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A proposal for a demultiplexer based on plasmonic metal–insulator–metal waveguide-coupled ring resonator operating in near-infrared spectrum

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ABSTRACT

In this paper, a proposal is investigated and simulated for a demultiplexer based on plasmonic metal–insulator–metal (MIM) waveguide-coupled ring resonators working in the near-infrared region ($\lambda = 1310$ and $\lambda = 1530$). The proposed structure is made up of SiO_2 as insulator embedded in silver as the metal layer. It is possible to realize demultiplexing function between desired wavelengths using the proposed structure with appropriate geometrical parameters for slits and ring resonators. Three-dimensional simulations, utilizing the finite-difference time domain algorithm, are used to obtain demultiplexing function with minimum ratio equals to 9.59 ($[Mean|E_{Port\,B}|^2]/[Mean|E_{Port\,A}|^2] = 9.59$ for source is on at $\lambda = 1310$ and $[Mean|E_{Port\,A}|^2]/[Mean|E_{Port\,B}|^2] = 38.63$ for source is on at $\lambda = 1530$). Furthermore, the size of the device is in the range of hundred nanometers as its major advantage to realize compact plasmonic integrated circuits.

1. Introduction

Surface plasmon polaritons (SPPs) are propagating waves that travel along a metal–dielectric interface due to interactions of free electrons in the metal side with the incident photons from the dielectric side, which result in exponentially decaying field profile in the both sides [1,2]. The unique property of SPPs are their lateral confinement and guided transportation of electromagnetic energy in a sub-wavelength resolution, which can overcome the diffraction limit, as the known obstacle in conventional optics, to achieve nanoscale photonic devices usable for high integration purposes. Hence, photonic devices based on SPPs have been arisen as the appropriate alternative for nanophotonics applications. Recently, various different MIM plasmonic waveguide [3], insulator–metal–insulator (IMI) waveguides [4] and combined waveguides [5] structures have been investigated numerically or experimentally. Among these waveguides, MIM waveguides, in particular, exhibit low transmission loss and strong localized field confinement [6–8], and have led to the development of sub-wavelength photonic devices such as couplers [9–12], splitters [13,14], Mach–Zehnder interferometers [15,16], multimode-interferometers [17], U-shaped waveguides [18], Y-shaped combiners [19], photonic bandgap structures [20], Bragg mirrors [21] and filters [22–24]. Among these types of waveguides, MIM waveguides, in particular, demonstrate strong localized field confinement and low transmission loss [6–8]. These structures and devices are fundamentally composed of coupled waveguides with

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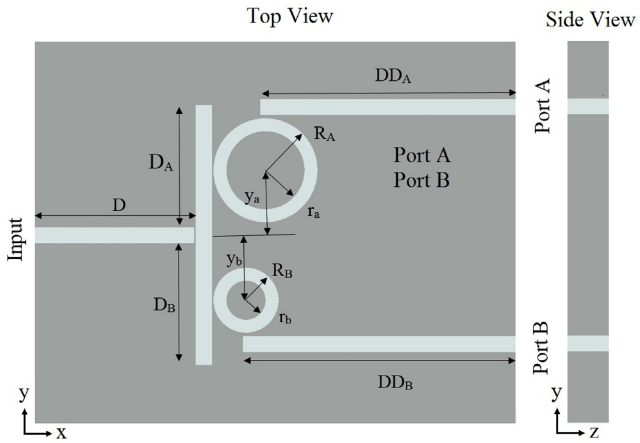

Fig. 1. Schematic illustration of the MIM waveguide-coupled ring resonator.

Table 1
Geometrical parameters of structure.

Symbol	Value (nm)
D	500
D_A	400
D_B	400
DD_A	800
DD_B	850
R_A	160
r_a	120
R_B	100
r_b	60
y_a	200
y_b	200

resonators. Optical multiplexer and demultiplexer are important devices that are widely used in optical communication systems. The optical multiplexer receives several signals with different wavelengths from multiple input ports and transmits a single signal which comports all the input wavelengths. The demultiplexer separates two or more different signals from each other and transmits each one to the different output ports. It is well known that nanoscale structures can be used in designing compact integrated optical circuits. Accordingly, demultiplexers are one of the important devices which can be employed in plasmonic structures such as plasmonic waveguides in a subwavelength dimension [25,26]. recently, various designing for demultiplexers are repored such as metal–insulator–metal waveguide coupled with a stub resonator that operate in $\lambda = 900–1100$ nm [11], plasmonic demultiplexers which consist of concentric grooves on a gold film that operate $\lambda = 800$ nm [27], Tunable multi-channel wavelength demultiplexer based on MIM plasmonic nanodisk resonators in near-infrared spectrum, and based on gold nanorings arrays [12]. There is another approach to design plasmonic demultiplexer based on gold nanorings arrays by localized surface plasmon resonance (LSPR) [28]. The fundamental topic here is the operating spectrum of the proposed device that can be realized by nano ring resonator that operates at original $\lambda = 1310$ and communication $\lambda = 1550$ wavelengths. There is a great interest to produce integrated photonic devices that are able to work at near infrared region (NIR) which is the most important and practical optical communication spectrum.

The following short statement will reveal this paper step by step: in Section 2 the proposed structure of demultiplexer and its theory are introduced. In Sections 3 and 4, the paper is finalized by discussing the obtained results and concluding.

2. The proposed structure

Fig. 1 shows schematic of the structure consisting two horizontal and one vertical MIM waveguides coupled to two ring resonators with different sizes. The metal that used in the structure is silver (Ag) and the dielectric material is SiO_2, where the considered optical properties of silver have been based on Johnson–Christy constants [29,30]. One end of each horizontal waveguide is sealed and the other one works as a device port whereas the both ends of the vertical waveguide are sealed. The geometrical parameters of the device are given in Table 1. To ensure only the fundamental transverse magnetic (TM) mode excitation in the MIM waveguide, the widths 'w' of the waveguides and ring resonators are fixed at 45 nm [31].