Implementing the Geometric Phase for Designing the Axially Asymmetric Metasurface Element

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Abstract: Designing a metasurface with appropriate phase correlation between light's linear and circular polarization states is challenging. The focus here is obtaining the geometric phases from different geometric shapes for optimum dielectric metasurface design.

1. Introduction

Polarization-sensitive detection by recovering the full set of Stoke parameters with subwavelength-scale metasurface has been developing recently with a reasonable promise to combine modulated linear and circular polarizations (LP and CP) in the same design. Intelligent pattern recognition with the full feature by the polarized state of light can be revealed by the degree of polarization and orientation angle of the polarization ellipse. For the metasurface, the design parameters include three spatially varying dimensions and their orientation angles at each lattice, which attributes to a unique phase correlation between the neighboring lattice to control the transmission and phase of the propagating light wave. The key is full-phase control, for both propagation and geometric. Extensive literature has proven the results for different meta-element geometry, but almost all of them are limited to axially symmetric elements [1]. Controlling the CP with axially asymmetric elements is less explored [2–5]. In this work, we propose to engineer the asymmetric metasurface elements and explore their corresponding functionalities in the evolution of the Pancharatnam-Berry (PB) phase using the Finite Difference Time Domain (FDTD) simulation method.

2. Simulation of different shapes and phase profiles with full axial rotation:

The theoretical limit of the PB phase imposes the restriction that if the metasurface element provides < $\pi/4$ phase retardation with a π rotation angle, then the element will not be able to control the total phase range [4]. Limitation

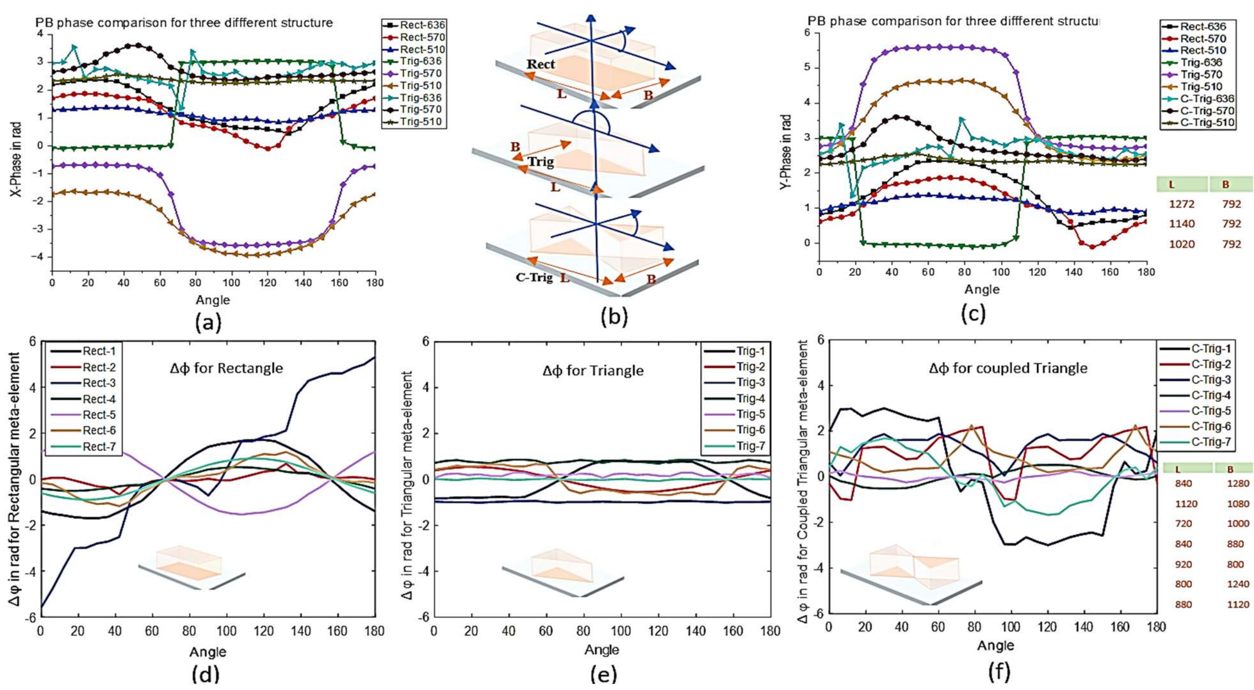

Fig. 1. Phase evolution for different shapes of meta-element with rotational angle.

on the propagation phase comes with reducing the height of the meta-element. Although the triangle and the coupled triangle shape used here reduce the filling factor by 50% compared to the same dimension of a rectangle, those yield better transmission. So, we want to explore how to control the PB phase with those shapes for modulating CP light.

3. Results and discussion:

In Fig.1, we implement the full axial rotation of these three types of structures. A triangle has less rotational symmetry than a rectangle and a coupled-triangle of both-axis symmetry. So, the phase difference $\Delta\phi$ in the bottom row of Fig.1 is the absolute phase difference between the rotational x and y phase in reverse order, which seems to remain more consistent for the asymmetric element compared to the axially symmetric one. The simulation uses an L45 source. Interestingly, in Fig. 1 (a) and (b), for the triangle meta-element length to unit cell ratio from 0.79 to 0.71 and 0.63, the gradual phase unlocking through phase reversal could be utilized as a new control. The phase remains locked in the structure for certain angular rotations, which could be due to the lattice interaction and pave a way for counterbalancing the geometric phase. With the increasing x and y dimensions of the triangle and C-triangle, the corresponding orthogonal propagation phase profile does not remain uniform as a rectangle, as shown in a C-triangle phase and transmission library in Fig.2.

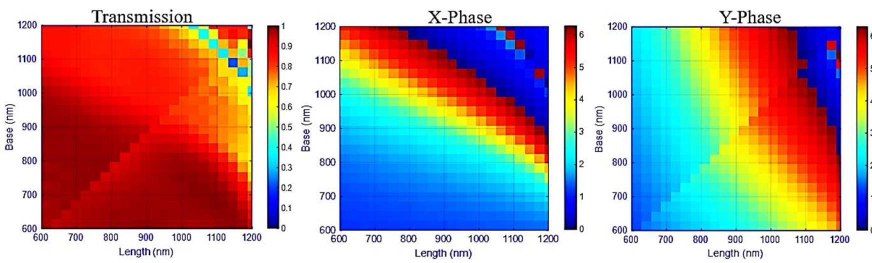

Fig. 2. Transmission and phase library for 2150 nm height coupled-triangular nanoantenna.

In this work, we will also compare the rotational phase evolution using the FDTD simulation and try to find the correlation between the input polarization state, structural anisotropy in the presence of lattice symmetry, and neighboring coupling. This effort can be challenging as the actual PB phase can become more complicated [6,7]. Particularly, in the presence of more rotational symmetry in shape, phase retardation becomes more unpredictable, which interns reasoning the scope of asymmetric meta-element. Lastly, it is noted that phase evolution is a local phenomenon in the lattice point of the metasurface and is inherently dependent on the symmetry of the lattice and incident polarization state. It will be left to further investigation with the anisotropic element and aperiodic lattice to explore the higher-order PB phase in our future work.

4. Reference:

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