Near-field Scanning Terahertz Microscopy of Metasurface

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As artificial materials engineered to have properties that have not yet been found in nature, metamaterials enable exciting physics and technologically important capabilities ranging from negative refraction, invisibility cloaking, to super-resolution imaging, with applications across science and engineering. [1-3] The research on metamaterials has been carried on broadly at microwave frequency and optical frequency, as well as at terahertz frequency. In the terahertz regime, the spectra response of metamaterial was usually examined and discussed in the far-field region, however, there are few works on the near-field characteristics of the metamaterial. Here, we studied the terahertz response of one kind of metamaterials, named the metasurface, by adopting the near-field scanning terahertz microcopy (NSTM) system.[3]

Here, by adopting the C-shape split-ring resonators (CSRRs) with phase discontinuities, we proposed a metasurface-based terahertz flat-lens array. We experimentally examined and explored the unique characteristics of the flat-lens array by using the NSTM. We show that the proposed flat-lens array is flexible, robust and broadband. Meanwhile, we demonstrate a convenient and robust idea of controlling handedness-dependent anomalous surface wave (SW) wavefront - title and focusing/diverging - in the launching process utilizing metasurfaces by engrafting the phase discontinuities concept.

Meanwhile, by arranging two metallic apertures orthogonal to each other with a distance $s = \lambda_{SW}/2$, where λ_{SW} is the SW wavelength, we found that, under circularly polarized plane wave incidence, the phase value of the launched SW is solely dependent on the orientation angle θ of the apertures whilst the phase sign is solely dependent on the handedness of the incident circular polarization. With such metallic apertures as the building block of the metasurface, nearly arbitrary phase profile can be achieved using arbitrary excitation patterns. [4,5]

Fig. 1a and c illustrate two sample photos of metasurfaces with linear and parabolic phase profiles for SW launching, respectively. The metallic apertures are designed to resonate at 0.75 THz. A near-field terahertz scanning microscope (NTSM) system which allows two dimensional (2D) scan of the SW electric field was applied to map the SW field distributions. And the circular polarizations were achieved by utilizing a quartz-based terahertz quarter waveplate (@ 0.75 THz).

Fig. 1b and c illustrate the experimental results of the linear-phase-profile metasurface. As the incident polarization is switched from left-handed circular polarization (LCP) to right-handed circular polarization (RCP), the propagation angle switches its direction due to the reversed phase gradient. As for the parabolic-phase-profile metasurface, opposite SW wavefront polarity (focus to diverge) is also observed, see Fig. 1e and f. Both our corresponding simulated and theoretical results show great agreements with the experimental results.

In summary, we have experimentally demonstrated a near-field research on metasurfaces by using the NSTM system. Such a system offer promising potential applications in high resolution detections, near-field distributions, and others.

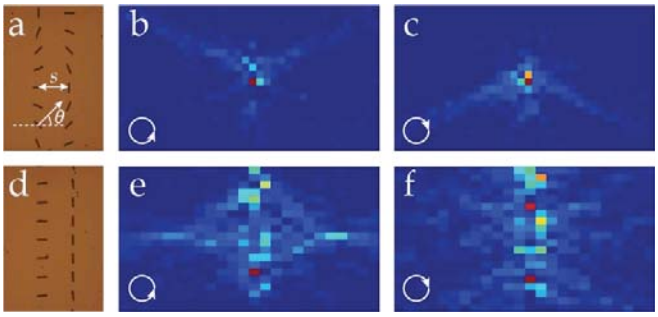

Fig.1 a. Sample photo of the metasurface with linear phase profile. b and c, Experimental field mapping of the launched SW by the linear-phase-profile metasurface under LCP and RCP incidence, respectively. d. Sample photo of the metasurface with parabolic phase profile. e and f, Experimental field mapping of the launched SW by the parabolic-phase-profile metasurface under LCP and RCP incidence, respectively.

References

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