A Plasmonic Multi-directional Frequency Splitter

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Abstract **-Based on plasmonic metamaterials, we propose a plasmonic multi-directional frequency splitter with band-stop filters. Such a plasmonic splitter consists of three specially-designed metal gratings with finite thickness. Electromagnetic waves at the designed frequencies are confined and guided along the three grating structures and better isolation between different gratings is achieved with the band-stop filters. The experimental verification of the frequency splitter has been implemented in microwave frequencies with excellent agreements to full-wave simulations.**

I. INTRODUCTION

At visible frequencies, the electromagnetic (EM) surface waves supported at the metal surfaces are referred to surface plasmon polaritons (SPPs) [1]. SPPs can be tightly confined within distances of the order of wavelength in the dielectric and is much less than wavelength in the metal. Recently, researches have shown that metal surfaces drilled with sub-wavelength holes or grooves will produce field confinement in the microwave frequency [2-3]. The structured metal surface in microwave behaves like a planar metallic one at optical frequencies [3]. Thus the structural metallic surface with holes or grooves is capable of supporting surface EM modes known as "spoof" or "designer" SPPs which provides an effective method to guide and manipulate EM waves. The structural metallic surface belongs to plasmonic metamaterials.

Efficient unidirectional nanoslit couplers were proposed to ensure a unique propagation direction for SPPs [4]. The directional control of SPPs waves propagating through an asymmetric plasmonic Bragg resonator was demonstrated in [5]. A bidirectional subwavelength slit splitter for THz waves was proposed to guide the electromagnetic waves at different frequencies in the predetermined opposite directions [6]. The experimental investigation to split SPPs waves has been conducted in both microwave frequencies [7] and visible frequencies [8]. A grating with triangular grooves has been proposed due to the ability of higher confinement and lower bending loss [9]. A multi-directional surface wave splitter excited by a cylindrical wire was then proposed [10]. More recently, an ultrathin dual-band plasmonic frequency splitter based on a composite grating structure with nearly zero thickness was presented [11].

The isolation between the three grating branches of the mulit-directional surface wave splitter [10] is too low at low frequency, such as 5GHz. In this paper, we combine one specially designed band-stop plasmonic filter with such frequency splitter to improve the isolation. The simulation and measurement results agree well.

II. DESIGNS AND VERIFICATIONS

In [11], periodic grooves with two different depths are etched on a metallic strip with nearly zero thickness. According to the authors, the dispersion relation of the spoof SPPs in the low frequency band is mainly dominated by the deeper groove, while the spoof SPPs in the high-frequency band is primarily determined by the shallow groove. In this work, we construct a similar structure as shown in Fig. 1. The red rectangular faces on both ends are defined as port 1 and port 2, which are used to add excitation source (TM mode) in the CST microwave studio. The groove depths are denoted as d_1 and d_2, respectively. The groove period, groove width and grating depth are p, w and D, where p = 5mm, w = 2mm and D = 5mm.

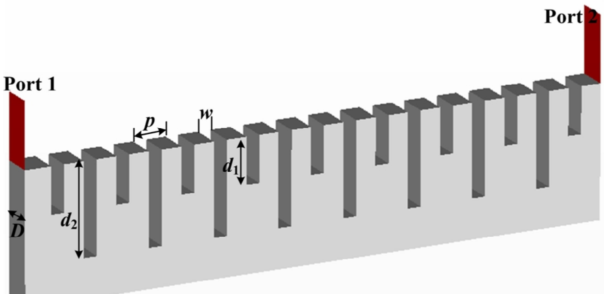

Figure 1 the structure of band-stop filter

The transmission spectra (S_{21}) is calculated and the results are shown in Fig. 2. Here d_2 is fixed to 14mm, and d_1 varies from 4mm to 7mm. It can be seen that the structure actually works as a band-stop filter. For the dual-band frequency splitter in [11], both working frequencies fall out of the stop-band. More works will be done to explore the deep physical mechanism for the stop-band filter.

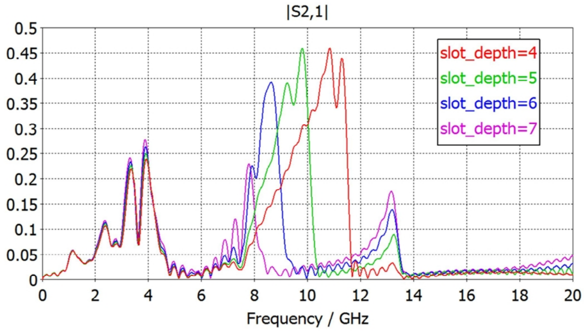

Figure 2 The transmission spectra (S_{21}) of the band-stop filter

We use such stop-band filter to improve the isolation between the three branches for multi-directional plasmonic frequency splitter at low frequencies. The detailed design principles for multi-directional SPPs splitter are explained in details [10]. The novel structure is given in Fig.3 (a), where the previous band-stop filter is put before each waveguide branch. The groove depths for these three branches are 4mm, 7mm and 11mm, respectively. For the stop-band filter, the deeper groove depth is 14mm. The fabricated sample and experimental setup are also shown in Fig. 3(a). For the multi-directional frequency splitter proposed in [10], the simulation result at 5GHz is shown in Fig. 3(b). It can be seen that the isolation between the three branches is bad at 5GHz. The simulation result and measurement result for the splitter in this paper are shown in Fig. 3(c) and (d). We can see that the isolation is much better and the simulation result agrees well with the experimental result. It shows that the plasmonic three-way frequency splitter with stop-band filters has better performance.

III. CONCLUSIONS

We have proposed and fabricated a three-way plasmonic frequency splitter with band-stop filters, which has improved the isolation between the three branches at low frequencies and increase the performance of previous multi-directional surface wave splitter[10].The frequency splitter in the microwave frequency has been modeled by using the full-wave simulation method and experiments have been conducted for verification. The experiment and simulation results are in good agreements. Next we will try to explain why the band-stop filter works and to fabricate more realistic plasmonic multiplexer for application.

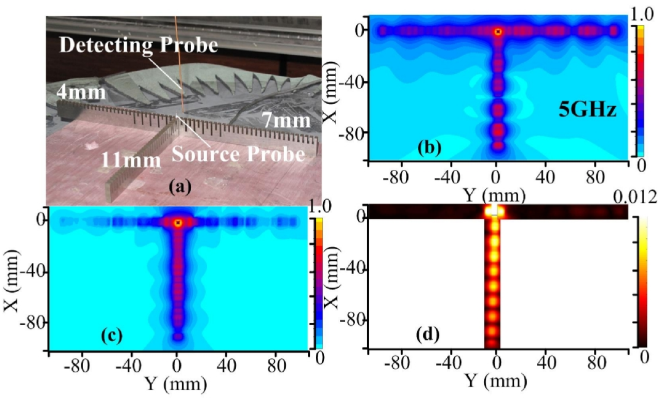

Figure 3 (a) the three-way frequency splitter sample and experiment setup; (b) simulation result for the splitter [10] at 5GHz; (c) and (d) simulation and experimental result for the novel splitter at 5GHz

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