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Abstract

This paper presents the use of a nonlinear micro-ring device known as a Panda ring resonator for wavelength division multiplexing (WDM) and dense wavelength division multiplexing (DWDM). The system is formed by the OMEM/ONEM devices, from which a cross connection of optical signals using an MEM is designed and simulated using the surface plasmon waveguides, a nonlinear micro-ring device known as a Panda ring...

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AN OMEM/ONEM SYSTEM DESIGN AND FOR WDM/DWDM TRANSMISSION USING PLASMONIC MICRO-RING WAVEGUIDES

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Abstract

This paper presents the use of a nonlinear micro-ring device known as a Panda ring resonator for wavelength division multiplexing (WDM) and dense wavelength division multiplexing (DWDM). The system is formed by the OMEM/ONEM devices, from which a cross connection of optical signals using an MEM is designed and simulated using the surface plasmon waveguides, a nonlinear micro-ring device known as a Panda ring resonator is used to form the high-density cross connection via the multiplexing system. The device material is the InGaAsP/InP, from which the different wavelength input sources can be coupled and multiplexed by the array waveguide (AWG). The cross connection system consists of four panda rings with the serial connection, from which the cross connection of those eight input wavelengths, from which the cross connected signal can be formed via the output ports. Such a proposed system is a free-space link of WDM/DWDM, which is allowed to have the high capacity transmission use, while the compact device is the other advantage and the small size device allows the potential of the MEM/NEM device applications.

1. Introduction

The increasing in demand of users and power budget has accelerated the researches and investigations for the appropriated devices that can be obtained the large bandwidth devices, in which the hybrid multiplexer such as a bidirectional multiplexing device is recommended, where the transmission rate of Tbs^{-1} for optical interconnection is achieved. Till date, there are the effective ways employed to develop the hybrid or advanced multiplexing technologies, which are included the wavelength division multiplexing (WDM), polarization division multiplexing (PDM), spatial division multiplexing (SDM) [1], etc., in which the long-haul optical communications can be accommodated. Utilizing the interference of optical beams provides a fundamental principle to realize the wavelength-selective response desired for WDM filters, which is well known that the Mach-Zehnder interferometer (MZI) is a basic device with two-beam interference and a single-stage MZI has a sine-like the spectral response. The improved spectral response can be synthesized with the multiple cascaded MZIs by coupling coefficients optimization to control the critical phase delays [2]. Another form of the multi-beam interferometer is based on optical cavities, e.g., Fabry-Perot cavities, micro-ring resonator (MRR), etc. [3, 4], where the periodical Lorentzian spectral responses are employed and the series of resonance wavelengths selected. However, the recent devices such as wavelength division multiplexer and optical cross-connecter (OXC) can offer telecommunication companies option of expanding the bandwidth (bit rate) capacity without the additional fiber budget. Thus, by using the new technologies, the problem of adding fiber power budget by using the WDM and OXC equipment can expand the capacity of the current fiber. In the transmission, each WDM/DWDM system must originate and terminate at an OXC or DCS (digital cross-connect signal) port, from which the OXC or DCS port is needed to add or drop the traffic at the origin and destination of each demand within the network. Since the OC-48 level will be modeled [5], where the OXC and DCS equipments are employed to be the functionally equivalent characteristics, which has been realized that most photonic integrated devices are polarization dependent due to the birefringence of optical waveguides, which is summarized in Table 1, where the various ways to realize waveguide-type PBSs are provided, including the multimode interferometers (MMIs) [6, 7], DCs [8], photonic crystal structures [9, 10], AWGs [11], MRRs [12], etc.

The whispering gallery modes of light within a Panda ring resonator has been investigated clearly and analyzed by the researchers in the given references [13, 14], from which the WGMs can generate the coupling effect between the center and two side rings by controlling the appropriated ring parameters. In the case of the triple ring system is employed, where the input signals are entered into the input ports with different wavelengths, which are allowed the WDM/DWDM applications. Principally, the input sources can be the modulated input signals including with the required information with different users. However, the other modulation port is the add port, which can be used to increase channel capacity or signal strength, while the drop port and through port outputs are performed as the reference or transmission usages. Generally, the through port outputs are the multiplexed signals, where the cross connection of WDM/DWDM is performed. But in this case, the same signals can be obtained by the WGMs with the appropriated control, in which the free space link can be applied. From the schematic drawing in Figure 1, the free space output can be detected and operated by the MEM/NEM concept. MEM/NEM device has been recognized as a key device for many types of research and investigations [15], which there are many works used such devices for various applications [16, 17], where most of them used the compact and high performance as the key advantages of the device. The WGM history was established by the various subjects long time ago [18], where the one appears within the optical device called a *nonlinear ring resonator* is very interesting. From which the use of such concept for optical MEM/NEM usage is possible, while the use of them for WDM/DWDM is also useful. The cross connection (OXC) in the optical network is required for the high transmission capacity, where the increasing in the input/output ports can be formed for high-performance network.

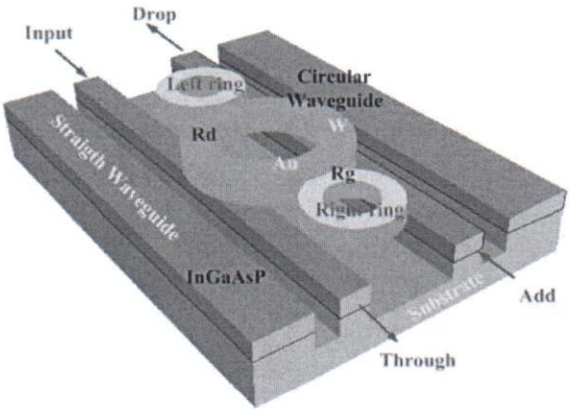

Figure 1. A schematic diagram of a Panda ring structure model using the modified ADD/DROP ring resonator.

Since micro-optical-electro-mechanical system (MOEMS) switch is an important technique for many required properties such as fast time switching, low insertion loss, and uncomplicated electronic control. Till date, the MOEMS technologies are applied for WDM and DWDM network, network elements such as filters, switches, and modulators [19]. However, the requirement of future WDM networks with high transmission capacity, very fast optical switching and compactness by multilayer cross connection is still needed, where the use of MOEMS switching has been established in free-space [20] using the waveguide methods [21]. In additions, the other forms of switching have been studied caused by its high interconnection flexibility and implemented in 1×2 MOEMS switch based on the silicon-on-insulator and polymeric waveguides [22] and WDM configurations [23]. In this paper, the plasmonic optical cross connection (POXC) device is designed using the whispering gallery modes (WGMs) mechanism, from which the simulation result and system interpretation are manipulated. In the simulation, the finite difference time domain (FDTD) technique is applied by using opti-wave programming, where the experimental data was based on the characteristics of devices and schematic model design. Consequently, the 1×4 OXC-MOEMS is based on plasmonic modified ADD/DROP ring resonators and WGMs, where shown free spectral range (FSR), full-width at half maximum (FWHM) with high Q factor are obtained. A variety of applications such as sensors, optical switching, and optical computation can be the highlight investigations, which is focused on the compound silicon structure and characteristics. The advantage of the proposed cross connect device design is the free space connection, in which the fast high power budget and speed transmission can be achieved, which can be covered the large demand users. In this proposed work, the WGM outputs at each centre Panda ring within the system can produce the free space output signals that can be used for a short-range cross connection, where the less signal degradation of the system can be achieved, from which the DWDM is useful for high-density transmission, which will be our continuous research works.

2. Theoretical Background

Recently, the optical waveguides configured by the ring resonator structures have been applied for many applications, for instant, tunable lasers, switching, modulators, compensators, and biosensors, etc., where moreover the performance of ring resonators can be used as the optical filter in the passive optical network (PON) applications but it is limited by the internal losses. In this work, the whispering gallery mode of light within the micro-ring resonator (MMR) is applied for optical communication circuit usage, where the whispering gallery mode generated within micro-ring resonator was studied and interpreted [24], from which the electromagnetic field in the form of WGM can be described by the time-dependent Maxwell's equations and used to form the surface plasmon polariton (SPP) OXC.

In the simulation model, all initial device parameters presented by using the fabrication parameters, which will be demonstrated in the following section. A novel 1×4 array POXC WDM switching combined with the laser module for WDM-PON is manipulated by opti-wave programs. An array POXC WDM switching device is constructed by the modified ADD/DROP ring resonator and excites an acoustic mechanical of the WGM light wave within micro-ring resonators. The WGMs electromagnetic waveform is explained in 2D and 3D FDTD methods based on the "Yee' scheme" [25] and "Berenger's perfectly matched layer" absorbing boundary condition was applied [26]. A proposed ring resonator demonstrated in Figure 1. Through port fields and drop port fields can be calculated as in equations (1) and (2).

$$E_{Th} = x_1 y_1 E_{in} + (jx_1 x_2 y_2 \sqrt{k_1} E_4 E_L E_1 - x_1 x_2 \sqrt{k_1 k_2} E_R E_{ad}) e^M, \quad (1)$$

$$E_{Dr} = jx_2 \sqrt{k_2} E_R E_L e^M + x_2 y_2 E_{ad}, \quad (2)$$

where $x_1 = \sqrt{1 - k_1}$, $y_1 = \sqrt{1 - y_1}$, $x_2 = \sqrt{1 - k_2}$, $y_2 = \sqrt{1 - y_2}$, $M = -\frac{a}{2}\frac{L}{2} - jk_n \frac{L}{2}$, the parameter, κ_1 and κ_2 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, the input wavelength (λ) and $L = 2\pi Rad$, Rad is the radius of center ring resonator. The circulated light field of the ring radii left and right are E_L and E_R, respectively. Methodology, the simulation results are achieved by using the MATLAB programming, where the device parameters are given as follows: ring material is InGaAsP/InP, $R_1 = R_r = 2\text{um}$, $R_{ad} = 3$, $A_{eff} = 0.1\mu\text{m}^2$, $n_{eff} = 3.14$, $n_2 = 1.3 \times 10^{-17} \text{cm}^2\text{W}^{-1}$, $\kappa_1 = \kappa_2 = \kappa_3 = \kappa_4 = 0.5$, $\gamma = 0.01$, $\lambda_0 = 1{,}550\text{nm}$.

3. High Density Cross Connection

By using the opti-wave simulation, the WGMs can be resonated and organized to localize within plasmonic center ring and two side rings, which depend on the parameters and conditions in Table 1. The WGM signals can also be controlled by the center ring and circulated by gold coating at the bottom that can be useful to provide wavelength for an optical cross-connection control by the various width of plasmonic ring coating. Figure 2 shows system diagram of an OXC WDM switching network for 4 wavelength system are (I) $w = 2.1\text{um}$ at 700nm, (II) $w = 3.2\text{um}$ at 800nm, (III) $w = 4.1\text{um}$ at 900nm, and (IV) $w = 5.3\text{um}$ at 1,000nm. A schematic of the WDM and DWDM system using WGM illustrated in Figure 3 that the POXC device applied in the block of MOEM system for optical line terminal (OLT) and optical network unit (ONU). As a result, the cross connection of 4 wavelength switching device is shown in Figures 4 and 5. The normalized power transmission of 4 wavelength POXC device provided various outputs be received by the Drop ports as in Figure 4. Figure 5 demonstrates the results of 3D FDTD simulation the POXC device with $w = 3.2\text{um}$ versus various input wavelength which the proposed POXC device on-resonance at 800nm wavelength. Therefore, the power transmission by opti-wave, the proposed model compare with plasmonic ring resonator [8] and dielectric ring resonator [9] are shown with (a) power transmission at drop port, (b) the time response of the device at 62fsecs and (c) the normalized power transmission that the proposed has the highest performance at -18dBm.

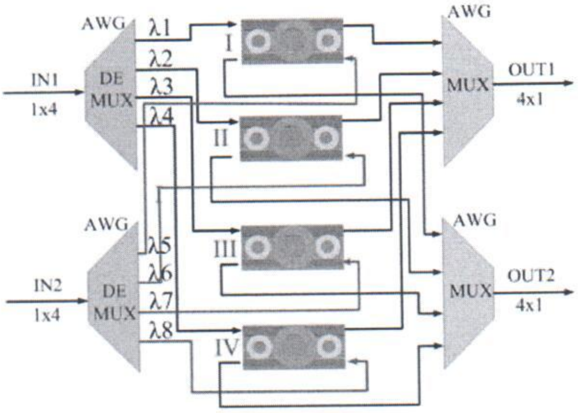

Figure 2. A 1×4 matrix of the POXC device for WDM switching.

Table 1. Simulation parameter for POXC system design

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	

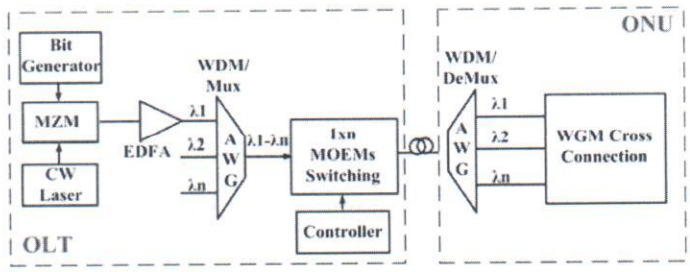

Figure 3. A schematic of the WDM and DWDM system using plasmonic waves and AWG.

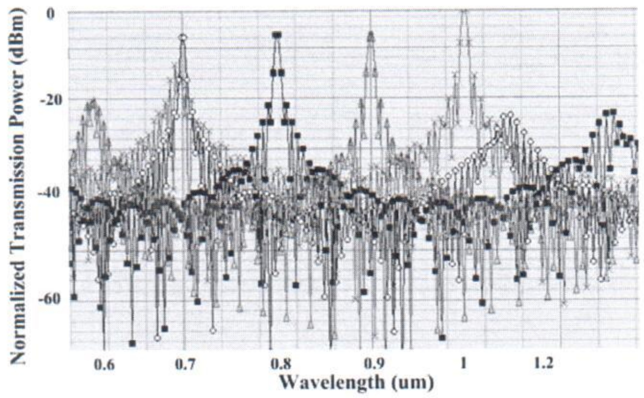

Figure 4. Simulation result of A POXC of 4 wavelength switching device.

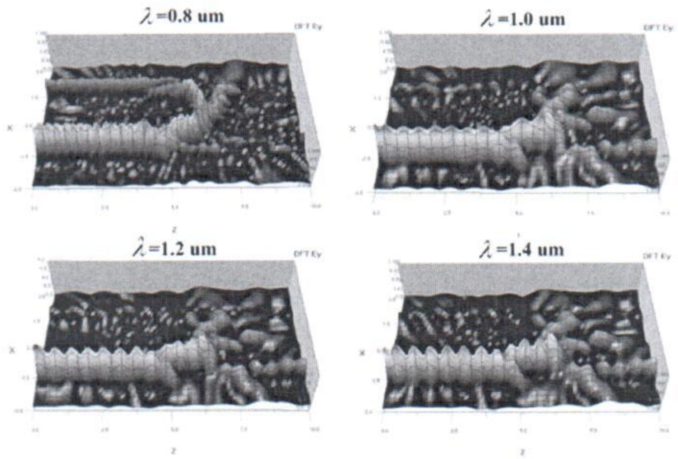

Figure 5. An FDTD simulation the POXC device with w = 3.2 micrometre (um) versus various input wavelength.

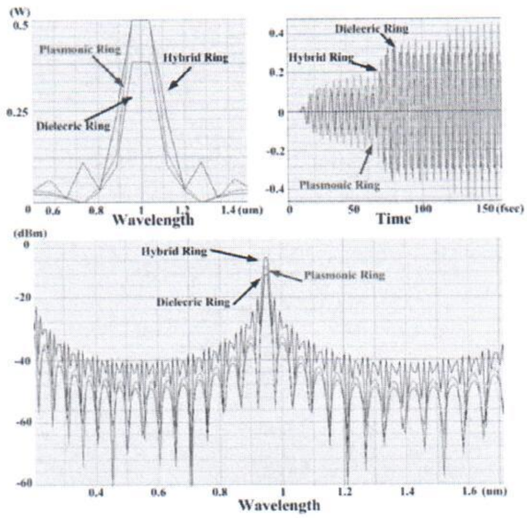

Figure 6. The power transmission by opti-wave, the proposed model compare with plasmonic ring resonator [8] and dielectric ring resonator [9].

4. Conclusion

This paper has proposed the use of a waveguide in the form of circular rings or disks, which is called an *OMEM/ONEM system*. From which the input signals are coupled into single/dual bus waveguides, where they act as the micro-optical-electro mechanical system (MOEMS) optical switch, where the optical switching networks based on modified ADD/DROP ring resonators can be operated in the forms of WDM/A-DWDM. In the simulation, the finite difference time domain (FDTD) technique is applied by OptiFDTD and MATLAB programming, where the high Q factor (28,500), FSR = 1.4THz, FWHM at-3dB = 400GHz and compactness of these filters are obtained and suitable for the dense WDM in the integrated optic device plat form. In applications, the optical cross connection for switching networks based on plasmonic ADD/DROP ring resonators can be modified with whispering gallery mode (WGM) technique which makes possible the network operator to simply and remotely reconfigure the access network, which will be the interesting for the future investigations.

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