A Two-Way THz Frequency Splitter Using CPS-Based SSPPs

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***Abstract*—A two-way terahertz frequency splitter using coplanar strip (CPS)-based spoof surface plasmon polaritons (SSPPs) is presented. The guided slow waves at different frequencies can be localized at different positions along the proposed CPS-based SSPP structure, where two CPS branches are introduced as the output ports. To validate the feasibility of the proposed idea, the dispersion characteristics are calculated and two-dimensional (2D) electric field distributions are simulated.**

I. Introduction

Rainbow trapping effect, as one of the slow light phenomena, was first reported by Tsakmakidis et al. [1], which has been used for the applications in optical signal processing and enhanced light-matter interactions [2]. To realize the field-trapping function in terahertz or microwave frequency regime, some designs based on spoof surface plasmon polaritons (SSPPs) were reported since SSPPs have advantages of strong confinement to electromagnetic (EM) waves [3-6]. However, the previous works mainly focus on the traditional SSPP structures which are mainly developed from microstrip or slotline [3-7].

Recently, a THz CPS-based SSPP waveguide was proposed with strong confinement to the EM waves and low propagation loss feature [8]. In this paper, a THz EM wave-trapping circuit is developed based on this spoof plasmonic waveguide, then a two-way THz frequency splitter is presented. The 2D electric fields distributions located in different planes at different frequencies are demonstrated to validate the fields releasing and trapping ability for the 2-way frequency splitter application.

II. Proposed Structure for Fields Trapping

The THz EM wave-trapping structure developed from CPS is shown in Fig. 1, which consists of the dual striplines (i.e., CPS) along the y direction with periodic array of transverse length-different stubs symmetrically loaded to the CPS. It is characterized by the following parameters: widths of CPS and loaded stubs (i.e., W and W_n), gap of the CPS S, length of stub L_n, and the lattice constant or period D. The metallic part is assumed to be perfect electric conductor (PEC) with the thickness of T_1 = 100 nm, and the substrate is using polyimide with the relative dielectric constant (ε_r) of 2.9, loss tangent of 0.003, and the thickness of T_2 = 20 μm.

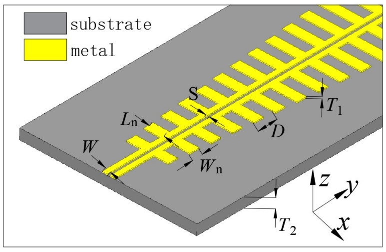


Fig. 1. Proposed CPS-based spoof plasmonic waveguide structure.

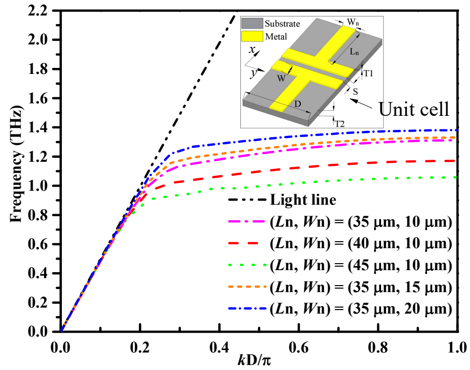


Fig. 2. Dispersion curves of the proposed CPS-based SSPP unit cell with different dimensions. The geometric parameters of L_n = 35 μm, W_n = 10 μm, W = 5 μm, D = 22.5 μm, and S = 2.5 μm are fixed for all curves except the parametric sweeping.

To obtain the dispersion curves, numerical eigen-mode simulations are carried out by the commercial software, CST Microwave Studio. The dispersion relation of the fundamental mode is obtained as displayed in Fig. 2, where k denotes propagation constant along the y axis. The dispersion curves of the proposed structure significantly deviate from the light line. This deviation is more apparent as the length of stubs L_n increases or the width of the stubs W_n decreases while other dimensions remain unchanged. The asymptotic frequency shifts down from the value of 1.4 THz to 1.1 THz as the two parameters (L_n, W_n) are selected from (35 μm, 20 μm) to (45 μm, 10 μm), respectively. Since the dispersion curves are sensitive to the length of the transverse stub L_n, we design the fields-trapping structure with different transverse stub lengths, gradually changing from 14 μm to 70 μm with the step size of 2 μm. As can be seen in Fig. 3, the EM waves at 1 and 1.2 THz will be trapped at different locations of the proposed structure where L_n = 50 μm and 40 μm, respectively. The principle of such structure is similar to that proposed by Zhou et al. [9].

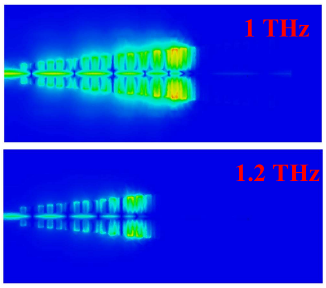


Fig. 3. Simulated magnitude distribution of electric fields on the *x-y* plane 2 um above the proposed circuit at 1 THz and 1.2 THz.

III. Proposed Frequency Splitter

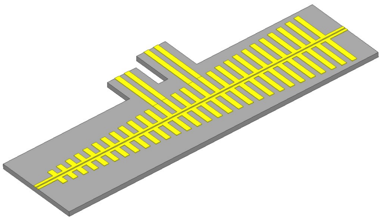
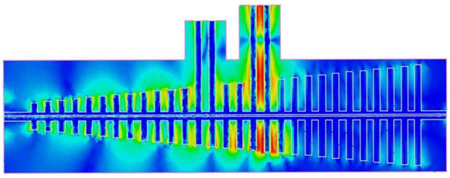
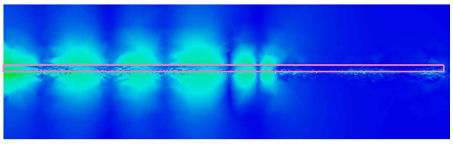


Fig. 4. Proposed THz frequency splitter.



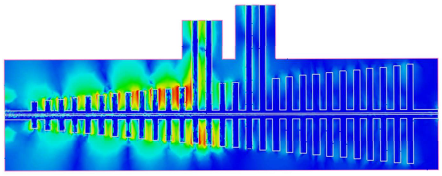
(a)



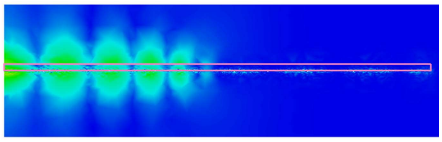
(b)

Fig. 5. 2D distribution of the simulated electric fields at 1 THz: (a) *y*-component electric fields on the *x-y* plane. (b) *z*-component electric fields on the *y-z* plane.

The two-way frequency splitter is implemented by introducing two CPS branches as the output ports located at different positions of the proposed structure where the EM waves at the required frequencies are trapped. According to the transmission line theory, by setting the lengths of the loading CPS branches to an odd multiple of λ/4, the trapped fields can be efficiently released. The SSPP slow waves will smoothly propagate along the loading branches with the mode conversion from SSPP to CPS waveguide. The propagation wavelength λ of the SSPPs on the CPS probes is obtained with the help of CST commercial software. The whole structure is modeled with the frequency solver of CST simulation. The 2D electric fields distributions at 1 and 1.2 THz are illustrated in Fig. 5 and 6, respectively.



(a)



(b)

Fig. 6. 2D distribution of the simulated electric fields at 1.2 THz: (a) *y*-component electric fields on the *x-y* plane. (b) *z*-component electric fields on the *y-z* plane.

IV. Conclusion

This paper proposed a 2-way frequency splitter using CPS-based SSPPs. Simulation and corresponding analysis are carried out and demonstrated showing good performance of the proposed frequency splitter.

Acknowledgment

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References

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