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Logic Gates Through Three Core and Dual Core Nonlinear Directional Couplers Operating in Continuous Wave Mode

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ABSTRACT

We have studied and obtained logic gates through three-core nonlinear directional couplers and dual-core nonlinear directional couplers operating in continuous wave mode in which the laser signal has the same wavelength. In symmetrical three-core nonlinear directional couplers with its identical cores in a planar arrangement was studied using a control pulse applied to the first core. In dual core the structure was the asymmetric two core switching process was held in symmetrical triangular fiber couplers and three-core nonlinear directional couplers using the coupled mode of the nonlinear Schrodinger equation. The logic gates, AND, OR and NXOR were generated from the triangular three-core nonlinear directional couplers, while planar three-core nonlinear directional couplers produced logic gates AND, NAND, OR and XOR. For this two basic modes were considered. The first triangular structure with three symmetrical core were considered from an equilateral triangle and used a control signal applied to the first core. In the second model the symmetric cross structure with three cores in a parallel equidistant arrangement. We have obtained optical logic gates in a fiber coupler doped with erbium, leaded the resonant non linearity to change the refractive index which helped to reduce the device switching energy threshold.

KEYWORDS

Logic gate, Core, nonlinear, coupler, control pulse, symmetric, switching, directional, control signal, mode.

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INTRODUCTION

MeneZes et al. [1] studied triangular and planar coupler with two configurations operating in continuous regime and obtained AND, OR, NAND, NOR, XOR NXOR and NOT logic gates. They analysed the extinction ratio figure of merit of the logic gates. The triangular symmetric structure was composed of three cores in an equilateral triangle using a

control signal applied to the first core. The two configurations have a planar structure with three symmetrical cores in equidistant parallel arrangement with different control signal input positions.

Agrawal [2] made study of nonlinear optical field and on the propagation of short optical pulses inside optical fibers. The nonlinear Schrodinger equation was used for the nonlinear phenomenon of self phase modulation that leaded to the formation of solitons in the presence of anomalous dispersion. The study showed the importance of non-linear processes such as spin off of higher order soliton and the intrapulse Raman effect. They also studied the performance of three different dual core asymmetrical nonlinear directional couplers including an increase and a decrease in self phase modulation profile. A study of the extinction ratio of the device was made, observing the device's transmission characteristics through the cross channel.

Sobrinho et al. [3] studied four possible situations were analysed for two input logic gates, modulating the incoming pulses by time shift and allowing a variation of the modulation adjustment parameter offset coding.

Almedia et al. [4] made numerical study on transmission and switching solitons in asymmetric nonlinear directional couplers, developed with dispersion decreasing fiber. The coupler consists of two separate parallel fibers, on with a dispersion decreasing fiber profile and another with a constant profile and truth tables were obtained for logic gates AND, OR and XOR.

Meneze et al. [5] presented a numerical analysis of triangular nonlinear dual core fiber coupler, planar symmetric and asymmetric, propagating a soliton pulse, which used the nonlinear responses of Kerr effects, delayed and instant analysed to implement a optical half adder. For this purpose eight configurations were analysed with regard to fiber nonlinear directional coupler with two symmetric and six asymmetric configurations. In the simulation the symmetric asymmetric planar features with three cores in a parallel equidistant arrangement, three logic inputs and two output power. To compare performance of optical half adders the figure of merit of the logic gates were used.

Singhi et al. [6] made study with optical Boolean circuits implemented with a semiconductor optical amplifier and Mach-Zehnder interferometer that are simulated and analysed at 10Gb/s. They have proposed new designs for half-adder, half subtracted and 4bit decoder for various results and results of different bit rates. The designs consisted of data that serves as a pump generated by a clock wave laser and another acting as blocking probe laser mode. The results were useful for the design of other fully complex optical circuits that used the data ports as the basic building block.

Uthaya Kumar et al. [7] studied switching in three-core nonlinear directional couplers and logical operations using all optical control. To achieve results symmetrical trans-pacific cable models were used with planar geometry and other core with the equilateral triangular geometry and the use of Fourier series. The coupler direction characteristics were demonstrated by the curve. The chloroform filled the triangular core showed all logical operations i.e. OR, NOR, AND, NAND, XOR, XNOR and NOT with low input power.

Yaghoubi et al. [8] made study of all logic gates based on the theory of non linear directional coupler. The experiments they used two waveguides. These waveguides had similar properties in the material and length when applied to gates. Bream PROP software was used and they observed that the desired output signal power was reached, using incomplete coupling and half adder function was obtained from the AND and XOR gates.

Guo et al. [9] study was made for obtaining optical logic gates based on two kinds of refractive index, grating and polymer film doped with azo dye. To perform the study they used an interference recording method with two 532 nm laser beam in which the characteristics of the transient grating in films were recorded with different polarization states by monitoring the intensity of first order reading diffraction of the 632.8 nm laser beam. They found that the transient grating in polymeric films was established and deteriorated in seconds.

Saboia et al. [10] performed an analysis of a directional optical fiber coupler embedded in a photonic crystal was proposed, which was driven by an external control signal allowing switching cell work in fully optical switch. The method used for switching an external control signal of low power in the central coupling region which acted as a waveguide. They used the plane wave expansion method, a time domain finite difference, besides the binary method of propagation.

Sharifi et al. [11] used a general method to design all optical gate considering photonic crystal and functions based on the logical threshold concept with a regular pattern on the inputs. There was a cascade junction of the photonic crystal, performed by a power level threshold detector and a new method has been introduced to change the power level threshold for the design of various gates and logic functions. The power of inputs and out change the power level threshold for the design of various gates and logic functions. The powers of inputs and outputs ports and functions of the study was homogeneous and operated with a bit rate of 500 Gbit/s.

Goudazi et al. [12] studied an optical logic gate structure based on line defects and defect points in two dimensional photonic crystal. The process occurred in a square lattice of silicon photonic crystal bars. The device has two inputs and two output ports. They proved that the initial phase difference between the two input ranged was $\frac{\pi}{2}$, they interfered constructively or destructively to perform the logic functions. Rocha et al. [13] made study of propagating characteristics of soliton pulses of Pico seconds through odd-drop optical filters based on a uniform medium without losses and non-linear Gaussian grids couplers. For the temporal profiles, nonlinear coupled mode equations were considered. These devices were solved numerically and performed the extraction of an optical signal, since there was reflection of a pulse previously alternated between adjacent waveguides, where extraction efficiency occurred best at low power levels.

Rani et al. [14] reported the independent polarization of optical logic gates in silicon-insulator photonic crystal which consisted of two dimensional lattices of honey comb with two photonic air holes for transverse electric and transverse magnetic modes in the optical communication windows. The response time and the bit rate for the transverse magnetic polarizations at the wavelength 1.55 nm showed good results. Shaik and Ranges Wamy [15] studied new structures of all optical logic gates based on two dimensional photonic crystal square lattice type with silicon rods dipped in air have been proposed. The proposed structures were based on a waveguide T-shaped optimized edge. An additional input port was included in the structure, along with the actual input ports required for a logic gate. The result showed that the T-shaped waveguide operated as a NOT gate and appropriate change in the phase value of digital input 'I'.

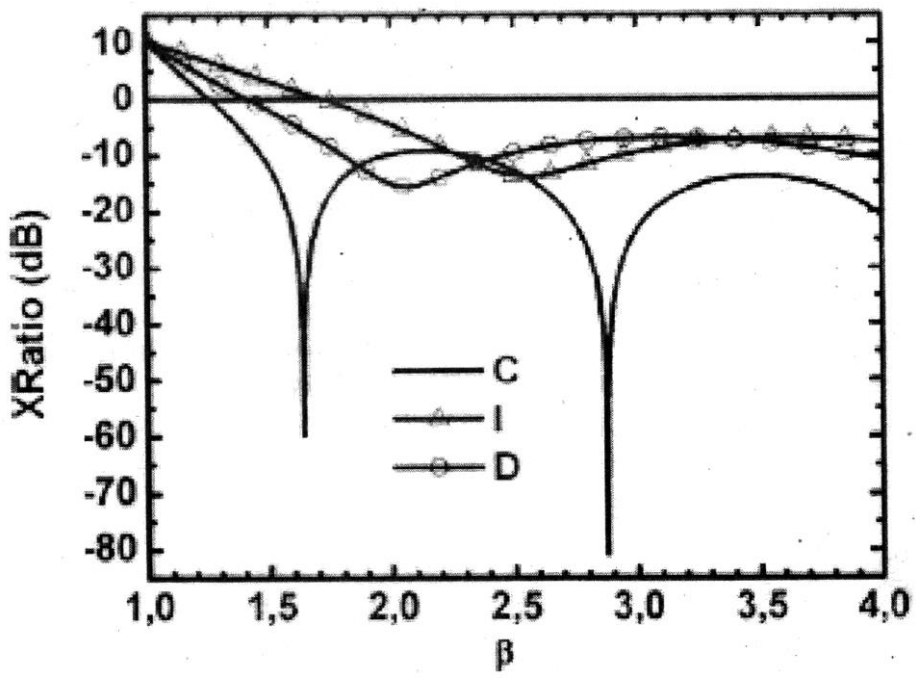
METHOD

We have studied the performance of three different dual core and three core asymmetrical non-linear directional fiber coupler including increase and decrease in the self phase modulation profile. A study of the extinction ratio of the device was made observing the device's transmission characteristics through cross channel. We have observed that the performance of logic gates AND, XOR and OR in the three couplers depended on the non linearity profile, concluding that to operate the asymmetric coupler as a logic gate that controlled the non linearity profile in order to optimize completely the characteristics of transmission and extinction coefficient. We have used different ways of pumping for obtaining of logic gates. The operation of an all optical logic gate based on symmetrical non linear directional coupler, operating with a pulse-position modulation. The performance of a symmetrical non linear directional coupler revealed logical functions AND and OR applied in the transmission and processing of signals in all optical thermally diffused mode system. This arrangement consisted of the symmetrical non linear directional coupler was developed with ultra short soliton light pulse of two pico seconds, which has been modulated using pulse position modulation which effectively served to break the device symmetry and generated logic gates. Four possible situations were analysed for two-input logic gates. A numerical study on

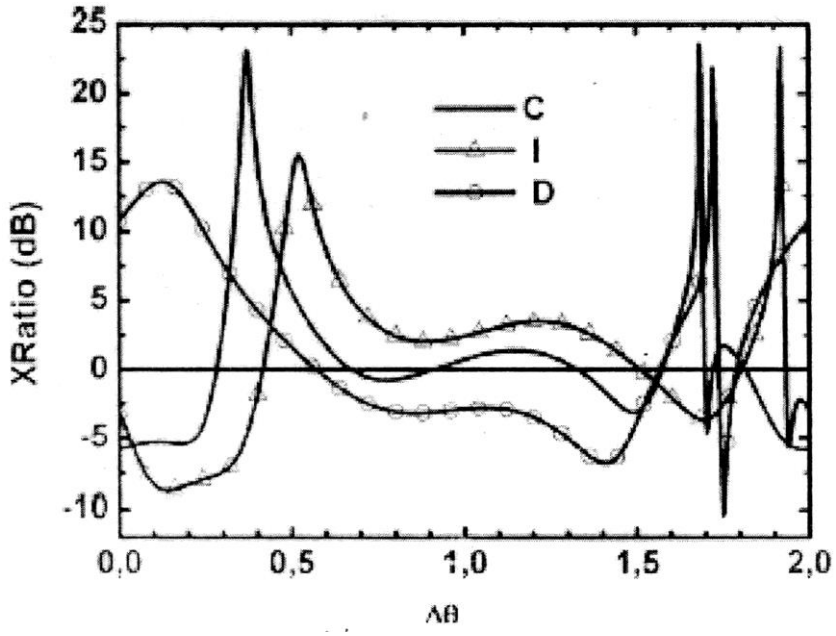
transmission and switching of fundamental solitons asymmetric non linear directional couplers developed with dispersion decreasing optical fiber.

RESULTS AND DISCUSSION

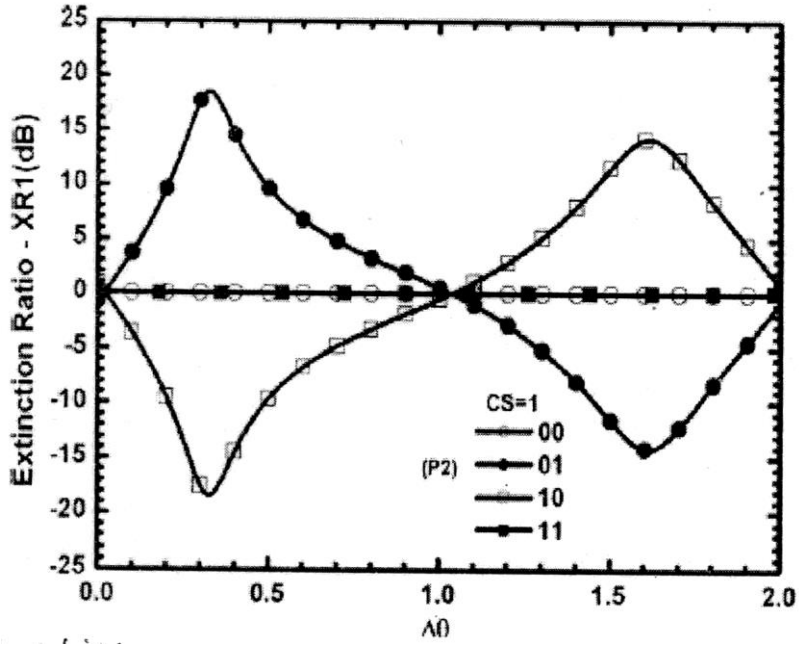
Graph (1) shows the result of extinction ration when the pumping was alone in channel two. Specially with beta equal to one, the output light was present an channel one. When beta increased, the extinction ration decreased indicating that the light returned to channel two, making possible the obtaining of logic gates. Graph (2) shows that when pumping for both inputs one and two, a strong presence of light was found in guide one and guide tow. We also found that the phase value $\Delta\varphi$ of extinction ration was increasing for two of the couplers with maximum value 23.40 dB was obtained for constant profile $\Delta\varphi = 1.68p$. Graph (3) shows that when $\Delta\varphi = 0.32\pi$ there are strong peak values where most of the output energy is switched to the output control 02 and 01. For control signal the extinction ratio values are near thus the energy fractions of outputs 01 and 02 are identical. Graph (4) shows that extinction values are always negative for any variation of $\Delta\varphi = \Delta\theta\pi$ with strong fluctuations. It shows that the switched power switches between outputs 02 and 01. Most of the energy is present in the channel 02. In phase value the signal is switched predominantly in 02. For crossed phase = $1(\Delta\varphi)$ the values of extinction ratio are alternated, sometimes positive and sometimes negative. Then it was found that three core nonlinear directional couplers provided AND, NAND, OR, XOR and NOT gates where as dual-core nonlinear directional coupler provided XOR, AND and OR gates. Graph (5) presents the unification of transmission curves as a function of input power to the instantaneous peak and cases of non linear delayed Kerr response between the switching powers. In nonlinear directional fiber couplers the critical power for the signal is completely transmitted to the core three then returns to the core two and finally to the core one.



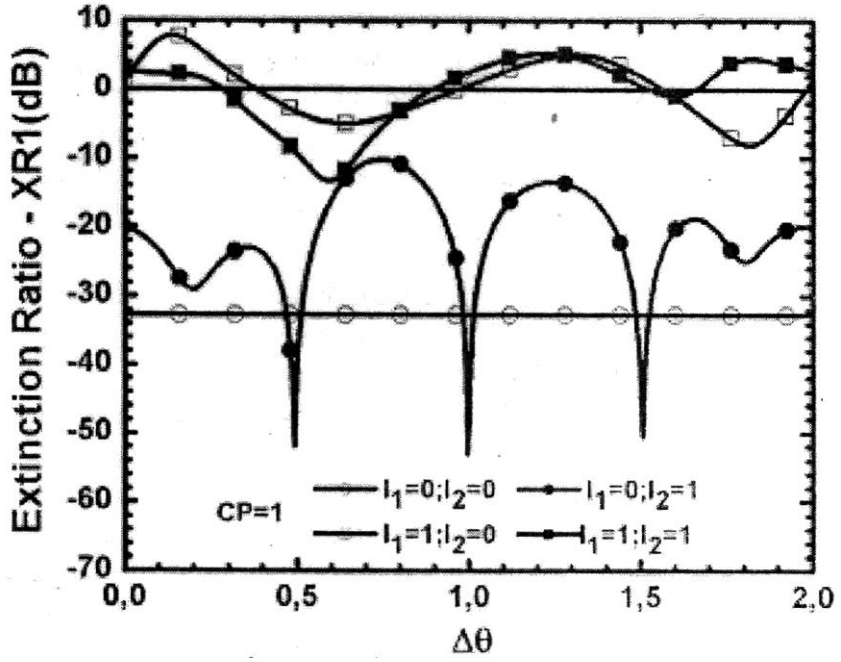
Graph 1: Extinction ratio with incident light, pumping for channel 2.



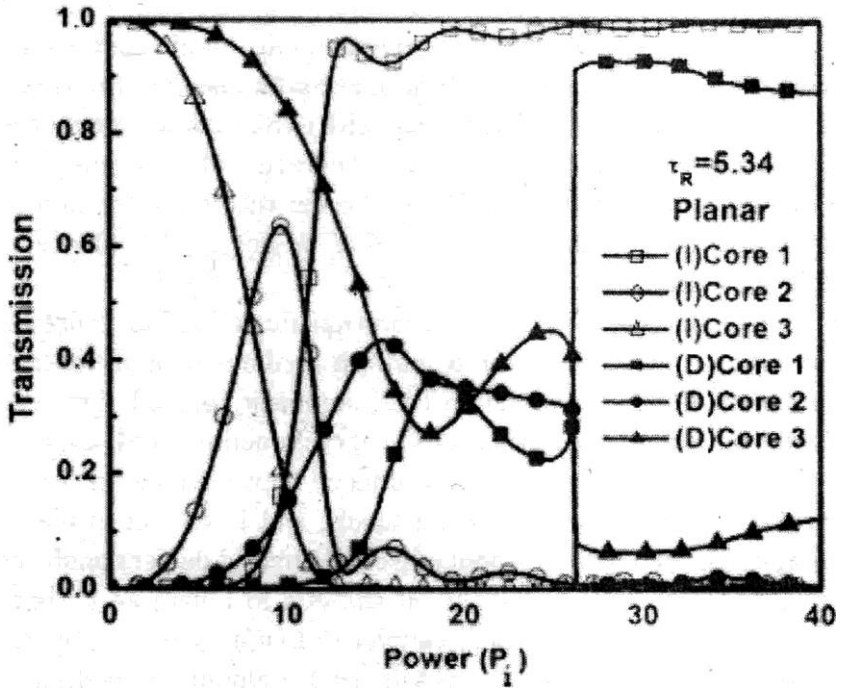
Graph 2: The phase extinction ratio is increasing for two of the couplers with maximum value.



Graph 3: Extinction values (dB) are near 0, thus the energy fractions of output O1 and O2 are identical



Graph 4: The values of extinction ratios are alternates, sometimes positive, sometimes negative.



Graph 5: Unification of transmission curves as a function of input power to the instantaneous peak in a nonlinear directional fiber coupler.

CONCLUSION

We have studied for obtaining logic gates through dual core and three core nonlinear directional couplers operating in continuous wave mode. The analysis was made for devices through their performances in linear and nonlinear regime, considering the various optical characteristics. We have observed the generation of all optical gates using optical fiber couplers. The non linear characteristics of the fiber and generation of optical codes using Bragg gating was studied. The study was made for obtaining of optical logic gates in fiber devices couplers, filters and interferometers in on off switching mode

including the use of figure of merit of the logic gates. We have found that application for the linear and nonlinear effects affected inherent to the fiber. These studies have applications in the obtaining of optical logic gates through the control of characteristics of the fibers such as nonlinearity profile, dispersion profile, control pulse, pumping pulse among others. The optical fibers are essential in the development of communications and data transmission with strong positive characteristics in bandwidth of data transmission as well as the transmission speed. Simulation was used in the analysis of effect of dispersion in optical logic gates. We have used semiconductor optical amplifiers. The dependence of output quality factor in input pulse energy, pulse width, semiconductor optical amplifier life time of the line width of the enrichment factor and power saturation were observed. It was found that the production of logic gates and half adders with relaxed nonlinearity in fiber couplers are useful for communications and transmission of data. The optical logic gates based on nonlinear optical fiber couplers present important characteristics such as security in information traffic, high transmission rate and capacity and optimizing effective data transport. The obtained results were compared with previously obtained results and were found in good agreement.

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