Nanoplasmonic Ultra Compact, Low Insertion Loss UWB Band-Pass Filter Using Square Ring Resonators

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***Abstract* –This article presents the design and analysis of a nanoplasmonic ultra wide band (UWB) band-pass filter based on metal insulator metal (MIM) slot-waveguide using three square ring resonators (SRRs) for obtaining ultra wide band nature at optical frequencies. This filter shows the low insertion loss due to the zero coupling gaps and no mismatch between the fed-lines and SRRs. Hence, the proposed filter shows the insertion-loss of much better than 1.13 dB in the pass band while the return-loss of filter is larger than 8.4 dB from 1434.50 nm to 1650 nm wavelengths in the stop band.**

Index Terms–Nanoplasmonic, UWB, SRRs, Band-Pass, Filter

I. Introduction

Surface plasmon polaritons (SPPs) are the electromagnetic (EM) waves which can coupled to the conduction electron oscillations at the interface of the metal-dielectric slot at optical frequencies [1]. The MIM slot-waveguide based nanoplasmonic devices consist of two metal claddings and an insulator, which can easily restrict the incident light in the dielectric region [2]. Several plasmonic devices have been introduced based MIM waveguide structure due to its simple fabrication, strong field strength, lower propagation and bending losses. Few of them include like, filters [3], modulators, switches [4], diplexers [5], and couplers [6, 7].

The next generation nanoplasmonic filters are highly desirable for modern wireless communication systems due to its high performance, low cost, ultra compact size and less space occupation in the circuit [8]. The nanoplasmonic SRRs can fulfill the requirements to use in the design of many band pass filters. The coupling gaps between the SRRs and fed-lines can influence the resonant frequency of the SRR and also experiences as of high insertion loss. Hence, a coupling-gap in the structure has been proposed to decrease the high insertion-loss in the filter structure [9]. However, the improved structures of the filter still have coupling gaps in between SRRs and fed-lines.

In this paper, a new ultra compact UWB band pass filter is proposed with low insertion loss [9] and sharp rejection by adding a square stub at the corner of the three SRRs. The new wide band filter shows the low insertion loss due to the zero coupling between the SRRs and fed-lines of the structure and the majority of the losses of the UWB filter is contributed by the conductor and dielectric material. The frequency responses of the filter structure can be calculated by applying finite difference time domain (FDTD) simulation software tool CST microwave studio suite.

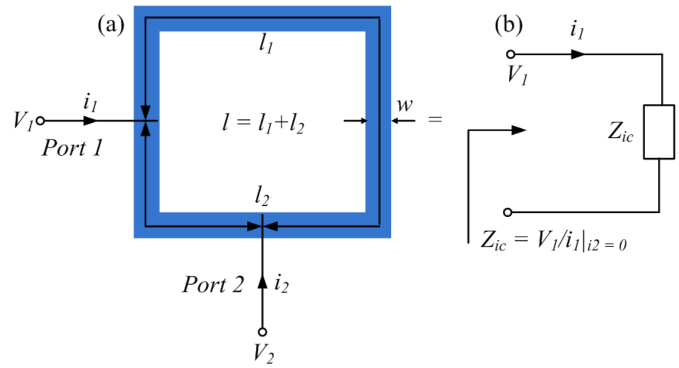

Fig. 1 Geometry of the proposed cascaded SRR with square stub at $\phi = 45^0$

Firstly, a nanoplasmonic MIM slot-waveguide have designed by utilizing noble metal silver and silica as dielectric material with a dielectric constant (ε_d) of 2.50 [10]. The complex permittivity of the silver has been defined by using Drude model [10],

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

Fig. 1 shows the nanoplasmonic ring resonator, it can be directly connected to the two orthogonal fed-lines of the single SRR and zero coupling-gap is applied in between SRR and fed-lines of the structure. The circumference (l_r) of SRR is defined by using [11],

$$l_r = n\lambda_g = 2\pi r \quad (2)$$

Where n is mode number and λ_g is the wavelength of the guiding structure.

II. The Geometry Of the Plasmonic UWB Filter With Low Insertion Loss

The UWB nature of the SRR filter structure can be obtained by adding a square stub in each SRR of the filter structure at $\phi = 45^0$. The geometry of the nanoplasmonic UWB band pass filter structure is shown in Fig.2. The electric fields of the nanoplasmonic SRR can perturbs by the square stub of the resonator, then the resonator can be exited to a UWB response in the filter at optical frequency bands.

To obtain the UWB nature in the filter structure three cascaded SRRs with added square stub are connected by two wire transmission line with length of $l = \lambda_g/4 = 120$ nm as shown in the Fig. 2. The physical dimensions filter structure is

$L_1 = L_2 = L_3 = 760$ nm, $L_4 = 1060$ nm, $w_1 = 160$ nm, $w_2 = 80$ nm and the radius of the each SRR is $l_1 = l_2 = 600$ nm and $w = 80$ nm shown in Fig. 2 respectively. The perfect-matched-layer (PML) boundary conditions tend to be applied on the filter structure. The grid sizes of the structure along the x and y directions are set to be $\Delta x = \Delta y = 5\ nm$ respectively.

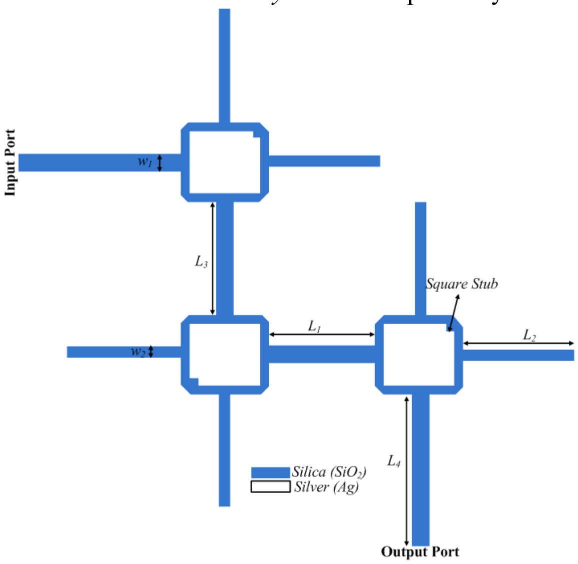

Fig. 2 Schematic of the cascaded SRR with square stub at $\phi = 45^0$.

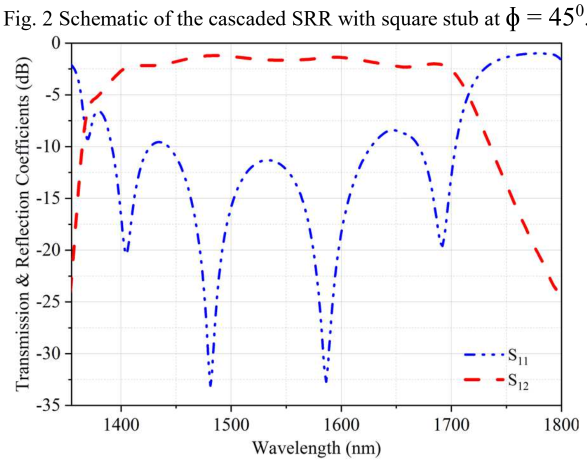

Fig. 3 Transmission and reflection coefficients of entire SRR filter structure from 1300 nm wavelength to 1800 nm wavelength.

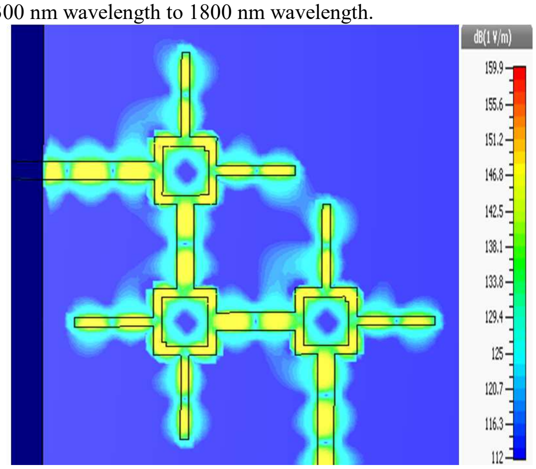

Fig. 4 The electric field distribution of the SRR based UWB band-pass filter structure.

The insertion-loss and return-loss of the UWB filter structure at optical frequencies shown in Fig. 3. The fractional band width (3 dB) of the filter structure is about 45.5%. The filter has an insertion loss of better than 1.13 dB in the pass band while the return loss of filter is larger than 8.4 dB from 1434.50 nm to 1650 nm wavelengths in the stop band. The magnitude of the field distribution of the entire filter structure at optical frequencies shown in Fig.4.

III. Conclusion

A new ultra compact, low insertion loss, UWB band band-pass filter have been proposed and numerically analyzed by applying FDTD simulation software tool CST Microwave studio suite. This filter have been designed by using three square ring resonators with square stub at $\phi = 45^0$for obtaining UWB nature in the filter structure. The designed filter shows the low insertion loss due to the zero coupling gaps and no mismatch between the fed lines and resonator. Therefore, the designed filter shows the 1.13 dB in the pass-band while the return-loss of the filter is larger than 8.4 dB in the stop band from 1434 nm to 1650 nm wavelengths. The new plasmonic filters designed for justify the duplex systems in the subwavelength scale wireless communication systems.

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