolution of $160 \mu\text{rad}$ (object distance = 2.5 m). The target is back-illuminated by a hot-plate. Examples of field imaging: (c) exhaust plumes from an aircraft through clouds, (d) van and (e) car driving in a parking lot. Figure adapted from [4].