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Complementary bilayer metasurfaces for enhanced terahertz wave amplitude and phase manipulation

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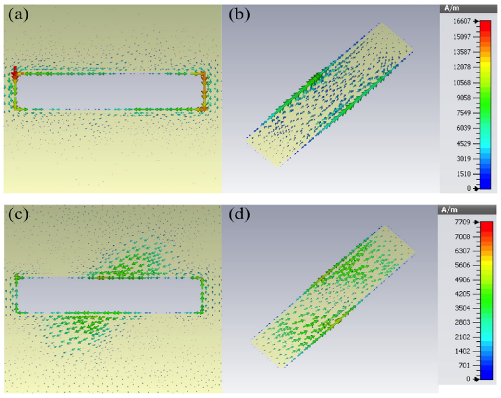

Surface current distributions of the metal aperture and metal cut-wire at 0.25 THz and 0.80 THz.

Abstract: Manipulation of terahertz wave by metasurfaces has shown tremendous potentials in developing compact and functional terahertz optical devices. However, there are still some obstacles that limit the practical applications of these meta-devices, such as low working efficiency and narrow operating bandwidth. Here, we propose complementary bilayer metasurfaces for enhanced terahertz wave amplitude and phase manipulation. The metasurfaces are composed of one layer of metal cut-wire arrays and one layer of their complementary aperture arrays separated by a dielectric spacer. The complementary apertures in the metasurfaces give rise to extraordinary optical transmission. When metal cut-wires are positioned near the apertures, the structures can manipulate the cross polarization conversion and phase dispersion of terahertz wave through the near-field coupling between transverse magnetic resonances in the metal apertures and electric resonances in the metal cut-wires. Particularly, when the thickness of the dielectric spacer is 8 μm and the rotation angle between the cut-wire and the aperture is 45°, the metasurfaces demonstrate a phase delay of 180° between two orthogonal axes with the same transmission amplitude between 0.70 and 1.0 THz, enabling a 45° broadband polarization conversion. A transmission peak at 0.25 THz can be observed for the co-polarized light. This peak corresponds to the extraordinary optical transmission effect in the metal apertures. A small peak for cross-polarized light at 0.25 THz corresponds to a weak excitation of the dipole resonance in the metal cut-wires. Numerical simulated surface current distributions in these two layers show opposite directions, indicating that a magnetic dipole can be formed within the circulating currents between the aperture and the cut-wire. The strong coupling between these two layers leads to a transmission peak at 0.80 THz. Furthermore, the phase dispersion of the transmitted light is modified by this coupling effect and a phase delay of 180° between 0.70 and 1.0 THz is achieved. When the metal cut-wires are rotated with respect to the apertures, the phase delays maintain 180° in a broadband with a small shift of the frequency. When thickness of the dielectric spacer increases, the resonance frequency of the metal aperture decreases, while the frequency of the coupled magnetic dipole resonance increases. When the thickness of the dielectric spacer is smaller, a larger transmission peak for the cross-polarized light is achieved. This indicates that a thinner dielectric spacer would provide a stronger coupling between the aperture and the cut-wire. Meanwhile, with a thinner dielectric spacer, a broader bandwidth for the phase delay of 180° can be realized. Such complementary coupled bilayer metasurfaces offer a new method to control the amplitude and phase dispersion of terahertz wave and promise great potential for applications in terahertz meta-devices.

Keywords: metasurfaces; terahertz; polarization; wave manipulation

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