Dual-Band Conversion Between Polarization States Based on Metasurface with Broadband Performance

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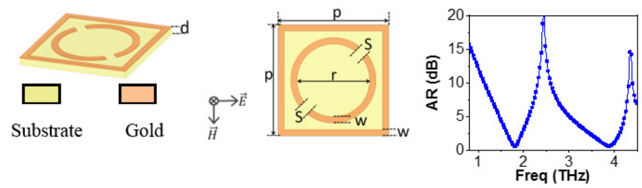
***Abstract*—Dual-band operation for terahertz (THz) wireless systems to merge multiple systems into a single one is a challenging problem. We propose a dual-band THz polarization converter using metasurfaces in transmission modes. It is singly layered which makes it a very simple structure. Dual-band conversion from linear wave to circular wave is reported over 20% of centre frequencies (1.6-1.97 THz, 3.35-4.16 THz) which is very broadband.Idea is verified by simulation and experiment.**

I. INTRODUCTION

Polarization converters have been investigated in the past because of their abilities to manipulate polarization states of electromagnetic waves. Conventional polarization converters are based on bifringent structure. However, such converters have the drawback of narrow bandwidth and large size. Metasurfaces, being ultra-thin, highly efficient, having ease-of-fabrication and small weight have been explored for a variety of applications including linear to circular polarization conversion[1]. Although multifunctional THz polarization converters have been proposed[2], a simple dual-band polarization converter to have volume and size reduction is yet a challenging problem. Zang et al. proposed metasurface based dual-band structure but it was based on reflection based metasurfaces [3]. Recently, Naseri et al.[4] proposed a transmission-based polarization converter in the microwave band but it worked over <5% bandwidth and the structure was based on three metallic layers. In this paper, we present the design of dual-band transmission-based polarization converter with broad transmission using singly layered metasurfaces.

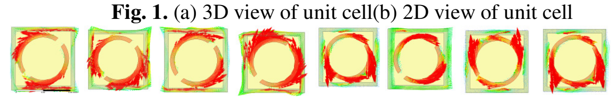
II. RESULTS

Using the concept of mutual interactions between two different resonators for dual-band operation, we propose a unit cell consisting of nested split-ring and square ring. The unit cell for the proposed converter is as shown in figure 1. Where circular ring is diagonally split to introduce diagonal symmetric yet anisotropic structure. This introduced split tailors cross-coupling effect so that two orthogonal components may have the same magnitude and ±90˚ phase shift. Gold was used as a conductor with $\varepsilon_{Au} = 1 - \frac{\omega_P{}^2}{(\omega^2 + i\gamma_c\omega)}$, $\omega_P = 1.37 * 10^{16}$, $\gamma_c = 1.22 * 10^{14}$. Whereas polyimide quartz having dielectric constant ε_r of 4.0 was used as a substrate. Full-wave electromagnetic simulation was carried out in High Frequency Structure Simulator (HFSS) using floquet ports and master-slave boundary conditions. The performance criterion for most of the electromagnetic systems is set to be within 3dB of axial ratio. Incident x-polarized wave is divided into two orthogonal transmitted components t_{xx} and t_{xy}. To have dual-band linear to circular polarization conversion, t_{xx}=t_{xy} and $\varphi_{xy} - \varphi_{xx} = \pi/2$within two bands of interest.



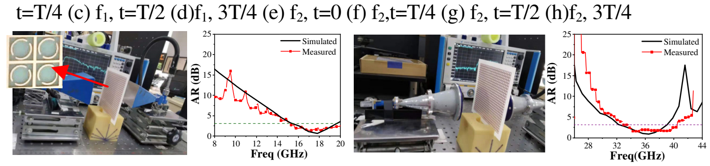
(a) (b) (c)

Fig. 1. (a) 3D view of unit cell(b) 2D view of unit cell



(a) (b) (c) (d) (e) (f) (g) (h)

Fig. 2.Surface current distribution of the proposed converter at (a) f_1, t=0, (b)f_1, t=T/4 (c) f_1, t=T/2 (d)f_1, 3T/4 (e) f_2, t=0 (f) f_2,t=T/4 (g) f_2, t=T/2 (h)f_2, 3T/4



(a) (b)

Fig. 3. (a) test setup for Ku-band (b) test setup for Ka-band

Fig.1(c) shows the axial ratio for the transmitted wave. It is clear that from 1.6~1.97 THz, and 3.35~4.16 THz axial ratio is < 3dB so transmitted wave is circularly polarized. Most interestingly, the separation between operating frequencies can be controlled by *r*, *S* and *w*in the unit cell. Surface current vectors at the outgoingsurface of the converter are as shown in fig. 2for f_1=1.79THz, f_2=3.92THz. It can be seen that with every quarter cycle, surface currents are rotated 90˚ in a counter-clockwise rotation for f_1 and clockwise for f_2. Hence transmitted wave is LHCP at f_1 and RHCP at f_2.

To validate the performance, the proposed converter was designed and fabricated in Ku and Ka-band because of easy fabrication and testing environment. For this, FR4 substrate with thickness 0.3mm was used. Figures 3(a) and 3(b) show simulation and measurement results. It can be concluded that the proposed converter will have very good performance in THz band as well.

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