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EDITORIAL

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# Ultracompact wide-FOV near-infrared camera with a wafer-level manufactured meta-aspheric lens

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**Abstract**

Hybrid metasurface–refractive systems have often raised concerns about their overall volume and the complexity of mechanical alignment. This reported study presents a fully integrated meta-aspheric optical system that realizes a wide field of view within an ultracompact volume of 0.02 $cm^3$.

Expanding the field of view (FOV) of imaging modules enables vision systems to capture more comprehensive scenes [1], which is highly desirable for applications such as surveillance, autonomous navigation, and augmented reality. Conventional wide-angle designs, however, generally rely on multiple refractive elements, such as fisheye [2] or compound lenses, which inevitably increase the size and complexity of the optical system. Reconciling wide-angle imaging with compact, lightweight, and highly integrated optical hardware has therefore become a central challenge in the development of next-generation vision systems.

Hybrid metasurfaces-refractive systems [3–5] have emerged as a promising route to combining the advantages of conventional optics and planar nanophotonics. Yet in most earlier demonstrations, the two components were fabricated separately and assembled afterwards using external mechanical mounts, making precise alignment difficult and limiting system compactness. The study "Ultracompact Wide-FOV Near-Infrared Camera with a Wafer-Level Manufactured Meta-Aspheric Lens", recently published in *Light: Advanced Manufacturing*, presents a wafer-level integration strategy that addresses these challenges [6]. As shown in Fig. 1, the meta-aspheric lens is realized through two parallel fabrication processes, electron-beam lithography for the metalens and laser direct writing followed by nanoimprint lithography for the aspherical lens, before wafer bonding enabled by active mask alignment with micrometer-level precision. Notably, the geometric and optical parameters of the entire system, including glass thickness, aperture radius, and the phase profiles of both lens component, are co-optimized to ensure robust imaging performance. The resulting system achieves a 101.5° FOV, a total track length of 3.39 mm, and an F-number of 1.64 within an overall volume of only 0.02 $cm^3$, highlighting its strong potential for wearable near-infrared vision applications.

This work reflects the continuing shift of metasurface optics from proof-of-concept demonstrations toward practical, manufacturable imaging systems. Although metalenses [7, 8] have enabled diverse functionalities, including achromatic imaging [9–11], multiplexing imaging [12, 13], narrowband imaging [14–16], and tunable imaging [17, 18], their broader adoption remains constrained by trade-offs among key optical parameters such as numerical aperture, focusing

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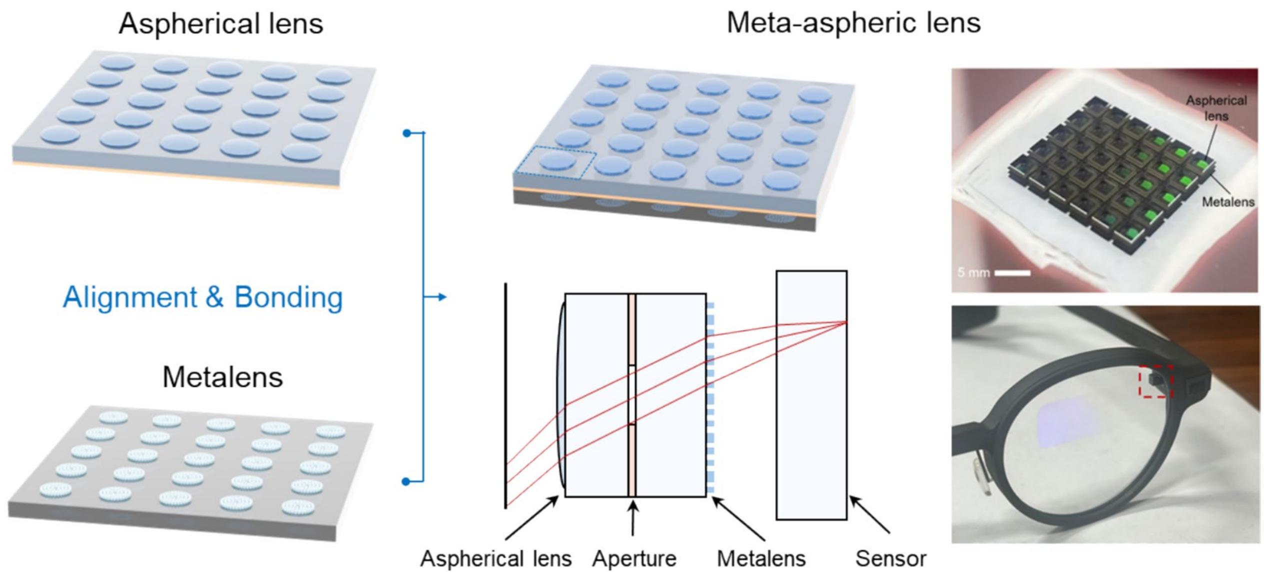


**Fig. 1** Wafer-level fabrication, optical integration, and application demonstration of the meta-aspheric lens system. The left panel illustrates wafer-level alignment and bonding between the aspherical lens wafer and the metalens wafer, while the central schematic shows the optimized hybrid optical layout. The photographs on the right present the fabricated device (top) and its integration into an AR-glass prototype (bottom), underscoring the compactness and practical potential of the approach. Images of real products are reproduced from Ref. [6]

efficiency, spectral bandwidth, diameter, and FOV, as systematically analyzed in a recent review [19]. These limitations become particularly severe in wide-FOV systems, where the angular sensitivity of meta-atoms, steep edge-region phase gradients, and undersampling-induced aliasing can all degrade off-axis imaging performance. Importantly, such bottlenecks are increasingly understood not as purely optical-design problems, but as system-level constraints rooted in material properties, fabrication precision, and integration capability. In this context, alignment should be regarded not merely as a packaging issue, but as a decisive factor linking nanophotonic design to real imaging performance. This is especially true for hybrid or cascaded meta-optical architectures, where even small angular or translational deviations between layers may substantially compromise functionality. The present work is therefore notable not only for its ultracompact wide-FOV design, but also for demonstrating how wafer-level fabrication and active alignment can be incorporated into the system architecture from the outset. Looking ahead, emerging alignment techniques inspired by high-order differentiators [20] and nonlocal bound states in the continuum [21] may provide additional routes toward nanoscale registration with improved sensitivity and robustness. Together with advances in optical materials [22] and scalable manufacturing [23, 24], such developments could help overcome current limitations in wide-FOV meta-optics and accelerate the transition of compact meta-optical systems from laboratory prototypes to practical deployment.

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