Realization of all-optical NOR gate based on four wave mixing, non-linear effect in SOA

Saumya Saxena
Department of Electronics & communication, Saroj Institute of Technology & Management, GBTU, Lucknow, U.P, India

Shyamal Saxena
IBM, Pune, India

Sadaf Zahra Rizvi
Department of Electronics & communication, Saroj Institute of Technology & Management, GBTU, Lucknow, U.P, India

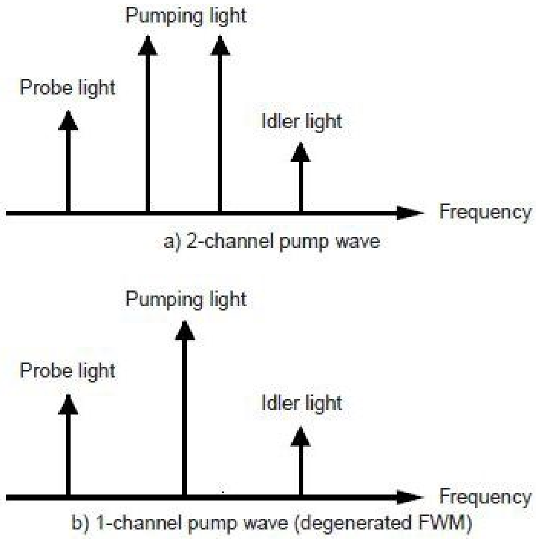
Abstract - A novel approach towards the realization of all optical NOR gate based on Semiconductor optical amplifier(SOA), has been presented in this paper, exploiting Four wave mixing(FWM), non linear effect in SOA's. The design and simulation of the circuit has been described with the help of Optiwave software version 7.0 and have been optimized by measuring the output at different values of input parameters like input optical power, injection current and active region length of SOA. Here, in this paper the optimized output has been presented. Several approaches have already been suggested for designing all optical logic gates which includes cross gain modulation(XGM), cross phase modulation(XPM) and Machzehender interferometer (MZI) structure etc. In this paper we will use the idea to generate FWM signals by keeping two data pumps(A and b) frequencies fixed at 193Thz and 193.1Thz respectively, which will generate the FWM at 193.2Thz

Keywords:- Four wave mixing(FWM), Cross gain maodulation(XGM), cross phase modulation(XPM) , Semiconductor optical amplifier (SOA), variable optical attenuator(VOA), Band pass filter(BPF), EDFA.

I. INTRODUCTION

A non linear device called as semiconductor optical amplifier(SOA), emerged as a practical solution for all-optical signal processing function, where one signal has been controlled by the other signal.
SOA based optical signal processing devices can easily handle complex signal and process the data rates of upto 40Gb/s with much less power consumption of (1W), however modern high speed electronic equpimnts consumes much more power than 10kw and requires equivalent power to remove the heat generated by the equipment.also all-optical SOA devices can readily be integrated to form an array of devices with smaller footprints. such kind of SOA based optical signal processing founds vast application in Telecommunication field. Especially, tasks such as wavelength conversion and signal regenartion are remarkable in telecom network.

All-optical signal processing devices is not a replacement of the electronic system, it just increases the effectiveness , capacity and flexibility of the next generation system in optoelectronics domain. In this paper ,design of all-optical NOR gate has been simulated and analyzed ,using a non-linear behavior called four wave mixing(FWM) in SOA.
FWM occurs when light of three different wavelengths is launched into a fiber, giving rise to a new wave (know as an idler), the wavelength of which does not coincide with any of the others. FWM is a kind of optical parametric oscillation.



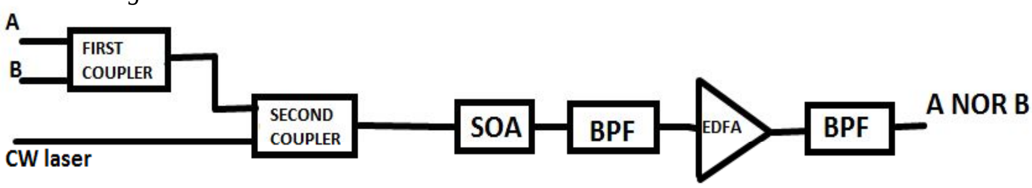
Above, figure shows four-wave mixing in the frequency domain. As can be seen, the light that was there from before launching, sandwiching the two pumping waves in the frequency domain, is called the probe light (or signal light). The idler frequency '$f$idler' may then be determined by the equation:

$$f_{\text{idler}} = f_{\text{p1}} + f_{\text{p2}} - f_{\text{probe}}$$

This paper is broadly divided into three sections. The first section shows the introduction about all-optical devices and SOA and its non-linear effects(FWM). Section 2 describes the operation principle behind the design of all-optical NOR gate and section 3 describes the simulation and its results.

II . OPERATION PRINCIPLE

A. Block Diagram:-



Block Diagram Of All-Optical NOR GATE

The working principle of optical NOR gate is based on the generation of FWM signal. So we have to fix the frequencies of data pumps and probe pump. In this design of NOR gate we are filtering the signal of probe pump only (output is detuned from FWM). The frequencies of data pumps and probe pump are taken as below. SOA injection current, transmitter input power and active region length of SOA are taken as variable in the design to get the optimum result, but for frequency domain analysis it has been fixed to describe the working principle and to present the optimized results in this paper. The values taken are as follows:

Table1: Input Parameters

S.No.	Parameter	Value
1	fA	193THz
2	FB	193.1THz
3	Output power of both the transmitters (A and B)	20dbm

Table 2 : SOA Parameters

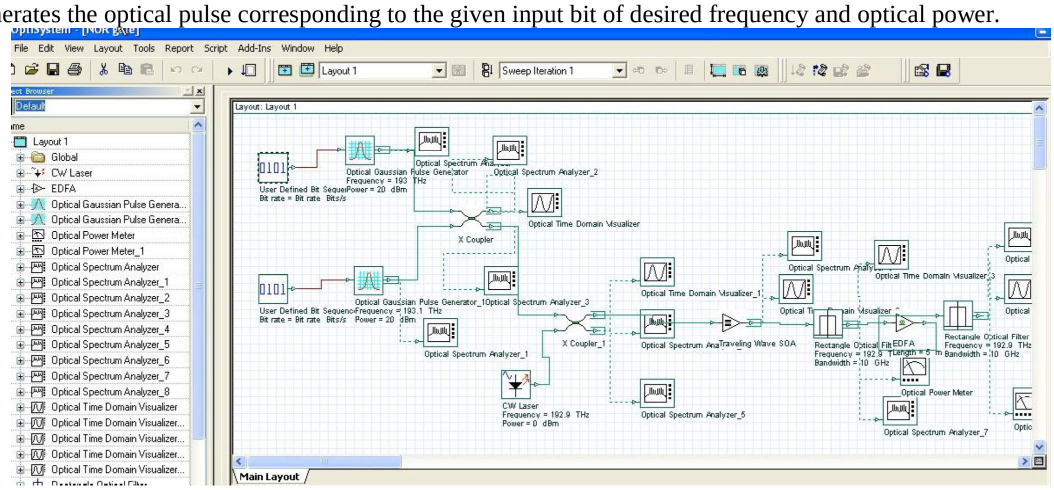
S.No.	Parameter	Value
1	SOA Injection current	0.8A
2	Active region length of SOA	0.0005m

In this design of Optical NOR gate two data pumps (A and B) which can carry data signals and a probe pump (CW Laser) is used to generate the logic of NOR gate. The output of two data pumps are coupled together by the first coupler to get a logic of OR gate i.e the output will be high when any one of the input is high, this output is coupled with probe pump by second coupler and the output of this second coupler is fed to the SOA. Now three signals of different frequencies are given as an input to the SOA, these input signals will generate the FWM signal when any two inputs signal are high(logic 1). The power of each data pump and probe pump is coupled together, When FWM signal is generated it spreads the power of CW laser and if we filter the signal of CW laser by BPF (tuned at the frequency of probe pump), a lower value of power will be obtained which can be considered a logic '0'. When both the data pumps are at logic '0' no FWM signal will be there at the output of SOA, so the total power of CW laser will be there at the output of BPF and it can be considered as logic '1'. The signal of CW laser is selected by first BPF and amplified, this amplified signal is again passed through the second BPF with the center frequency of CW laser to remove the unwanted signals

III. SIMULATION AND RESULTS

(A) Simulation:-

Circuit of optical NOR gate designed on Optiwave software is shown in figure below. The transmitter A and B is designed by combining the bit sequence generator and optical Gaussian pulse generator. The bit sequence can be given as input but here only one bit has been used to generate the logic. Optical Gaussian pulse generator generates the optical pulse corresponding to the given input bit of desired frequency and optical power.



Simulation of NOR gate on Optisystem software is done and is analyzed in the frequency domain by optical spectrum analyzer and in time domain by optical time domain analyzer, power meter is also used to measure the power at the output of every component. The generated logic can be obtained by measuring the power at the output, and optical time domain analysis is also important to see the shape of input and output signals.

(B) *Results*:-

As per the logic of NOR gate , the output is high(1) only when both the inputs are low, otherwise low(0). To verify the logic the values of input optical power, injection current, and active region length of SOA is fixed. The outputs are analyzed in two domains, these are frequency domain and time domain. Optical Spectrum analyzer has been used for frequency domain analysis and Optical time domain visualizer is used for time domain analysis. Also optical power meter is used to check the output power levels . The results obtained are as follows:

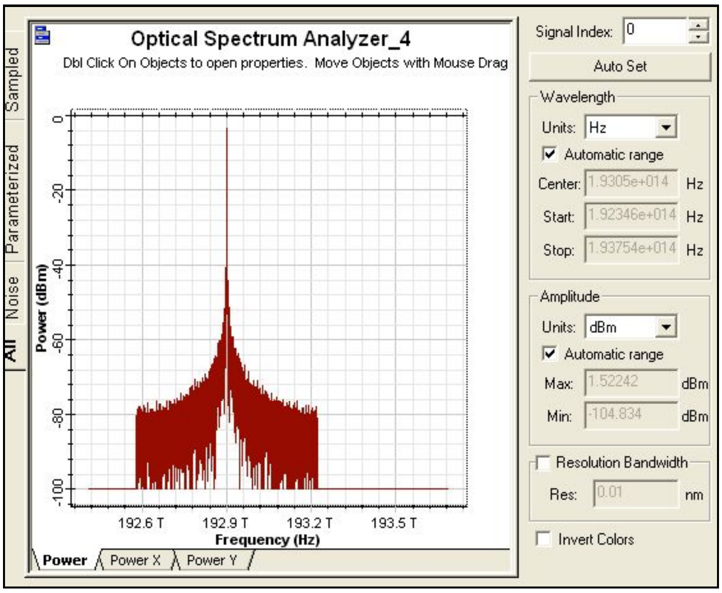


Fig 1: Spectrum analyzer at the output of SOA when both the inputs are low

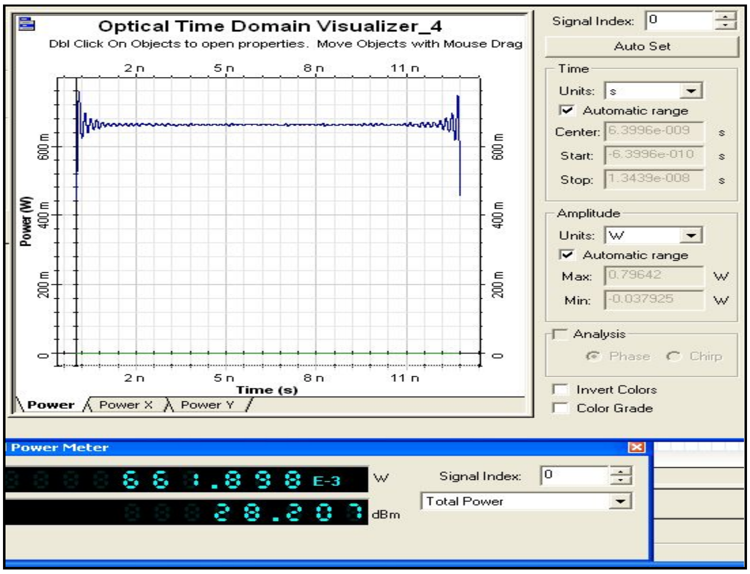


Fig 2:Output of time domain visualizer and power meter at A=0 and B=0

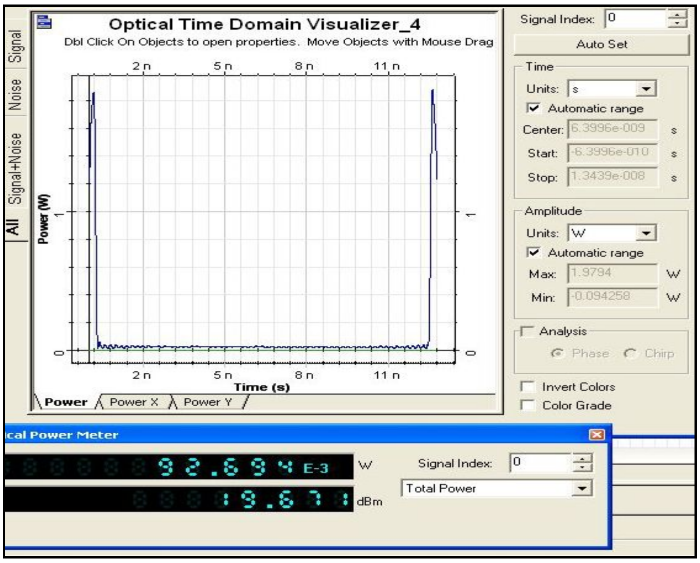


Fig 3: Output of time domain visualizer and power meter at A=0, B=1

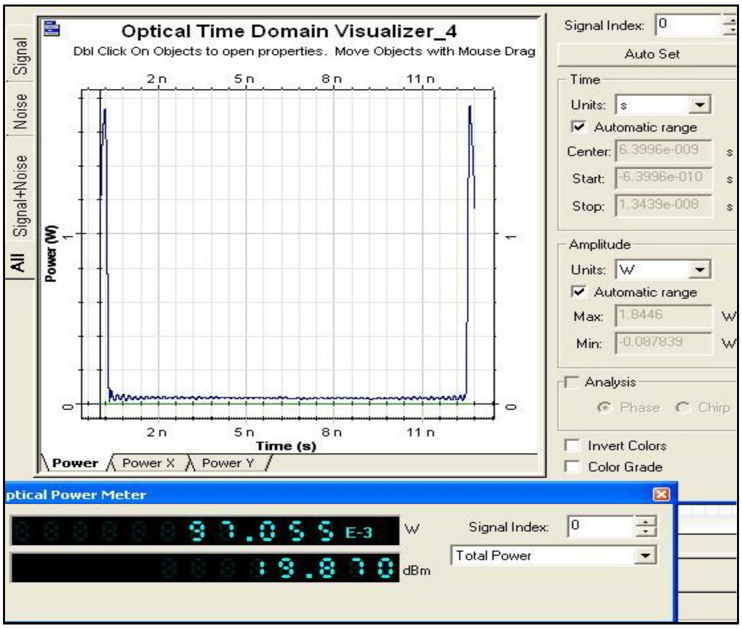


Fig 4: Output of time domain visualizer and power meter at A=1, B=0

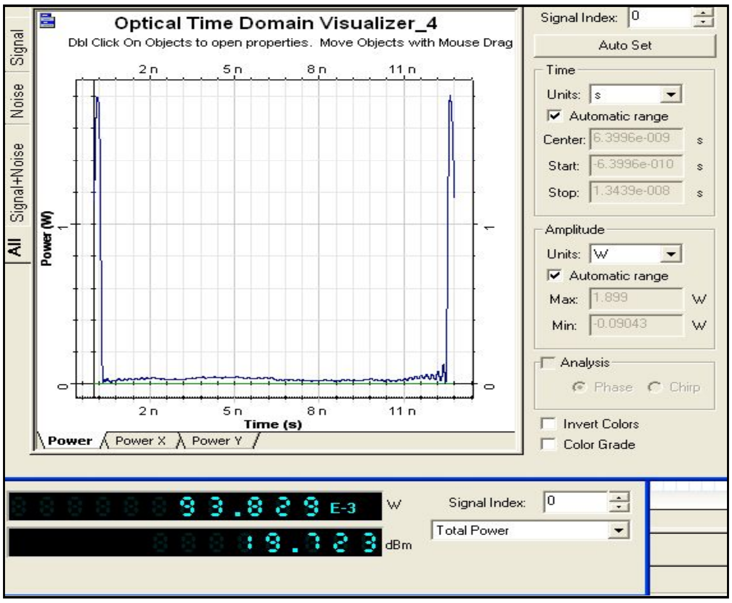


Fig 5: Output of time domain visualizer and power meter at A=1, B=1

Above results are corresponding to different logical inputs, so to generate the logic at the output, truth table is prepared as follows:

S.No.	A	B	Output Power (W)	Output power (dbm)	Logic
1	0	0	661.898e-3	28.207	1
2	0	1	92.694e-3	19.671	0
3	1	0	97.055e-3	19.870	0
4	1	1	93.829e-3	19.723	0

Table 3 : Truth table for optical NOR gate

From above truth table we can see that the output power is low when any of the input bit is high, so we conclude that the output power is corresponding to a NOR gate.

IV. CONCLUSION

Simulation of All-optical NOR gate has been successfully performed using Four wave mixing(FWM) property of SOA and the logic has been verified by checking the power levels at the output of SOA ,for all the possible input combinations. The great advantage of SOA gates is that they can be integrated to form gate arrays.

Similarily all the other logic gates can also be realized with the help of the above proposed circuit of NOR gate . Since the optical gates are the basic elements for designing any combinational and sequential circuits. So this NOR gate design along with all other optical logic gates can be utilized to design the other circuits for switching and memory devices used in the next generation optical networks.

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