Large Area Electrically Tunable Metalens

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Primary CNF Tools Used: Heidelberg DWL2000, ASML DUV stepper, Gamma auto-coater, CVC sputterer, Oxford 81, 82, and 100 etchers

Abstract:

Our tunable optics technology enables dynamic tuning of metalenses with voltage-resolved precision. We have demonstrated electrically controlled focal length tuning of over 100% as well as the capability of adjusting for astigmatism and image shift at the same time. We have also developed a method for designing and fabricating metalenses of large areas: two-centimeters in diameter and beyond.

Summary of Research:

Large Area Metalenses [1]. Optical components, such as lenses, have traditionally been made in the bulk form by shaping glass or other transparent materials. Recent advances in metasurfaces provide a new basis for recasting optical components into thin, planar elements, having similar or better performance using arrays of subwavelength-spaced optical phase-shifters. The technology required to mass produce them dates back to the mid-1990s, when the feature sizes of semiconductor manufacturing became considerably denser than the wavelength of light, advancing in stride with Moore's law. This provides the possibility of unifying two industries: semiconductor manufacturing and lens-making, whereby the same technology used to make computer chips is used to make optical components, such as lenses, based on metasurfaces. Using a scalable metasurface layout compression algorithm that exponentially reduces design file sizes (by three orders of magnitude for a centimeter diameter lens) and stepper photolithography, we show the design and fabrication of metasurface lenses (metalenses) with extremely large areas, up to centimeters in diameter and beyond. Using a single two-centimeter diameter near-infrared metalens less than a micron-thick fabricated in this way, we experimentally implement the ideal thin lens equation, while demonstrating high-quality imaging and diffraction-limited focusing.

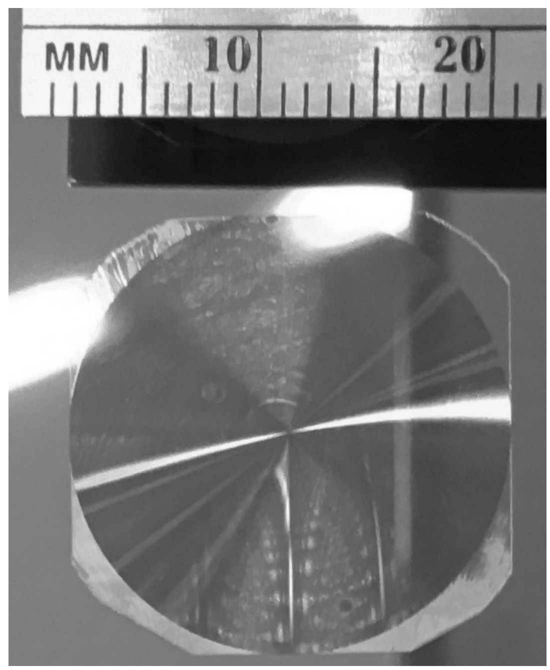

Figure 1: Our metasurface lens with diameter of 2 cm.

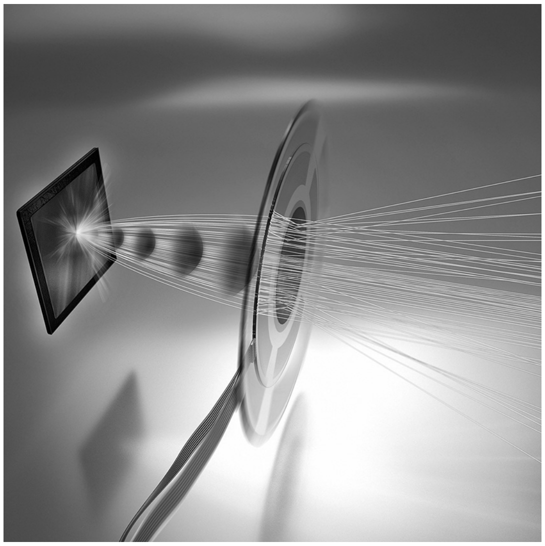

Figure 2: Schematic operation of adaptive metalens, which can perform simultaneous electrical adjustment of focal length, astigmatism, and image shift.

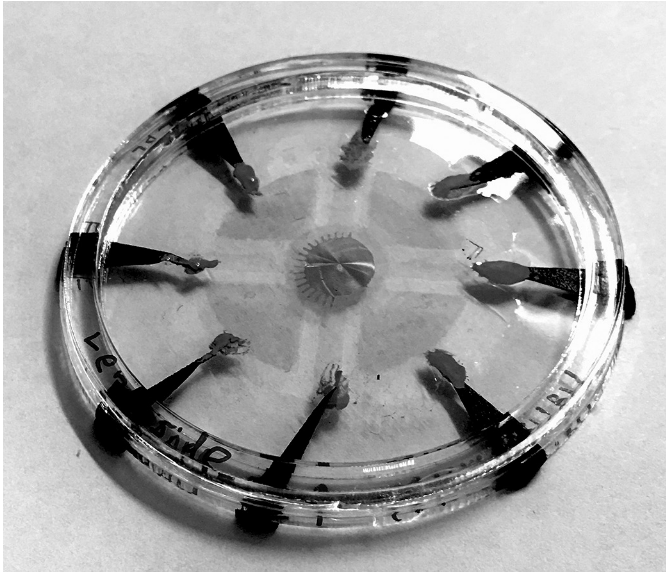

Figure 3: Photo of adaptive metalens device.

Adaptive Metalenses [2]. Focal adjustment and zooming are universal features of cameras and advanced optical systems. Such tuning is usually performed longitudinally along the optical axis by mechanical or electrical control of focal length. However, the recent advent of ultrathin planar lenses based on metasurfaces (metalenses), which opens the door to future drastic miniaturization of mobile devices such as cell phones and wearable displays, mandates fundamentally different forms of tuning based on lateral motion rather than longitudinal motion. Theory shows that the strain field of a metalens substrate can be directly mapped into the outgoing optical wavefront to achieve large diffraction-limited focal length tuning and control of aberrations. We demonstrate electrically tunable large-area metalenses controlled by artificial muscles capable of simultaneously performing focal length tuning (>100%) as well as on-the-fly astigmatism and image shift corrections, which until now were only possible in electron optics. The device thickness is only 30 μm.

Our results demonstrate the possibility of future optical microscopes that fully operate electronically, as well as compact optical systems that use the principles of adaptive optics to correct many orders of aberrations simultaneously.

References:

[1] A. She, S. Zhang, S. Shian, D.R. Clarke, and F. Capasso, “Large area metalenses: design, characterization, and mass manufacturing,” Opt. Express 26, 1573-1585 (2018).

[2] A. She, S. Zhang, S. Shian, D.R. Clarke, and F. Capasso. 2018. “Adaptive metalenses with simultaneous electrical control of focal length, astigmatism, and shift.” Science Advances 4 (2): eaap9957. doi:10.1126/sciadv.aap9957. http://dx.doi.org/10.1126/sciadv.aap9957.