Multi-wavelength Switching Using Hybrid Plasmonic Add/drop Multiplexer

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Abstract

In this study, the novel device hybrid plasmonic add/drop multiplexer (HPAM) by surface plasmon polariton (SPPs) mechanism is demonstrated. Hybrid plasmonic add/drop multiplexer is used to optical multiwavelength switching networks make potential operator to generate and access of WDM/DWDM network. Methodology, the finite difference time domain (FDTD) techniques is applied by OptiFDTD programming which an experiment based on the characteristic of devices and schematic model design. Consequences, Au coupled provides a SPP mechanism operated on Add/drop ring multiplexer with multiwavelength switching. As a result, four wavelength users were selected 0.7, 0.8, 0.9, and 1 μm with a various size of SPP ring Au coupled. The high Q factor (28,500), FSR = 1.4 THz and FWHM at-3dB = 10 nm. A variety of applications, such as sensors, optical switching, and optical computation can be applied by plasmonic polariton mechanism.

Keywords: Hybrid plasmonic add/drop multiplexer, Multiwavelength switching, Surface plasmon polariton.

1. Introduction

The future networks with high transmission capacity, compactness by multilayer interconnection, and highly fast optical switching are greatly required. In order to enhance the capacity of an optical interconnect link as required, an effective solution is utilizing advanced multiplexing

technologies such as wavelength division multiplexing (WDM), polarization division multiplexing (PDM), spatial division multiplexing (SDM), etc. Conventionally, the multiwavelength switchable function of the fiber laser is determined by the characteristics of the comb filter. Recently, multiwavelength fiber lasers have been widely applied in optical measurement, coherent pulse synthesis, optical spectroscopy, dense wavelength division multiplexed (DWDM) fiber communication systems, fiber optic sensors, and microwave photonics systems [1-4]. Especially, the use of multiwavelength photonic and multiwavelength erbium-doped fiber lasers (EDFL) has been investigated widely due to their advantages [5-7]. Narrower Multiwavelength pulse trains and mode locked multiple wavelengths can be potentially realized to gain the bandwidth [8]. A highly dual functions laser concentrated Erbium doped fiber with nonlinear polarization rotation (NPR) is studied. The EDFL-NPR operates as a 3 distinct wavelength lasers, evenly spaced at 1.7 nm. [9] The key components on silicon-on-insulator are realized the multiplexing technologies. Silicon photonics has provided a very attractive platform to build ultrasmall integrated photonic devices. [9] One need to improve is the fabrication processes to reduced the dispersion and scattering loss. In order to have a high Q factor, an optimal coupling ratio in proportion to the critical coupling condition [10]. An interesting to have an ultra-large free spectral range (FSR) is micro ring resonator filters with a large tenability range of wavelength

Alternatively, waveguide ring resonators have been established for many applications [11-13], such as, tunable lasers, switching, modulators, compensators, and biosensors. The performance of ring resonators can support optical filter in Passive Optical Network (PON) applications but it is limited by internal losses. In this paper, the novel design of ADD/DROP ring resonator with the mechanism of surface plasmon polariton (SPP). The proposed hybrids plasmonic add/drop multiplexer is used to generate and switch multiwavelength access to WDM/DWDM network. The finite difference time domain technique is applied by OptiFDTD programming which an experiment-based fabricated devices characteristic and schematic model design.

2. Methodology

Light propagates by total internal reflections at the waveguide core-cladding interface. A mode of wave may propagate through the fiber, formally, a mode can be analyzed by a wave equation derived from Maxwell's equations and subject to boundary conditions imposed by the optical waveguide depending on the relative size of the core compared to the considered wavelength. On the other hand, a proposals of plasmonic waveguides and integrated components have been change, e.g. by using metal stripes embedded in a dielectric [14, 15], SPP band gap structures [16], V-groves planar metal surface [17, 18] and hybrid ring resonator [19] which demonstrated a nonlinear mechanism to improve the optical waveguide.

The proposed hybrid plasmonic add-drop multiplexer made by InGaAsP and coupled with Au ring thin film. The time domain simulation by beam propagation model (BPM) is base on FDTD method. A proposed HPAM demonstrated in Fig. 1., which Through port fields and Drop port fields can be analyzed as in Eq.1 and 2

$$E_{Th} = x_1 y_1 E_m + \left(j x_1 x_2 y_2 \sqrt{\kappa_1} E_4 E_L E_1 - x_1 x_2 \sqrt{\kappa_1 \kappa_2} E_R E_{ad} \right) e^M \quad (1)$$

$$E_{Dr} = j x_2 \sqrt{\kappa_2} E_R E_L e^M + x_2 y_2 E_{ad} \quad (2)$$

where $x_1 = \sqrt{1 - \kappa_1}$, $y_1 = \sqrt{1 - \gamma_1}$, $x_2 = \sqrt{1 - \kappa_2}$, $y_2 = \sqrt{1 - \gamma_2}$,

$$M = -\frac{\alpha L}{2} - j k_n \frac{L}{2}, \quad \kappa_1 \text{ and } \kappa_2 \text{ are the intensity coupling}$$

coefficient, γ_1 and γ_2 are the fractional coupler intensity loss, α is the attenuation coefficient, $\kappa_n = 2\pi / \lambda$ is the wave propagation number, $L = 2\pi \text{ Rad}$, Rad is the

radius of center ring resonator, E_L and E_R are circulated left and right ring light fields, respectively.

In the simulation model, gold (Au) coupled for surface plasmon polariton mechanism obtained from Eq.3.

$$\varepsilon(\omega) = \varepsilon_\infty - \frac{\omega_p^2}{\omega^2 + i\gamma\omega} \quad (3)$$

Which response by plasma frequency interaction was modeled by Drude [20] and 3D FDTD Perfectly matched layer by Berenger [21,22]. Using parameter of photonic and electrical model is shown in Table 1. The Au dielectric constant ε_∞ , the plasma frequency ω_p , and the collision frequency γ at room temperature are 6.8890 , $8.9601 \times 10^{16} \text{ s}^{-1}$, and $2.9715 \times 10^{13} \text{ s}^{-1}$, respectively.

(a) Hybrid plasmonic add/drop multiplexer design

(b) Refractive index of HPAM

(c) Schematic model by OptiFDTD design

Fig. 1. Hybrid plasmonic add/drop multiplexer with varied Au coupled ring (a) HPAM model (b) Refractive index of HPAM and (c) Schematic model by OptiFDTD design

3. Simulation results

Table 1. The parameter of photonic and electrical model for FDTD simulation

Parameter	Symbol	Typ.	Unit
SiO ₂ /InP substrate	Hsub	2	μm
InGaAsP waveguide width	W	400	nm
InGaAsP waveguide height	d	350	nm
TE Propagation losses	TE	2.5-4.5	dB/cm
TM Propagation losses	TM	2.5-4.5	dB/cm
Gold film height	HAu	100	nm
Gold film width	WAu	400	nm
Propagation losses	α	0.1	dB/μm
Propagation Length	Lsp	10	μm
Mode effective index	Neff	1.237	

In OptiFDTD simulation, the HPAM can be resonated within center ring and the surface plasmon polariton mechanism was generated by Au rings, which depend on the used parameters and conditions in Table 1. The circularly signals can also be controlled to switch on the various wavelength by width of Au ring at the bottom, which can be useful to provide wavelength for a Remote Access Point (RAP) link control. The proposed results are shown in Fig.2., FDTD simulation for HPAM model (a) $W = 0.2 \mu\text{m}$ which resonated at the $0.7 \mu\text{m}$ wavelength, (b) $W = 0.3 \mu\text{m}$ which resonated at the $0.8 \mu\text{m}$ wavelength, (c) $W = 0.4 \mu\text{m}$ which resonated at the $0.9 \mu\text{m}$ wavelength and (d) $W = 0.5 \mu\text{m}$ which resonated at the $1 \mu\text{m}$ wavelength.

Fig. 2. FDTD simulation for HPAM model (a) $W = 0.2 \mu\text{m}$ resonated at the $0.7 \mu\text{m}$ and (b) $W = 0.3 \mu\text{m}$ resonated at the $0.8 \mu\text{m}$ and (c) $W = 0.4 \mu\text{m}$ resonated at the $0.9 \mu\text{m}$ and (d) $W = 0.5 \mu\text{m}$ resonated at the $1 \mu\text{m}$ wavelength

4. Conclusions

The design of hybrid plasmonic add/drop multiplexer (HPAM) by surface plasmon polariton (SPPs) mechanism is studied. Hybrids plasmonic add/drop multiplexer is used to optical multiwavelength switching networks make potential operator to generate and access of WDM/DWDM network. Methodology, the finite difference time domain (FDTD) techniques is applied by OptiFDTD programming which an experiment based on the characteristic of devices and schematic model design. Results, four wavelength users were selected 0.7, 0.8, 0.9, and 1 μm with a various size of SPP ring Au coupled. The high Q factor (28,500), FSR = 1.4 THz and FWHM at-3dB = 10 nm.

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Fig. 3. FDTD simulation for HPAM model (a) 4 multiplex input signal and (b) 4 demultiplex output signal by OptiFDTD which only operate at 1 μm wavelength

In Fig. 3, An 4 user Switched generated by HPAM ring at 1 μm wavelength, a) 4 multiplex input signal and b) 4 demultiplex output signal by OptiFDTD which only operate at 1 μm wavelength. As a result, we are obtained The high Q factor (28,500) multiplexer with FSR = 1.4 THz and FWHM at-3dB = 10 nm. Therefore, the proposed HPAM design was used as a high passive switching, optical multiplexing network and many applications.

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