International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-3, September 2019

Design and Analysis of Step Impedance Resonator Based UWB Band Pass Filter using MIM Waveguide

M. Vishwanath, Habibulla Khan, Himani Goyal Sharma

Abstract**:** ***In this paper we have designed and analyzed step impedance resonator based ultra wide-band (UWB) band pass filter using plasmonic MIM waveguide. The UWB band pass filter has been designed by introducing a shot-circuited stub to implement the shunt inductance between two quarter wavelength (λ/4) step impedance resonators. There is a strong coupling between the stubs. The plasmonic UWB band pass filter has been designed at E band (1360-nm to1460-nm) optical wavelength. The band width of plasmonic ultra wide-band band pass filter is very effective compared to narrow-band band pass filter. The reflection and transmission characteristics, variation of reflection and transmission coefficents by varying the dimensions of UWB, field distribution of plasmonic UWB has been realized using full wave simulation by using commercially available CST microwave studio software. The UWB band pass filter can further used for the development of photonic integrated circuits (PICs).***

Keywords: Plasmonics, SIR, UWB, Band pass filter.

I. INTRODUCTION

Nano plasmonics offers an extensive awareness as a new technical innovation to overcome the diffraction limit for reducing the size of the photonic integrated circuits into nano-scale [1]. The limitations of the light wave in subwavelength scale lead through the localization and surface plasmons propagation along the interface of metal-insulator-metal (MIM) wave guiding structure. Metals are dealt with lossy plasma, which can be different from the idea of lossy conductor or ideal conductor principles used at GHz frequencies. The mode of the wave is identical to TEM mode; thus the supporting structures are designed by an equivalent transmission line.

Surface Plasmon Polaritons (SPPs) are the EM-waves that propagate along the metal-insulator interface. The MIM is the most promising technique as it guides the light at nano-scale mode. The research on nanoplasmonic metal-insulator-metal (MIM) waveguides [2-3] confirmed to be a best technique for guiding the light at nano-scale. Plasmonic MIM waveguide based band-pass filters have been studied and reported in [4-5]. Different nanoplasmonic wave guiding structure s have been designed to achieve the PICs like insulator-metal-insulator (IMI) wave guiding structure , metal-insulator-metal (MIM) wave guiding structure [6] and directional coupler [7]. Because of its subwavelength nature and the maximum degree of light internment, MIM wave guiding structure has been identified perfectly suitable such systems [8]. Several surface Plasmon polaritons (SPPs) based MIM wave guiding structure devices have been demonstrated numerically, such as tooth shaped filters [9], bends [10], antenna [11], Mach-Zehnder interferometers [12], Bragg reflectors [13], plasmonic switches [14], and multiplexers [15].

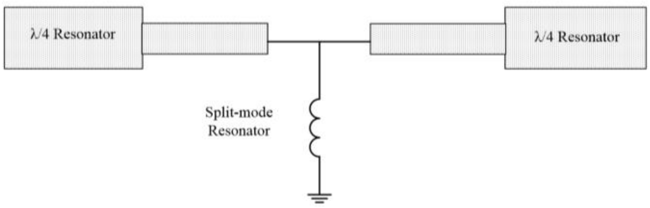

Fig. 1.Circuit structure of proposed step impedance resonator based UWB band pass filter using MIM waveguide.

The circuit structure of proposed step impedance resonator based UWB band pass filter using MIM waveguide has been shown in Fig. 1. The structure is designed with the help of two λ/4 step impedance resonators (SIR). SIR is the most promising structure for the designing of band stop and band pass filters at optical wavelengths. By using SIR the resonance can be easily changed over a frequency range by simply changing the structural parameters.

Recently UWB filters has drawn much attention in the wireless communication technology. There are lot of attractive benefits using UWB systems in the wireless communication system with required lower transmit power and higher data rates. There are lot of challenges that need to be addressed while designing the UWB filter, among them band width plays an important role. The UWB filter using split mode resonator is the most promising concept for the designing and implementation of UWB at optical wavelengths.

The band width of the UWB can be realized by the following equation:

Manuscript published on 30 September 2019
* Correspondence Author
M. Vishwanath*, Department of ECE, Koneru Lakshmaiah Education Foundation,Vijayawada, Andhra Pradesh, India. Email: visuklu@gmail.com
Habibulla Khan, Department of ECE, Koneru Lakshmaiah Education Foundation, Vijayawada, Andhra Pradesh, India.
Himani Goyal Sharma, Department of EEE, Poornima College of Engineering, Jaipur, India.

$$B.W = (\lambda_U - \lambda_L) \qquad (1)$$

Where λ_U is upper wavelength and λ_L is lower wavelength

II. DESIGN AND ANALYSIS OF SIR BASED UWB BAND PASS FILTER USING PLASMONIC MIM WAVEGUIDE

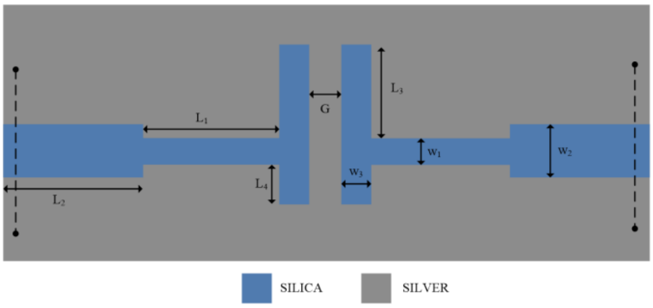

Fig. 2. Geometry of step impedance resonator based UWB band pass filter using MIM waveguide.

Fig. 2 represents the geometry of SIR based UWB band pass filter using MIM waveguide. The proposed UWB band pass filter using MIM waveguide. The proposed UWB band pass filter has been designed using most promising SIR structure. The UWB band pass filter is designed with the help of two λ/4 SIRs. The two λ/4 SIRS are separated by a gap G as shown in Fig. 2. The width and lengths of the λ/4 SIR is equal. The ports are parallel to each and with equal widths and lengths.

The proposed UWB band pass filter has been designed with the concept of MIM waveguide at optical wavelengths. The proposed UWB band pass filter using MIM waveguide has been designed with silver as an optical metal described by drude model [16] and the relative permittivity of the silver is given by

$$\varepsilon_m = \varepsilon_\infty + \frac{\omega_p^2}{j\omega(\Gamma + j\omega)}, \qquad (2)$$

Where $\varepsilon_\infty = 1.38 \times 10^{16}$ radian/ second, and T = 2.73×10^{13} radian/sec.

SiO_2 (Silica) has been utilized like an insulator ($\varepsilon_d = 2.5$). We carried out a full-wave simulation with a perfect boundary conditions. The mesh size is 5 x 5 and time step of $\Delta t = \Delta x/2c$, where c is the velocity of light in vacuum. Full-wave simulation has been carried out using CST micro-wave studio.

The dimensions of UWB band pass filter with fixed widths w_1 = 66 nm, w_2 = 106 nm, w_3 = 70 nm, length L_1 = 240 nm, L_2 = 550 nm, L_3 = 175 nm, L_4 = 109 nm and coupling gap G = 42 nm. Fig. 3 represents the UWB response of proposed plasmonic UWB band pass filter using SIR. The response is observed at optical wave lengths which ranges from (1260 nm-1675 nm). The reflection and transmission characteristics has been designed at optical wavelength E band (1412 nm). The proposed UWB band pass filter act as band pass filter from wavelength 1296(nm) to 1439 (nm). Thus the band width of proposed UWB band pass filter is B.W = 143. Thus this device can be used in the wireless communication systems.

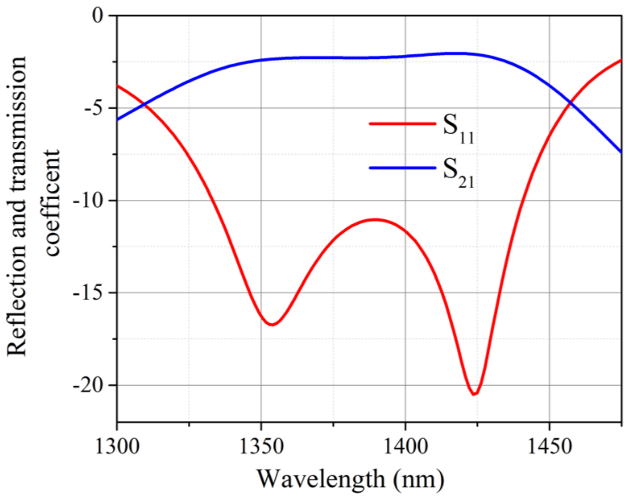

Fig. 3.Reflection and transmission coefficent of step impedance resonator based UWB band pass filter using MIM waveguide.

The variation in reflection and transmission characteristics of UWB band pass filter has been analyzed using the parametric width w_3. Fig.4 represents the variation in reflection and transmission coefficient with respect to width w_3. As the width w_3 increases the waveform shifts from left to right it means further it can be designed at any wavelength by changing width w_3. The gain of UWB band pass filter is minimum of 22dBi and maximum of 25dBi.

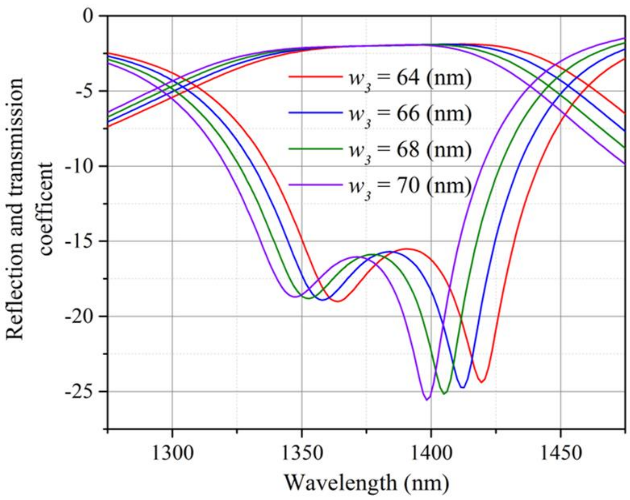

Fig. 4.Variation in reflection and transmission coefficients with wavelength as a function of width w_3.

The variation in reflection and transmission characteristics of UWB band pass filter has been analyzed using the parametric width w_2. Fig.5 represents the variation in reflection and transmission coefficient with respect to width w_2. As the width w_2 decreases the gain of the UWB band pass filter increases, further w_2 can be used for the changing gain depending on the requirement. Thus this UWB band pass filter acts as a universal device which can be used for multiple wireless applications. Fig. 6 represents the field distribution of UWB band pass filter using plasmonic MIM waveguide at λ = 1412 (nm).

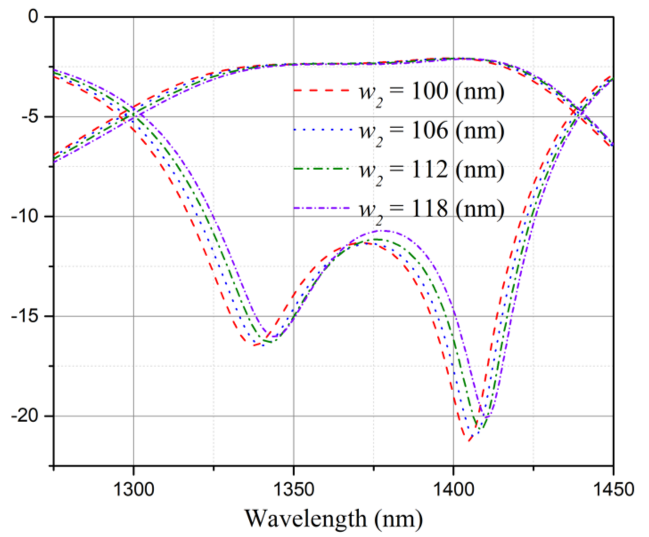

Fig. 5.Variation in reflection and transmission coefficients with wavelength as a function of width w_2.

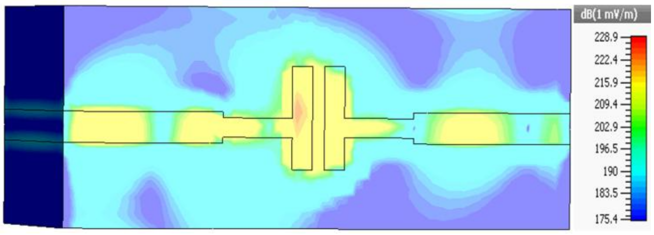

Fig. 6.field distribution of step impedance resonator based UWB band pass filter using plasmonic MIM waveguide at wavelength λ = 1412 (nm).

III. CONCLUSION

We have numerically analyzed step impedance resonator based UWB band pass filter using plasmonic MIM waveguide in this article. The ultra wide-band (UWB) band pass filter has been designed by introducing a shot-circuited stub to implement the shunt inductance between two quarter wavelength (λ/4) step impedance resonators. As the width w_2 decreases the gain of the UWB band pass filter increases, further w_2 can be used for the changing gain depending on the requirement. As the width w_3 increases the waveform shifts from left to right it means further it can be designed at any wavelength by changing width w_3. The field distribution of UWB band pass filter is also observed in this article. The plasmonic UWB has been realized using full wave simulation by using commercially available CST microwave studio software. The UWB band pass filter can further be realized in the development of wireless communication systems and photonic integrated circuits (PICs).

ACKNOWLEDGMENT

The authors acknowledge support by the Koneru Lakshmaiah Education Foundation, Guntur, Andhra Pradesh.

REFERENCES

1. R. Zia, M. D. Selker, P. B. Catrysse, and M. L. Brongersma, “Geometries and materials for subwavelength surface plasmon modes,” J. Opt. Soc. Am. A, vol. 21, no. 12, pp. 2442-2446, July 2004.
2. Z. Han, “Ultracompact plasmonic racetrack resonators in metal-insulator-metal waveguides,” Photonics Nanostructures - Fundam. Appl., vol. 8, no. 3, pp. 172-176, Apr. 2010.
3. S. Mokkapati, D. Saxena, N. Jiang, H. H. Tan, and C. Jagadish, “Plasmonic cavities for increasing the radiative efficiency of GaAs nano wires,” 2014 Conf. Optoelectron. Microelectron. Mater. Devices, COMMAD 2014, vol. 1, pp. 244-245, Dec. 2014.
4. J. Qi et al., “Independently tunable double Fano resonances in asymmetric MIM waveguide structure,” Opt. Express, vol. 22, no. 12, pp. 14688-14695, Jun. 2014.
5. O. Tsilipakos and E. E. Kriezis, “Microdisk resonator filters made of dielectric-loaded plasmonic waveguides,” Opt. Commun., vol. 283, no. 15, pp. 3095-3098, 2010.
6. S. R. Mirnaziry, A. Setayesh, and M. S. Abrishamian, “Design and analysis of plasmonic filters based on stubs,” J. Opt. Soc. Am. B, vol. 28, no. 5, p. 1300-1307, May 2011.
7. Ravi Kiran Chityala and Vinay Kumar Chandubatla, “Concurrent dualband nanoplasmonic MIM slot waveguide based directional Coupler,” International Jour. of Elect. And Elect. Rese., vol. 7, no. 1, pp. 217-219, May 2019.
8. L. Wu, P. Bai, X. Zhou, and E. P. Li, “Reflection and transmission modes in nanohole-array-based plasmonic sensors,” IEEE Photonics J., vol. 4, no. 1, pp. 26-33, Feb. 2012.
9. Xian-Shi Lin and Xu-Guang Huang, “Tooth-shaped plasmonic waveguide filters with nanometeric sizes 1,” Opt. Lett., vol. 33, no. 23, pp. 2874-2876, Dec. 2008.
10. A. M. Heikal, M. F. O. Hameed, and S. S. A. Obayya, “Coupling characteristic of a novel hybrid long-range plasmonic waveguide including bends,” IEEE J. Quantum Electron., vol. 49, no. 8, pp. 621-627, Aug. 2013.
11. Ravi Kiran Chityala, “Nanoplasmonic concurrent dual band antennas using metal-insulator-metal step impedance resonators,” Microwave and Optical Tech. Lett., Feb.2019.
12. J. Gosciniak, L. Markey, A. Dereux, and S. I. Bozhevolnyi, “Thermo-optic control of dielectric-loaded plasmonic Mach-Zehnder interferometers and directional coupler switches,” Nanotechnology, vol. 23, no. 44, pp. 444008 (1-9), Oct. 2012.
13. S. Zhu, H. S. Chu, G. Q. Lo, and D. L. Kwong, “CMOS-compatible plasmonic bragg reflectors based on cu-dielectric-si structures,” IEEE Phot. Tech. Lett., vol. 25, no. 21, pp. 2115-2118, Nov. 2013.
14. Y. B. Zheng, et. al, “Incident-angle-modulated molecular plasmonic switches: A case of weak exciton-plasmon coupling,” Nano Lett., vol. 11, no. 5, pp. 2061-2065, Apr. 2011.
15. V. Liu, Y. Jiao, D. A. B. Miller, and S. Fan, “Design methodology for compact photonic-crystal-based wavelength division multiplexers,” Opt. Lett., vol. 36, no. 4, pp. 591-593, Feb. 2011.
16. E. D. Palik, Handbook of Optical Constants of Solids. New York, NY,USA: Academic, 1985.G. O. Young, “Synthetic structure of industrial plastics (Book style with paper title and editor),” in *Plastics*, 2nd ed. vol. 3, J. Peters, Ed. New York: McGraw-Hill, 1964, pp. 15–64.