An UWB Band-Pass Filter Using Plasmonic Series and Parallel SRRs with Coupling Gaps

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***Abstract* –This article presents the design and analysis of the nanoplasmonic metal insulator metal (MIM) waveguide based ultra wide band (UWB) band-pass filter (BPF) using series and parallel square ring resonators (SRRs) with coupling gap (g). The proposed device behaves as an UWB bandpass character due to the coupling gap between resonators and fed-line. The proposed UWB filter aiming, transmitting the UWB pass band signals from 1235.74 nm to 1942.16 nm wavelengths with a return loss of higher than 10dB.**

Index Terms–MIM, UWB, SRRs, Coupling Gap, BPF

I. Introduction

Nanoplasmonic devices play an important role that allows the wave propagation in optical mode at subwavelength scale to bridge the gap between photonics and electronics in high density photonic integrated circuits (PICs). The characteristics of the propagating modes have recently been investigated for several plasmonic devices such as metallic nanowires [1], arrays of metallic nanoparticles [2], and metallic slot waveguide structures [3-5]. The plasmonic slot waveguide structures consist of two metallic layers and an insulating material; simply control the light in between two metal layers. Several device structures have been designed and analysed using MIM guiding structures due to their easy fabrication, stronger field distribution, lower propagation and bending loss, which includes power dividers [6], switches [7], and couplers [8].

The nanoplasmonic SRRs have many attractive features such as ultra-compact size, easy fabrication, less radiation losses, narrow bandwidth and low space occupation in the circuit [9], which have used in cell phones, satellite communication and nanoscale wireless networks. Hence, the SRRs are regularly used in the designing of filter structures [10], and couplers [11]. The coupling gap (g) in between the fed line and SRRs can fulfill the requirements such as narrowband resonance frequency and more insertion-loss in the proposed UWB device [12]. Hence, the proposed plasmonic filter with coupling gap (g) has fulfilled the UWB character at subwavelength scale.

In this article, a nanoplasmonic UWB filter is designed and numerically analyzed by using MIM waveguide based series and parallel plasmonic SRRs with small coupling gap (g) between the resonators and fed line. The proposed nanoplasmonic device exhibits the lower insertion-loss at related resonance frequencies. Hence, the designed filter topology considerably minimise the insertion-loss because of coupling gap (g) in between resonators and fed-line. The performance of the designed filter structure is analysed by fullwave simulation software tool (CST Microwave studio).

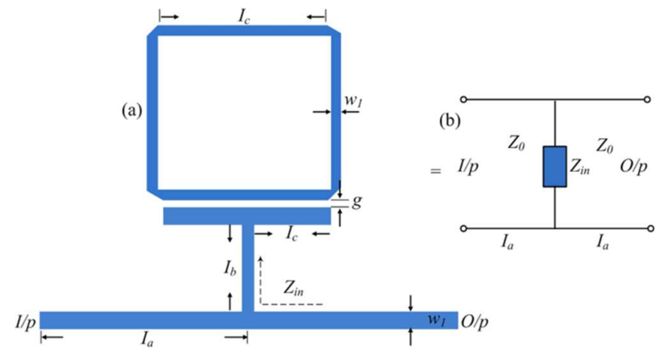

Fig. 1 (a) Schematic of the proposed filter structure with single SRR with coupling gap, (b) Simplified equivalent circuit.

The MIM slot waveguides are plays important role in the designing of plasmonic devices by using silver as noble metal and an insulator (SiO_2) with a dielectric constant (ε_d) 2.50. The dielectric of the noble metal has described by well-known Drude method [3],

$$\varepsilon_m = 1 - \omega_p^2 / \omega(\omega + j\gamma_p^2) \tag{1}$$

Fig. 1(a), (b) shows the schematic of the nanoplasmonic SRR with a coupling gap (g) and it is coupled to the resonators and fed line and its equivalent prototype circuit. The characteristic impedance (Z_{in}) of the two wire transmission line towards the SRR with the ring coupled line.

The input impedance of the circuit is given by [10],

$$Z_{in} = Z_0 \frac{Z_L + jZ_0 \tan(\beta l)}{Z_0 + jZ_L \tan(\beta l)} \tag{2}$$

where, Z_L and Z_0 are the load and characteristic impedances of the open stub. The phase constant of the open stub is β.

II. The Schematic of the Proposed SRR Based UWB Filter

The proposed plasmonic UWB-BPF have designed by using three plasmonic SRRs with the coupling gap (g) in between series and parallel SRRs and fed line to improve the pass band and rejection band in the filter structure. In Fig. 2, the schematic of the proposed device have shown and the proposed filter is designed by using a two wire transmission-line (TL) model which is periodically loaded by using three plasmonic SRRs with coupling-gaps (g). The physical dimensions of the proposed plasmonic filter structure are R_1 = 1200 nm, R_2 = 1320 nm, L_1 = 1320 nm, L_2 = 1190 nm, L_3 = 1200 nm, W_1 = 160 nm, W_2 = 60 nm and g = 60 nm. The perfectly matched layer (PML) boundaries are applied on the proposed UWB device structure. The grid sizes Δx = Δy = 5 nm are sets along x-y directions respectively.

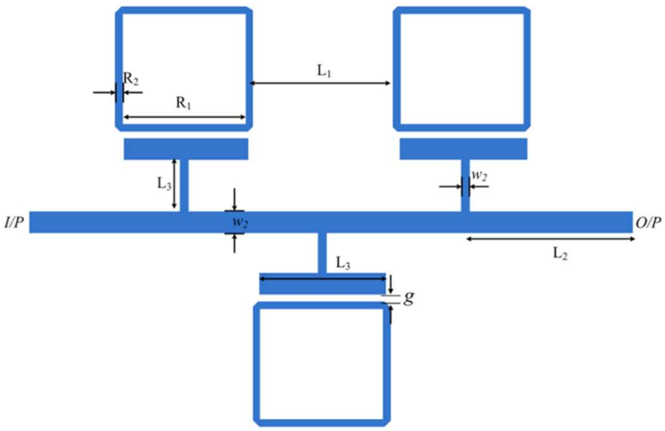

Fig. 2 The schematic of the proposed device structure using three SRRs with coupling gap (g).

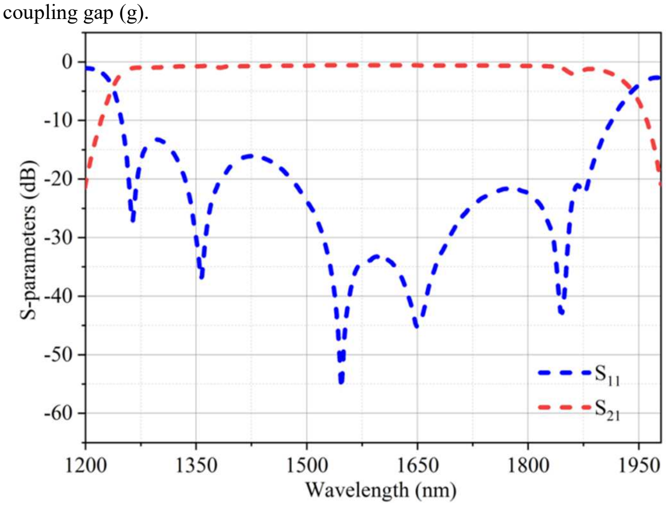

Fig. 3 The S-parameters of the proposed device with a whole UWB band pass nature from 1235.74 nm to 1942.16 nm wavelengths.

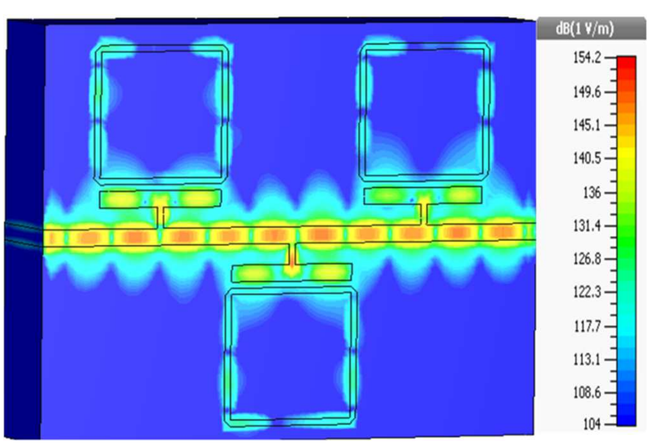

Fig. 4 The electric field distributions the proposed device at 1547.076 nm wavelength.

The whole UWB nature S-parameters of the proposed plasmonic filter at optical wavelengths are shown in Fig. 3. The frequency response of the plasmonic UWB filter with a whole pass-band nature from 154.36 THz to 242.60 THz is shown in Fig.3. The insertion loss of the middle band is 55 dB within in the whole UWB pass-band. On the other hand, the upper stop-band is extended up to 149.896 THz as estimated due to the induced coupling gap (g) between two series SRRs and one parallel SRR to the fed line. The 3 dB fractional band width is about 85% in the UWB filter structure. The magnitude of electric field distributions in plasmonic UWB device is shown in Fig. 4 at 1547.076 nm wavelength.

III. Conclusion

In conclusion, the nanoplasmonic UWB BPF have been proposed and analyzed by using three SRRs with coupling gap (g). The designed filter is behaves as an UWB bandpass character due to the series and parallel SRRs with coupling gap between resonators and fed line. These plasmonic UWB filter is designed at the fundamental mode with low insertion loss, ultra compact in size and operating with whole UWB bandpass nature from 1235.74 nm to 1942.16 nm wavelengths with a return loss of higher than 15 dB. Hence, the designed plasmonic UWB filter justifies the multiplex systems in the high density PICs and subwavelength scale wireless networks.

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