Flat Optics: Controlling Wavefronts with Optical Antenna Metasurfaces

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We have demonstrated a few flat optical components in the infrared spectral range using spatially inhomogeneous arrays of V-shaped optical antennas. The essence of these designs is using the array to create a phase gradient $d\Phi/dr$, which is equivalent to an effective wavevector along the interface, to bend the propagation of light.

By using phased antennas to create a circular interfacial phase distribution $\Phi=L\varphi$ (Fig. 1(a)), where L is an integer and φ is the azimuthal angle, we imparted orbital angular momentum of $L\hbar$ to an incident beam, creating a vortex beam in transmission [1],[2]. The power flow or Poynting vector of this peculiar beam follows a spiral trajectory, which has been visualized by interferometry (Fig. 1(b)). By imposing a hyperboloidal phase profile or other appropriate radial phase distributions on an interface, we have demonstrated flat lenses (Fig. 1(c)) with a number of desirable properties, including large numerical aperture, absence of spherical aberration and reduced comatic aberration [3]. By tailoring the spatial distribution of polarization response (Fig. 1(e)), we have demonstrated optically thin quarter-wave plate that generate high-quality circularly-polarized light over a broad wavelength range (Fig. 1(f)) [4].

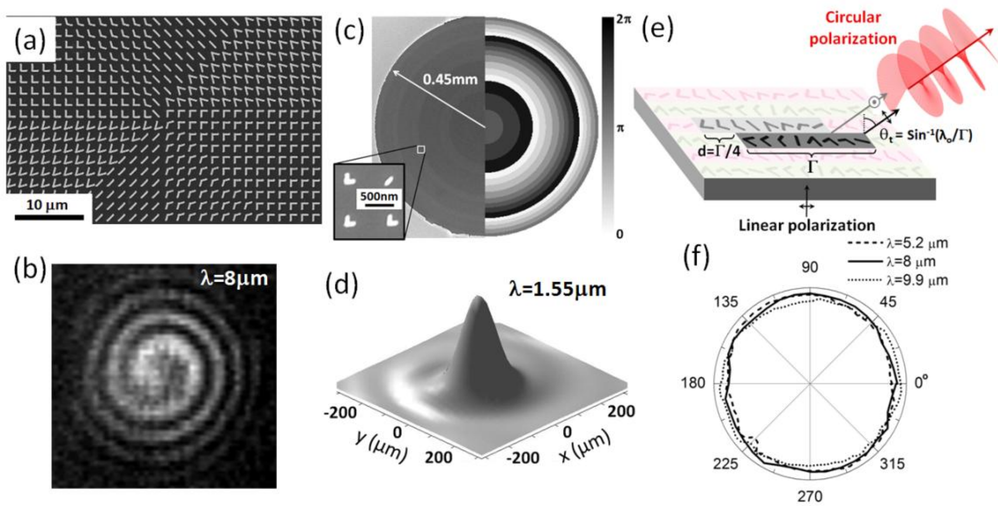

Fig. 1. Flat optical components created by using phased optical antenna arrays. (a) SEM image of a metasurface that generates an optical vortex beam. (b) Spiral interferogram created by the interference between the vortex beam and a co-propagating Gaussian beam. (c) Left: SEM image of a flat lens with 3cm focal length; right: Phase distribution introduced by the flat lens. (d) Measured intensity profile at the focal plane of the lens. (e) Schematic of an optically-thin quarter-wave plate. (f) Measurements show that the quarter-wave plate creates circularly polarized beams with high purity over a broad wavelength range from ~5μm to ~10μm.

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