High-efficiency Multiband Cross-Polarization Converter based on Metasurface at Terahertz Frequency

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***Abstract*—In this paper, we proposed a cross-polarization converter that simultaneously works at four terahertz regime in the transmission mode. The cross-polarization converter is composed of four metasurfaces and three dielectric layers interlaced with each other. It's able to efficiently convert a linearly polarized wave to its cross-polarized wave at 0.99-1.09*THz*, 1.10-1.29*THz*, 1.39-1.51*THz* and 1.60-1.65*THz* respectively. The neighboring unit cells of the central metasurface layer of the cross-polarization converter exhibit strong electromagnetic (EM) coupling. This converter takes favorable advantages of more operation frequency bands for linear polarization conversions, which indicating potential applications in terahertz detectors, antennas, imaging, communication systems and so on.**

Keywords—polarizer; mutliband; metasurface; terahertz; cross-polarization

I. INTRODUCTION

Polarization as the most important property of electromagnetic waves plays an irreplaceable role in many classical physical effects [1]. In recent years, metamaterials as an alternative to manipulate the electromagnetic waves polarization have attracted increasing attention [2]. Chiral and anisotropic metamaterials structural simplicity and easy fabrication have been used to manipulate polarization conversion of terahertz wave [3-4]. For example, Jiang et al. proposed an linear-to-circular polarization reflector using multiple resonance frequency-selective surfaces [5]. Gao et al. has experimentally demonstrated that a metasurface consisting of double L-shaped plasmonic antennas can convert linear polarized waves into their cross-polarized waves ranging from 0.2 to 0.4 *THz* based on the mutual coupling reasonably [6]. Ding et al. proposed slotted L-shaped cross polarization converters can convert a linearly polarized wave to its cross polarized wave at three different resonant frequencies, which are the results of the mode hybridizations between the slot and the metallic nanoantenna [7]. Song et al. had numerically and experimentally demonstrated a chiral metamaterials composed of tri-layer, which can separately accomplish broadband and multiband cross-polarization conversion for two orthogonal linearly polarized incident waves [8].

In this article, we present a multiband transmission polarization converter to manipulate the polarization of the electromagnetic waves. The designed unite cell of the metasurface contains four layers, which is able to realize the function of multiband cross-transmission conversion. It can convert a normally linearly polarized wave to its cross-polarization at four bands of 0.99-1.09*THz*, 1.10-1.29*THz*, 1.39-1.51*THz* and 1.60-1.65*THz*, respectively.

This paper is organized as follows. In Section II, the four layers structure is designed to realize the multiband polarization converter. Section III presents the simulation results of the converter. Conclusions are present in Section IV.

II. DESIGN OF THE METASURFACE

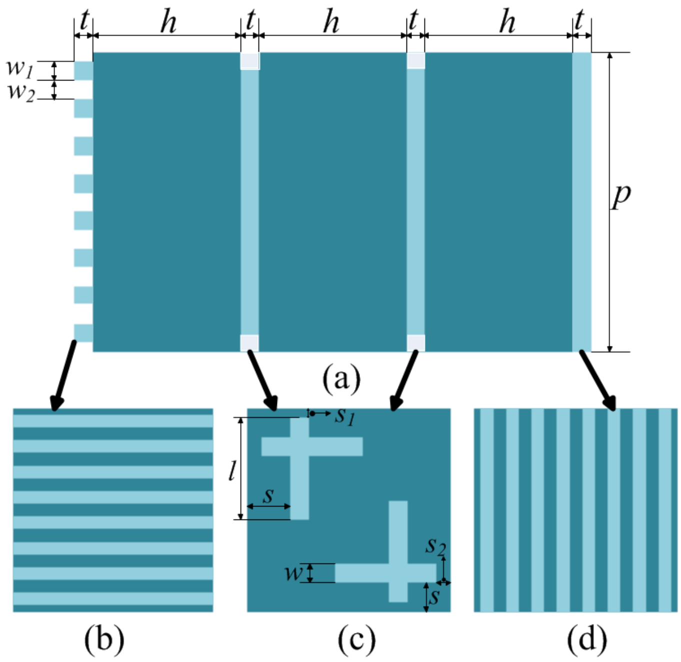

Fig. 1. (a)Unit cell structure diagram of the proposed polarization converter. (b) The grating of the upper layer. (c) The structure of the two middle layer. (d) The grating of the under layer.

A schematic configuration of the proposed transmission-mode linear polarization converter is shown in Fig. 1. It consists of two metallic grating, two abnormal cross-shape meta-surfaces and three dielectric spacers. The grating and two abnormal cross-shape meta-surfaces are gold. In the middle of the cell, there is a dielectric material of polyimide with a dielectric constant of 3, loss tangent of 0.001 and thickness h of 47nm. The other geometrical parameters of unit cell demonstrated as follows: p=92μm, h=47 μm, t=0.2 μm, l=44 μm, s=3 μm, s_1=6 μm, s_2=3 μm, w=8 μm, w_1=3.5 μm, w_2=12.5 μm.

III. SIMULATION AND RESULTS

The design was simulated using frequency domain solver in CST Microwave Studio. The simulation model is shown in Fig. 2. In the simulation, periodic boundary conditions were employed in the x and y direction to simulate an infinite periodic array, and a plane wave was incident downward on the top surface of the proposed design with an x-polarized electric field. Owing to further analyzing the polarization converter properties of the structure via the numerical simulation, we assume $\boldsymbol{E}_i=\boldsymbol{e}_x E$ represent the incident electric field with its polarization direction along x axis. When an x polarized EM wave impinges onto the device along the $-z$ direction, it first couples with grating 1 and is then converted to y polarized wave by the two middle abnormal cross-shape structures. At last, the rotated y polarized EM wave then couples with the other side grating 2. Consequently, the incident x polarized wave is converter into a y polarized wave when it passes through the polarization device.

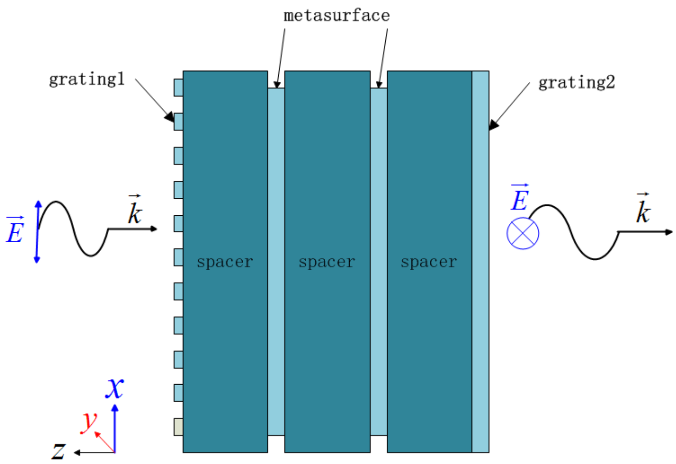

Fig. 2. Cross section of the proposed polarization converter

The Fig.3 shows simulated transmission coefficient of cross-polarization of the converter device. It shows that, in the frequency range of 0.99-1.09THz, 1.10-1.29THz, 1.39-1.51THz and 1.60-1.65THz, the cross-polarization transmission coefficient ≥ 0.8.

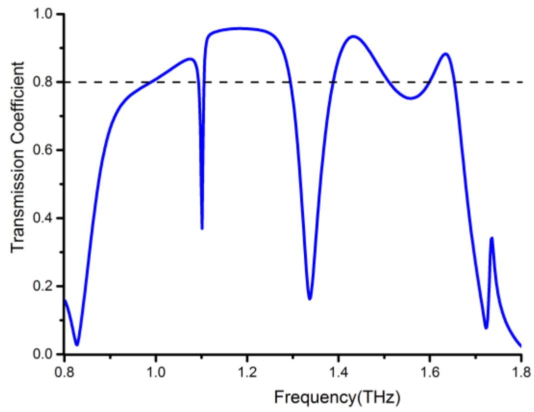

Fig. 3. Simulated transmission coefficient of cross-polarization

To evaluate the performances of the metasurface device, the polarization conversion efficiency (PCE) are calculated and shown in Fig.4. The polarization conversion efficiency is calculated by $PCE = t_{xy}^2$, and the t_{xy} represents the transmission coefficient. From the Fig. 4, which shows in the frequency range of 1.00 -1.24THz, 1.48-1.66THz, the PCE are greater than 0.6. From 1.05THz to 1.09THz, 1.10THz to 1.21THz, 1.55THz to 1.64THz the PCE ≥0.8.

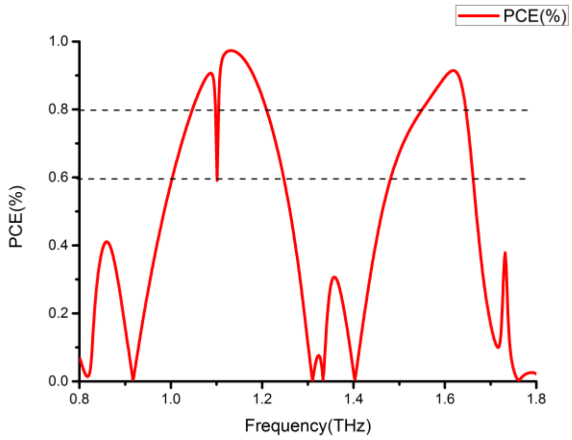

Fig. 4. Simulated polarization conversion efficiency(PCE) of cross-polarization

These result shows that the metasurface device can turn the linearly polarized wave to their cross polarized wave with four frequencies band.

IV. CONSLUSION

In conclusion, we proposed a multi-band polarization converter based on four layers metasurface. The designed polarizer can rotate an x polarization EM wave to its cross-polarization EM wave at 0.99-1.09THz, 1.10-1.29THz, 1.39-1.51THz and 1.60-1.65THz respectively. The proposed metasurface have many potential applications such as telecommunication, imaging, and sensing.

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