A Highly-Efficient and Compact Surface Plasmon Polaritons High-Pass Filter based on MIM waveguides

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Abstract: This letter presents design and simulation results of a highly-efficient and compact plasmonic high-pass filter based on a MIM waveguide. Numerical results reveal that by tailoring structural parameters, desired cut-off wavelength can be chosen.
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1. Introduction

With the skyrocketing demand in high-performance broadband networks and data storage for telecommunications, the need for development of fast and efficient optical circuits are becoming vitally important. The interaction of light with nanostructured materials provides a plethora of applications in sensing and communications that may contribute positively to a variety of modern-day society issues. First of all, they can enable ultra-fast connectivity for data centers, optical router as well as supercomputers. Then, it makes a huge impact through reduced optical power requirements (less CO2 emissions and reducing global warming). That is because, due to emergence of new applications such as industry 4.0, autonomous vehicles, remote robotic surgery, augmented reality (AR) and so forth, it is expected that by 2030, up to 25% of the global energy generation may be utilized by computer-based technologies. It is found that plasmonics based devices may contribute to remarkably reduce size, and improve efficiency and speed. In fact, one of the most effective ways to bypass the diffraction limit and thus, enabling light manipulation and localization of electromagnetic field at subwavelength scale is to employ materials with negative dielectric permittivity. This characteristic of materials can be found below the plasma frequency, resulting in exceptional electromagnetic mode confinement at the interface of a metal and a dielectric, known as surface plasmon polaritons (SPPs), that may pave the way for integration of photonics and CMOS-based electronics on the same chip. The plasmonic technology can be considered as a platform for next generation of optical interconnects, allowing integration of photonics and electronics components on the same chip with small footprint, and in an energy-efficient and cost-effective approach. Therefore, development of miniaturized and high-efficiency of optical circuits based on plasmonics effect may be of special interest [1- 3]. There are two types of plasmonics waveguide; insulator-metal-insulator (IMI) and metal-insulator-metal (MIM), however, MIM may be preferred for telecom applications, because of its great mode confinement and almost acceptable level of propagation loss. Consequently, various optical circuits based on MIM plasmonic waveguide such as switches [4], sensors [5], light-absorbers [6] and so on have been demonstrated. Among miscellaneous components, optical filters, which pass light at a specific wavelength, while attenuating others, are considered to be of great importance due to their extensive applications in flow cytometry, wavelength-division multiplexing (WDM) and De-Multiplexing, environmental monitoring, and fluorescence microscopy. Consequently, we have designed and numerically simulated a novel type of plasmonic high-pass wavelength filter based on MIM waveguide that functions in the near-infrared (NIR) range of the electromagnetic spectrum, and is extremely efficient and compact.

2. Design and Numerical Results of a Novel Plasmonic High-Pass Wavelength Filter

Figure 1(a) shows the schematic configuration of the new high-pass plasmonic wavelength filter. The structure is made of two layers of silver, whose complex permittivity has been taken from tabulated data of Johnson and Christy [7]. The insulator medium is assumed to be air.

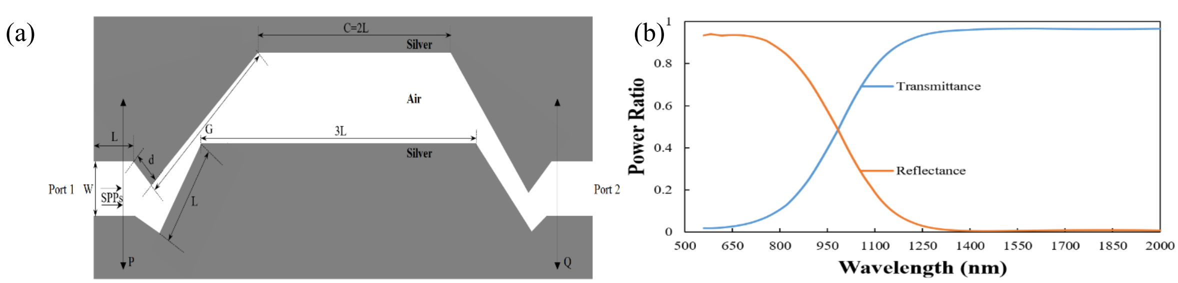

Fig. 1. (a) Schematic configuration of proposed plasmonic high-pass wavelength filter. (b) Transmission and reflection spectra.

We have used CST MWS, to obtain the numerical results in this letter. In the software tool, the frequency domain solver that is based on finite element method (FEM) is applied with the following properties. The grid sizes are set to be 5 nm $\times$ 5 nm along the x and y directions, respectively. The width of the waveguide is chosen in a way that is significantly smaller than that of the incident light wavelength, to ensure that only fundamental TM mode may propagate within the waveguide, that is excited by a dipole source. As it can be seen from the Fig. 1(a), two power monitors P and Q are located at an equal distance from the central waveguide to detect the transmitted and incident power. The transmission is determined as T=Pout/Pin. Figure 1(b) demonstrates the simulation results of the transmittance and reflectance profile of the high-pass wavelength filter for W=40 nm, which describes the width of the waveguide, L=50 nm indicates the distance between the input port of the waveguide and the left edge of the ramp, d=20 nm, represents the initial length of the ramp, G= 60 nm is the length of the second part of the ramp. The transmission and reflectance spectra of the high-pass wavelength filter is displayed in Fig. 1(b). The cut-off wavelength for a high-pass transmission profile is defined where the transmission reaches 1% [8], which is 566 nm.

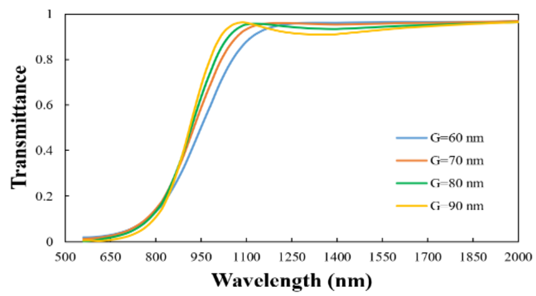

Fig. 2. The transmission spectra as a function of the wavelength for the suggested high-pass wavelength filter with various values of G

Figure 2 illustrates the transmission profile of the plasmonic high-pass wavelength filter for various lengths of G= 60 nm, 70 nm, 80 nm and 90 nm, while all other parameters are the same as in Fig. 1(b). It is clear that by increasing in the length of the second part of the ramp, G, one can easily tune the cut-off wavelength. For example, as G increases from 60 nm to 90 nm, the cut-off wavelength moves from 566nm to 665 nm. Moreover, we have found that changing the width of the input waveguide port, W, may provide an alternative solution for adjusting the desired cut-off wavelength of the suggested high-pass filter.

3. Conclusion

In conclusion, we have designed and simulated an-ultra compact and highly-efficient high-pass wavelength filter based on MIM waveguide that works at the near-infrared (NIR) range. The suggested filter is considerably more compact and efficient in comparison with previous research studies [9, 10], and may find applications in photonic integrated circuits (PICs) and in on-chip optical circuits.

4. References

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