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Ultra-broadband terahertz polarization transformers using dispersion-engineered anisotropic metamaterials

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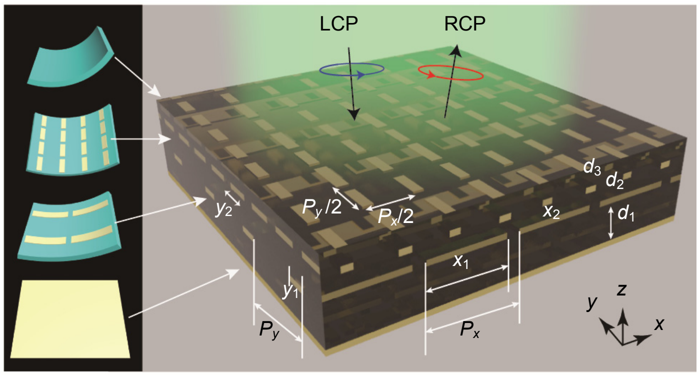

Schematic of the proposed anisotropic meta-mirrors for achromatic polarization manipulation.

Abstract: The ability to manipulate the polarization of electromagnetic waves is sought-after for numerous applications. Traditional polarization rotation devices utilizing natural occurring birefringence or total internal reflection effects are bulky. As an alternative solution, metamaterial-based converters exhibiting strong anisotropy or chiral can be extremely compact and thus flourished in the last decade. Nevertheless, metamaterial-based schemes suffer from the narrow bandwidth due to their highly dispersive meta-molecules.

Achromatic polarization converters operating in the terahertz band are highly anticipated due to the lack of suitable natural materials for terahertz device applications. Many excellent attempts have been carried out to extend the working bandwidth in different frequency regimes but at the cost of increased physical thickness, fundamentally ruled by the theoretical thickness-to-bandwidth ratio limit. Dispersion engineering is a promising method to approach the thickness-to-bandwidth ratio limit, which has been implemented in various meta-atoms such as, cross- and I-shaped metallic patch as well as split-ring resonators for broadband electromagnetic absorption and polarization manipulation.

In this paper, we propose the design of anisotropic metamaterials constructed by cascading meta-atoms with orthogonal orientation for two-dimensional dispersion management. Each meta-atom array behaves as an impedance-tuned interface, which dramatically modifies the complex reflection and transmission coefficients at the impedance interface. The cascading meta-atoms behave like a log-period configuration, well-known in broadband antenna design. By engineering the frequency-dependent impedances of the orthogonal meta-atoms, the reflection phase difference along the two axes of anisotropic metamaterials can approximate to a constant in a wide range.

Based on the above design principle, we numerically demonstrate the proposed anisotropic metamaterials with full released dispersion engineering ability in two dimensions can accomplish achromatic polarization transformation from 0.5 THz to 3.1 THz, i.e., the operation bandwidth is beyond 2-octave band. The polarization conversion ratio is higher than 80%, which exhibits excellent agreement with the theoretical calculation. Such design is scalable to other bands and can provide helpful guidance in broadband devices design.

Keywords: polarization conversion; terahertz; cascaded meta-atoms array

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