

# Design a 90 Degree Splitter WDM using Plasmonic Technique

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## ABSTRACT

The two channels of plasmonic filter structure are selective based on a nanocavity that proposed and numerically simulated by using the finite element method by using COMSOL4.4 software package. The required filtered wavelength can be investigated by selecting an appropriate length of the nanocavity and refractive index of dielectric that filled nanocavity. Two output channels structure based on two perpendicular nanocavities that proposed to design a subwavelength plasmonic splitter, and demultiplexer operating around 770 nm and 900 nm with the maximum transmittance of the two bands is 79% for channel1 and 84% for channel2. Three materials used to build structure, metal used as a silver and two types of dielectric quartz with refractive index 1.5 and erbium with refractive index 1.45.

## General Terms

WDM, plasmonic (WDM)

## Keywords

Plasmonics, Surface plasmon poltration, Localized surface plasmon, resonance wavelength,

## 1. INTRODUCTION

Electromagnetic waves incident on metal-dielectric interfaces and combined to propagate free electron oscillations in the metals, known as surface plasmon polaritons (SPPs), are considered as the technique that help to realization of highly integrated optical circuits because they can considerably the solution for the classical diffraction limit of light and manipulate light on the nano scale [1–4]. Metal-dielectric-metal (MDM) waveguide have special features because of its high confinement of the light, simplicity, and convenience for fabrication and integration into optical circuits. The form of functional plasmonic MDM structures have been implemented and fabricated, such as U-shaped waveguides [5], splitters [6], switches [7], [8], Y-shaped combiners [9], couplers [10], and M-Z interferometers [11], [12]. There is recognition that the communication between electronic systems constitute the main constraint to increase system speed and speed of data transfer. There is optimism that the optical communication hold great promise in eliminating congestion in the current connections because of characteristics that stem from the inherent parallelism of optics. Wavelength division technology [13]. Wavelength selection technique is one of the main technologies in the fields of optical communication. Candidates on the basis of nanocavities, [14], coupled cavity side [15], teeth or heel structure [16] - [17] has recently been investigated. However, All filters wavelength in previous research, a structure in the form of a cavity or stub which often reflect either the passband or stop it. The reflected or transmitted waves in such structures are in the same a single channel is difficult for you

to be separated from each other. However, the WDM, which is divide the light into several channels, and is a unit of light divider is the basic unit in WDM system. Recently, Gan *et al.* [18], [19] Suggested a plasmonic surface-wave divider based on a bidirectional subwavelength slit, and suggested split spectrally selective with metal insulating metal surface plasmon waveguide. However, all the dividers structures mentioned above have high volumes over several waves. Given the perspective of the integration of the components of the traitor within several micrometers, and people need to reduce the size of devices to meet the demand of high integration. In this paper, subwavelength SPP splitters and demultiplexers structures based on MIM nanocavities are proposed and demonstrated numerically by using the finite element method (FEM) in software package COMSOL4.4. The good feature of plasmonic demultiplexer used to solve huge size of optical integrated circuit problem and large size of optical (WDM) the principle of plasmonic should be used. With the development of artificial fabrication, plasmonic (WDM) devices may be fabricated and applied in future all-optical communications and integrated optical circuits. As an important plasmonic waveguide, the metal-dielectric-metal (MIM) structure has high confinement of light with an acceptable length for SPP propagation. Plasmonic wavelength demultiplexers (WDMs), which can filter specific wavelengths in different channels, will play very important role in the future all-optical communication systems. Figure 1 shows the two outputs plasmonic (WDM)

## 2. NANOCAVITY MODEL

Figure (1) shows the structure schematic of the nanocavity composed of three wide waveguides and two a narrow waveguide filled with quartz and erbium material. The structure can be deals with three MIM waveguides with different widths. Because the narrow width of MIM waveguide is much smaller than that of the wide MIM waveguide; here, has been called the narrower waveguide as nanocavity.

The dielectric constant  $\epsilon_m$  of silver can be compute based on applicable experiment data and a more detailed fit of the data reported by Johnson and Christy for silver [22]. The absorption band noted in the imaginary part of the dielectric constant between 0.3 $\mu$ m and 0.4 $\mu$ m that's because of absorption which is occurred in d-band electrons. The effective index of the waveguide decreases with the increasing of the width of waveguide  $w$  at the same wavelength. Therefore, the effective index  $n_{eff2}$  of the nanocavity part can be larger than  $n_{eff1}$  of the wide MIM waveguide part due to the difference of the width of the two waveguides and mediums filled in. The waves will propagated into the nanocavity because its higher effective index, when SPP waves propagate along the interface between metal and air.

The wave transmitted into the nanocavity will be partly reflected at two ends of the nanocavity, because of the index differences between  $n_{eff2}$  and  $n_{eff1}$ .

### 3. EFFECT LENGTH OF NANOCAVITY

It can be seen that the peak wavelength is proportional to the length of the nanocavity, which can be seen in the simulation results (see figures 2 a, b) in section five (using COMSOL4.4 software). Based on the theoretical analysis for effective refractive index, the operating wavelength of the proposed structure can be effectively modulated by altering the length of the nanocavity, and the effective index of surface plasmon polaritons (SPPs) in the cavity, which is determined by its width. Has been noted the transmission wavelength of each channel has been a linear relationship with length of the nanocavity and exhibits redshift while increasing the value of  $L$ , which is in conformity with the solution of Eq. below [21].

$$\lambda_m = \frac{2n_{eff} L}{(m - \phi\pi/\pi)}$$

Therefore, the required wavelength in each channel is obtained by properly selecting the specific parameters of the structure, such as the length or width of the nanocavity.

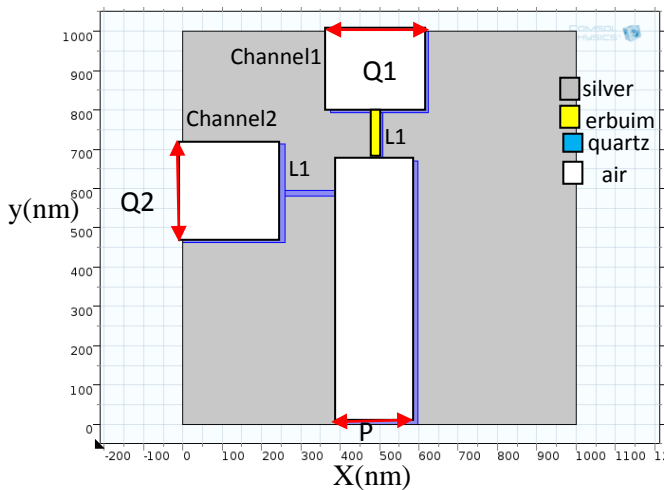


Fig. (1): schematic of plasmonic splitter and demultiplexer structure (top view).

### 4. EFFECT WIDTH OF NANOCAVITY

Above equation indicates the resonance wavelength behavior of each nanocavity (channel of the demultiplexing structure) depends mainly on two parameters: the length of the nanocavity, and the effective index of SPPs in the nanocavity, which is determined by its width. To fully understand how the width of the nanocavity structure influences on the SPPs propagation, Has been noted the width  $w$  at various wavelengths of the incident light are calculated and shown in figures 3 a, b.

One can see that the resonance wavelength of surface plasmon decreases with increasing width  $w$  of nanocavity. The width of nanocavity has been noted very narrow, but the light propagate through it, because the input light should be p-polarize or TM polarize, therefore create surface plasmon polariton and propagated through the nanocavity despite the wavelength of electromagnetic wave greater than the narrow nanocavity. In the classical optical communications the

incident light can not propagate through nano scale because diffraction limit. The problem of diffraction limit can overcome by plasmonic technique that used in this paper.

### 5. RESULTS AND DISCUSSIONS

The electric field  $E$  and magnetic field  $H$  are calculated along the interface of (WDM) silver metal with dielectric in the form MDM waveguide. It can be seen that the intensity of electric field  $E$  is maximum value at the resonance wavelength and decreased exponentially to the minimum value away from interface. In this section will show the propagations of field  $E$  and the demultiplexing effect for two monochromatic waves with different wavelengths of 770 nm and 900 nm launched into the  $1 \times 2$  wavelength demultiplexing structure. However, one can see that the wave with the wavelength of 770 nm is just passing through the nanocavity cavity of channel 1, while the wave with the wavelength of 900 nm is just transmitting from the nanocavity of channel 2. Figure (4a,b) depict the field distributions of normal electric field  $E$  with launching continuous waves at 770 nm and 900 nm, for channel one and two respectively. Figure (4) as an application of the wavelength-selecting properties, this aperture can be exploited to construct a nano plasmonic wavelength demultiplexer. The field distributions are in good agreement with the transmission spectra in figure (5).

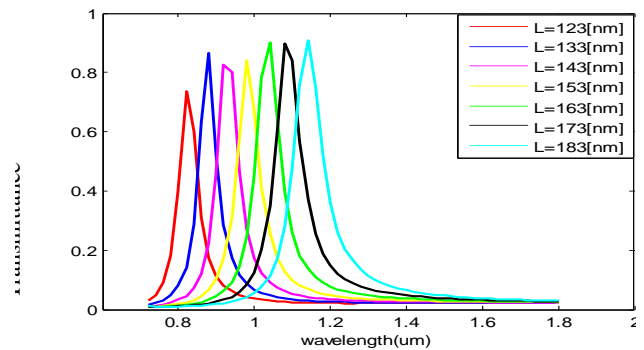


Fig. (2,a): Central wavelength at different length of nanocavity

The following table represent the length of nanocavity versus resonance wavelength

Table 1.length of nanocavity versus resonance wavelength

Length of nanocavity (nm)	Resonance wavelength
123	0.82
133	0.88
143	0.92
153	0.98
163	1.04
173	1.08
183	1.14
193	1.2
203	1.24
213	1.3

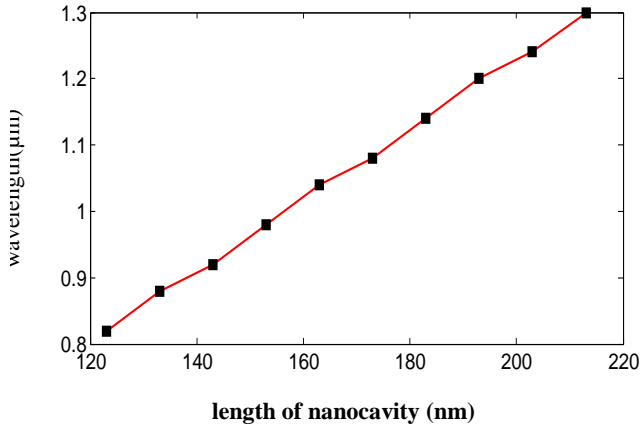


Fig . (2,b): wavelength function of length of nanocavity

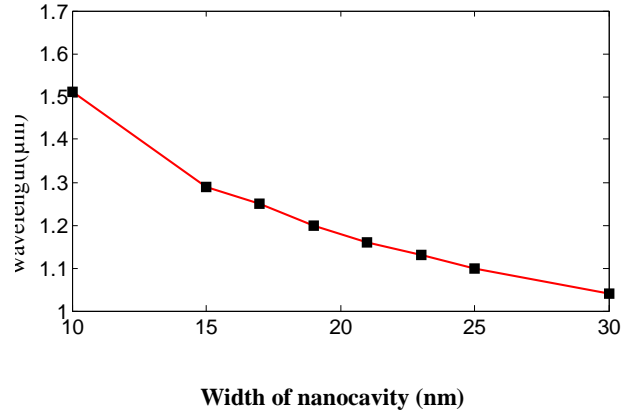


Fig . (3,b): Inversely relationship between width of nanocavity and wavelengths

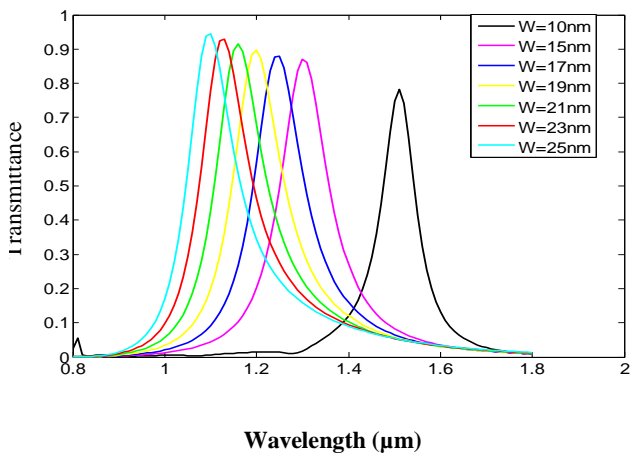


Fig . (3,a) Relationship the wavelength of the incident light and width of nanocavity

The following table data for the width of nanocavity versus resonance wavelength.

Table 2.Width of nanocavity versus resonance wavelength

Width of nanocavity (nm)	Resonance wavelength
10	1.51
15	1.29
17	1.25
19	1.2
21	1.16
23	1.13
25	1.1
30	1.04

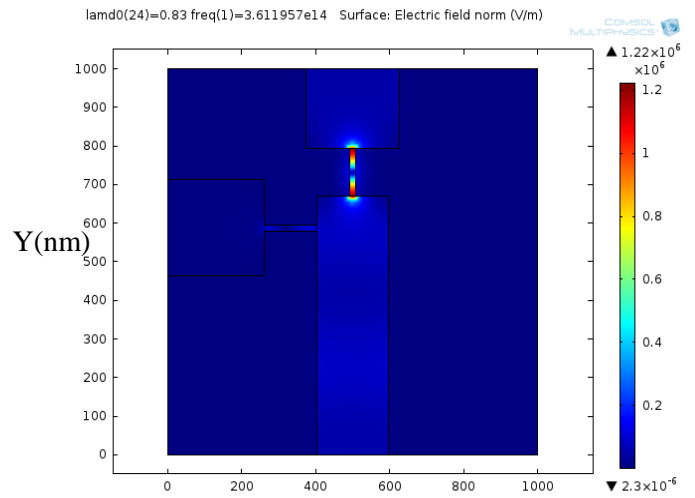


Fig . (4a)The contour profiles of surface electric field norm E of the wavelength demultiplexing structure at 770 nm

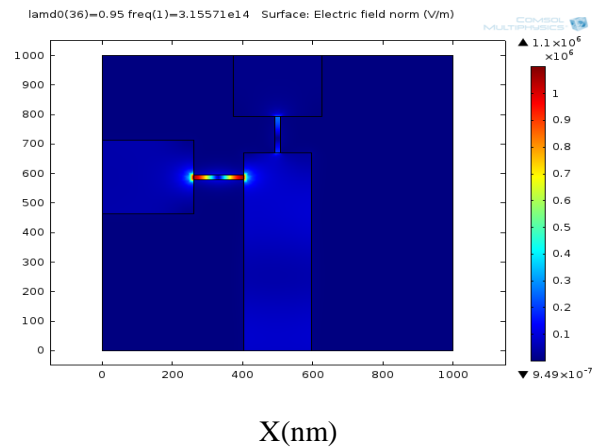


Fig . (4b)The contour profiles of surface electric field norm E of the wavelength demultiplexing structure at 900 nm

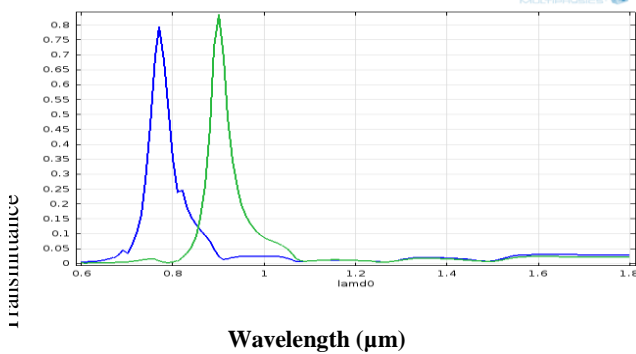


Fig. (5): Transmission spectra of the two output channels plasmonic splitter and demultiplexer structure .

## 6. CONCLUSION

In this paper, the resonance electric field of the light that propagated in the nanocavity of the plasmonic demultiplexer is investigated, when changing the nanocavity length and width. From simulation results, it is found that the charge density is maximum at the resonance wavelength cause the electric field to be enhanced and decayed exponentially. Has been conclude the two output channels selective plasmonic filter structure dependent on the distance and angle between them. The required filtered wavelength can be conclude dependent on an appropriate selecting the length of nanocavity. Two output channels' structure is proposed to design a subwavelength plasmonic splitter and demultiplexer, based on two nanocavity waveguides operating around 770 nm and 900 nm at special dimensions for resonators and ,there is possibility to chan Wavelength ( $\mu\text{m}$ ) and width of resonators and then change the resonance wavelength. The FEM simulation results reveal that this new structure is suitable for wideband wavelengths demultiplexing. The transmission spectra at the outputs of the two channels. One can see that channel1 and channel2 are selected 770 nm and 900 nm bands with the length nanocavity of channel1 is  $L1$  nm and channel2 is  $L2$  nm as shown in figure (1) . The transmission bands of 770 nm and 900 nm are selected, and the maximum transmittance of the two bands is 79% for channel1 and 84% for channel2. From the work conclude the small dimensions of proposed structures best choice for the fabrication of all-optical integrated devices and circuits for optical computing and communication, especially in WDM systems in the nanoscale .

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