A Reconfigurable and Ultra-Compact Plasmonic Filter based on MIM Waveguides at Optical Channels

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Abstract: This paper reports design and simulation of a tunable highly-efficient reconfigurable plasmonic filter based on MIM waveguides. Simulation results shown that by adjusting structural parameters, the device can work as a multipurpose optical circuit.
OCIS codes: (240.6680) Surface plasmon; (130.7408) Wavelength filtering devices.

1. Introduction

Emerging from the interaction of free electrons of plasma gas coupled to electromagnetic surface waves at a metal-dielectric interface, surface plasmon polaritons (SPPs) provide a unique contribution to advancement of photonic integrated circuits (PICs) [1]. SPPs' capabilities to overcome the traditional diffraction limit, carry and propagate both electrical and optical signals, as well as guide and confinement of light at deep subwavelength scales, make plasmonic-based structures a promising platform for integrating with next generation of photonic integrated circuits (PICs), which are both highly compact and highly efficient. Generally, there are two types of plasmonic waveguides; insulator-metal-insulator (IMI) which offer low propagation loss with low mode confinement, while metal-insulator-metal (MIM), thanks to its strong confinement of light with acceptable level of propagation loss, is considered to be incorporated into PICs. Therefore, various types of optical devices based on MIM plasmonic waveguides such as sensors [2], slow-light [3] and so forth are suggested. Optical filters, because of their wide range of applications in wavelength-division multiplexing (WDM) in optical signal processing, machine vision systems, fluorescent microscopy, and dispersion compensation are considered to be of great importance. On the other hand, size, efficiency, and potentially, the ability to provide several functions in a single structure are of great interest in the evolution of next generation of PICs. Thus, based on our previous studies [4, 5], we have proposed a reconfigurable and highly compact and efficient wavelength filter based on MIM waveguides, operating at technologically important telecom wavelengths. Numerical results reveal that by tuning the geometrical parameters, the proposed device can operate as a flat-top bandpass filter, a dual-band bandpass filter, as well as a short-wavelength cut-off filter, while maintaining a high level of efficiency.

2. Design and Simulation Results of proposed Reconfigurable Plasmonic Filter

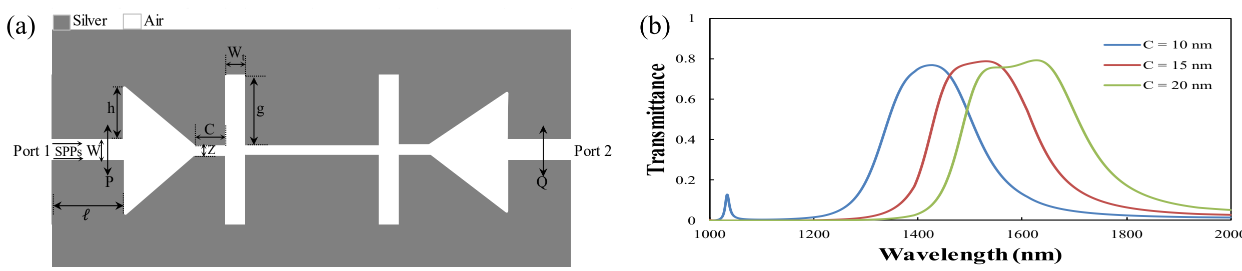

Fig. 1. (a) Schematic configuration of proposed multifunctional plasmonic structure. (b) Transmission spectra of the flat-top band pass plasmonic filter for various coupling distance of C.

Figure 1(a) shows the schematic configuration of the proposed nanoplasmonic wavelength filter. The structure is made of two layers of silver, whose complex permittivity has been taken from tabulated data of Johnson and Christy [6]. The insulator is air. The width of the waveguide W is set to be significantly smaller than the wavelength of the incident light to ensure that only fundamental TM mode can exist in the device, which is excited by a dipole source. The grid sizes are set to be 5 nm × 5 nm along the x and y directions, respectively. Two power monitors P and Q, respectively, are chosen to be located at equal distance from the central waveguide in order to detect the incident and transmitted power. The transmission is described as T=Pout/Pin. We have utilized a commercial EM software tool, CST MWS, to acquire the numerical results throughout this letter. The flat-top bandpass is realized by modulating the coupling distance C between the triangles and stub resonators, in which their coupling gives rise to a flat-top bandpass band. It should be pointed out that the focus of our study is to form a flat-top bandpass at optical channels and hence, all parameters are optimized for the best possible performance, considering the resonance wavelength position, size, and the efficiency of the structure. Figure 1 (b) exhibits the transmission spectra as a function of wavelength for the different coupling distances C=10 nm, 15 nm, and 20 nm, whereas W=10 nm denotes the width of the waveguide,

ℓ=100nm indicates the distance between the port and the left side of the triangle, h=90 nm is the height of the triangles, g=90 nm represents the length of the stubs, and W_t =20 nm is the width of the stubs, and Z=5 nm marks the width of the bus waveguide. It can be seen that by adjusting the distance between the triangles and stubs, the transmission of the flat-top bandpass can be easily tuned. For instance, the transmission efficiency for d=15 nm is more than 77%, while the intrinsic (ohmic) loss is accounted for more than 22.5%. The proposed filter here greatly enhanced the efficiency of the structure compared to graphene plasmonic flat-top bandpass filter [7].

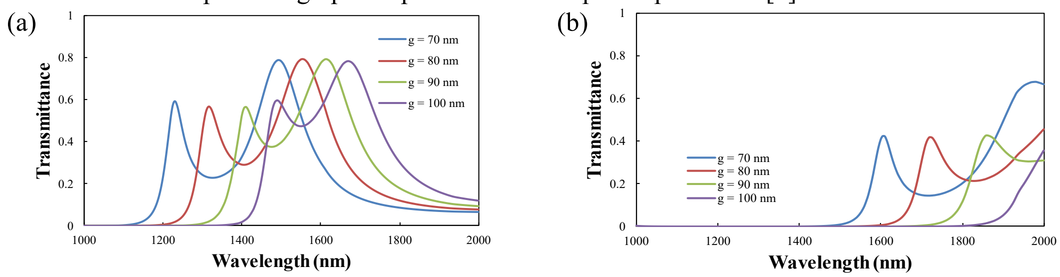

Fig. 2. (a) Transmission spectra as a function of wavelength for the suggested dual band pass plasmonic filter. (b) Transmission profile of the short-wavelength cut-off filter.

Figures 2 (a) demonstrates the transmission profile of the suggested dual-band bandpass plasmonic wavelength filter while the distance between upper and lower segments is chosen to be Z=10 nm and coupling distance is set to C=50 nm and Wt =10 nm, while all other parameters are kept the same as Fig. 1(a). It is clear that the structure does have two resonances at telecom wavelengths. For example, for g=80 nm, the two resonance wavelengths are 1316 nm and 1554.6 nm with transmission efficiencies of more than 56% and 79%, respectively. Furthermore, the resonance wavelengths can be easily tuned by modulating the length of the stubs. It is found that increasing g cause resonance wavelengths to be shifted towards longer wavelengths, while reducing g leads to shifting of the resonance wavelengths towards shorter wavelengths. The quality factor is defined as $Q = \frac{\lambda_{resoancne}}{FWHM}$ and is found to be 7.47 and 17.93, for the resonance wavelengths, respectively. Next, we investigate the effect of setting Z=Wt=5 nm, while all other parameters are the same as the Fig. 2 (a). Figure 2 (b) shows the transmission spectra of the short-wavelength cut-off filter for different values of the stubs' lengths. The cut-off wavelength is where the transmission is equal to 1% [4], which is found to be 1612 nm for g=80 nm, which clearly exhibits that the transmission is close to zero for a wide range of wavelengths. It is realized that by increasing the stubs' length, the cut-off wavelength is shifted towards longer wavelength. Finally, it is worthwhile to mention that the structure can also work as a nearly perfect absorber by modifying the geometrical parameters.

3. Conclusion

In conclusion, we have proposed a highly-compact yet efficient multifunctional plasmonic wavelength filter that operates at technologically important telecom wavelengths. The suggested plasmonic device is considerably more compact and efficient compared with recently proposed plasmonic structures [5, 7]. We thus hope that the suggested plasmonic device may pave the way for realization of fast, highly-efficient and miniaturized devices for on-chip applications and in point-of-care (POC) and medical diagnostic instruments.

4. References

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