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Realization of Binary Full Addition Module in Optical Domain Using SOA

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Abstract-Now days, Optical amplifiers are being invariably used for amplification of the signal in optical fiber communication for long distance transmission due to less power loss. Out of the three types of amplifiers (EDFA, Raman amplifiers and SOA) a SOA is an optical amplifier where the amplification is based on semiconductor gain medium. Therefore, by using non-linear properties of SOAs such as Four-Wave Mixing, Cross gain modulation and Cross phase modulation, they can be used to implement logic gates. These logic gates functions with optical amplifiers which allow amplification of optical signals without O-E & E-O conversion, therefore helps in fast processing of the system with minimum loss. We here demonstrate the implementation of full addition of two self generated 10 Gbits/s signals by using four SOAs. In this module, a full-adder operation is achieved by using two half adder in pure optical domain. This module can be used further in the implementation of ALU's and encryption decryption circuits.

Index Terms- SOA (Semiconductor Optical Amplifier), XGM (Cross Gain Modulation), FWM (Four Wave Mixing), O-E (Optical to Electrical), E-O(Electrical to optical), EDFA(Erbium Doped Fibre Amplifier), ALU(Arithmatic and Logic Unit), NRZ(Non Return To Zero).

1 Introduction

Binary logic gates are the basic building blocks of the digital logic families like adders, counters, decoders, registers etc. With the development of high speed optical networks the electronic logic circuits is a challenge in achieving higher bit rate due to the requirement of O-E and E-O conversion. To overcome this challenge the digital logic gates are implemented in the optical domain and that can be used in the future for the realization of all the logic circuits in optical domain[2]. The optical logic gates can be designed using the non-linear properties of SOA or using a non-linear fiber. The use of SOA is highly recommended due to its numerous advantages like high gain, high bandwidth along with its coherence and stability with optical networks. The paper is divided into various sections. Section II describes the advantages of all Optical networks, whereas section III describes the designing and implementation of optical logic gates using non-linear properties of SOA. Results and demonstration of setup is explained in section IV.

2 ADVANTAGES OF OPTICAL NETWORKS

The purpose of using Optical networks is primarily for the removal of O-E and then E-O conversion. These conversions affect the WDM system more severely as in WDM system for processing using electronic circuitary the wavelength needs to be demultiplexed and a separate transponder is required for every wavelength to convert it into electric domain[3]. These conversions results in increased complexity of the circuit, power loss and leads to increase cost of the overall system. So to meet the ever increasing demand of higher data rates in communication, optical based circuits will be the future.

Due to the higher potential of optical circuits in computation, various optical based digital devices has been designed and proposed like logic gates[1], counters, multiplexer using non-linear properties of SOA.

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3 DESIGN OF FULL ADDER

Working of SOA is based on the principle of stimulated emission where the electrons in the excited state are stimulated to release energy in the form of photons and the process continues until the photons form an amplified signal. This process results in the variation of charge density in SOA. Due to the variation in the charge densities SOA exhibits non-linear properties like FWM and XGM which are used for the realization of binary logic gates. When two input signals are given to the SOA with difference in frequency less than 6 nm and ratio of signal power to pump power approximately equal to 1, both the non-linear effects i.e XGM and FWM occurs simultaneously[4].

Input A	Input B	Input C_{in}	Sum (S_{out})	Carry (c_{out})
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

Truth Table of Full Adder.

When A and B at two different frequencies with different power levels and wavelength difference less than 6nm are given to SOA 1 the Cross Gain Modulation effect gives A(bar)B with input A as high and Input B as low whereas with input A

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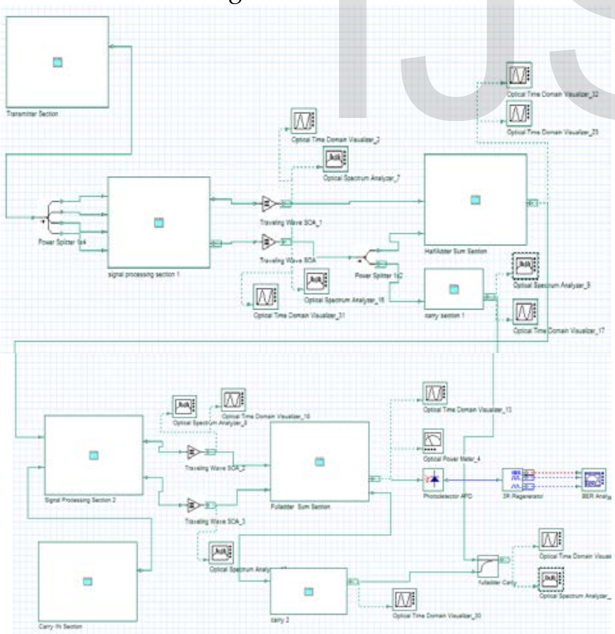
low and Input B high, XGM effect gives AB(bar). The value of XOR gate is high if any of the input is high. When both the inputs are high then the output of AND gate function AB is realized due to the effect of FWM in which harmonic SUM and DIFFERENCE of frequencies are generated. This signal AB is the carry generated by half adder circuit. The signals A(bar)B and AB(bar) are passed through the coupler which at output gives the output of XOR gate as SUM = A XOR B.

The two signals, SUM (S) along with new signal C_{in} with different power levels are given to SOA 2, the XGM effect here gives S(bar)C_{in} with signal S as high and signal C_{in} as low whereas with input S as low and Input C_{in} as high, XGM effect gives SC_{in}(bar). The signals S(bar)C_{in} and SC_{in}(bar) are passed through the coupler which at output gives the output of XOR gate as SUM (X) = S XOR C_{in}. This signal SUM is output of full adder.

When both the inputs are high then the output of AND gate function SC_{in} is realized due to the effect of FWM in which harmonic SUM and DIFFERENCE of frequencies are generated. This signal SC_{in} is the carry generated by second circuit. The carry outputs of both the circuits are passed through coupler which gives carry C_{out} of full adder circuit.

4 EXPERIMENTAL SETUP AND RESULTS

The experimental setup with block diagram for optical full adder is shown in Figure below.



Experimental Set Up

Two CW laser diodes are used to produce two Gaussian pulses at 1546 nm (Say Signal A) and 1550 nm (Say Signal B) with power 15 dbm & 17dbm respectively. The data input to each modulator is given through a NRZ pulse generator with 10 Gbit/s PRBS data. The modulated signals are then mixed in the coupler and the signal obtained is amplified by EDFA. A 1x4 power splitter splits the amplified signal into four sections.

The data required is extracted from the four branches with the help of Gaussian optical filters. These signals are passed through attenuators for their optimized power control and are coupled again. The average power of Signal A is 4.413dbm and that of Signal B is 14.262dbm. The signal A acts as probe signal and signal B as pump signal. This attenuated signal passes through SOA 1 and due to XGM property of SOA, function AB(bar) is realised which is extracted with the help of 0.6nm Gaussian optical filter at 1546nm. Similarly in the 3rd and 4th branch the signals A and B after attenuation are set to average powers of 17.435dbm and 3.362dbm respectively. Now signal A acts as pump signal and signal B as probe signal. When this signal passes through SOA 2, function A(bar)B is realised which is extracted with the help of 0.6nm Gaussian optical filter at 1550nm. Along with this, a new harmonic component of frequency is generated which realizes the function AB and is filtered by 0.6nm Gaussian optical filter at 1542nm. The information signals *AB* and *AB* are combined to perform *S* =*A* XOR *B*. The average power of signals *A*(bar)*B*, *AB*(bar), *AB* and *A* XOR *B* are 11.40dBm, 14.503dBm, -1.00dbm and 14.486dBm respectively.

Now, the output of half adder (Say Signal S) is obtained at frequency 1546 nm and 1550 nm. A frequency convertor converts 1546 nm frequency to 1550 nm so as to achieve the output signal at single wavelength i.e at 1550 nm. This output signal *S* and a generated signal (Say C_{in}) at 1546 nm is used as input signals for second half adder circuit. These two input signals are divided into two parts by using a splitter. These signals are again attenuated at different power levels and are then combined through couplers. In first Coupler, the input C_{in} is at high power of 10.368dBm which acts as pump signal where as input *S* is at low power of 1.475dBm which acts as probe signal. In SOA 3, the function SC_{in}(bar) is obtained due to XGM and is extracted by 0.6nm Gaussian Optical Filter at 1546 nm. Similarly, in second Coupler, the input C_{in} is at low power of 4.368dBm which acts as probe signal and input *S* is at high power of 11.475dBm which acts as pump signal. In SOA 4, the function S(bar)C_{in} is realized due to XGM and is extracted by 0.6nm Gaussian Optical Filter at 1550 nm. On combining these outputs through coupler, output of full adder (S XOR C) is achieved successfully. The output for carry out of full adder is obtained by combining the carry of two half adders.

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5 RESULTS

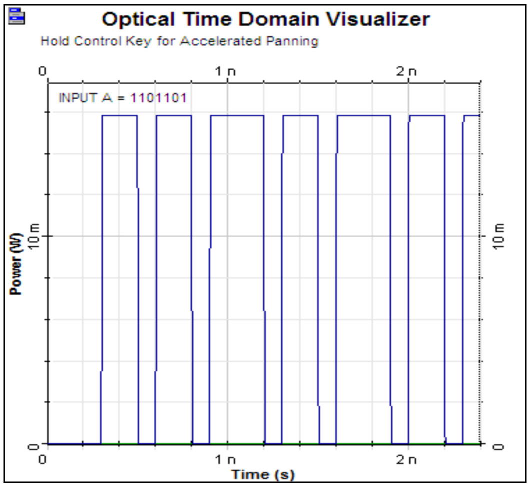

Figure 1. INPUT A = 1101101

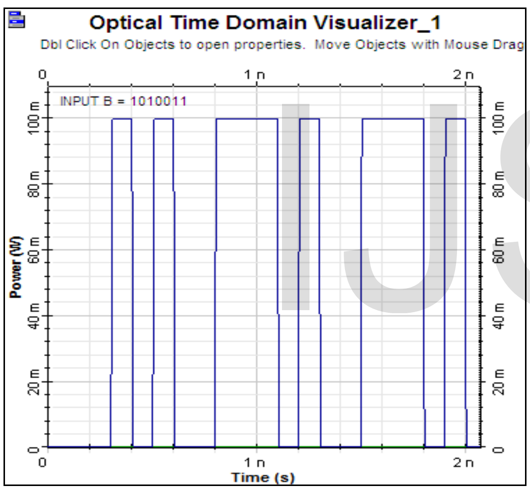

Figure 2. INPUT B = 1010011

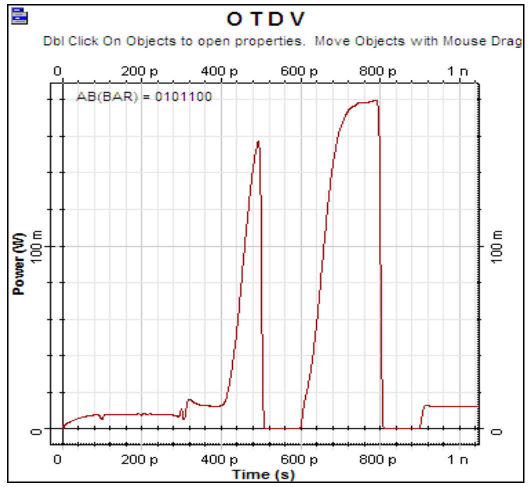

Figure 3. $A\overline{B}$ = 0101100

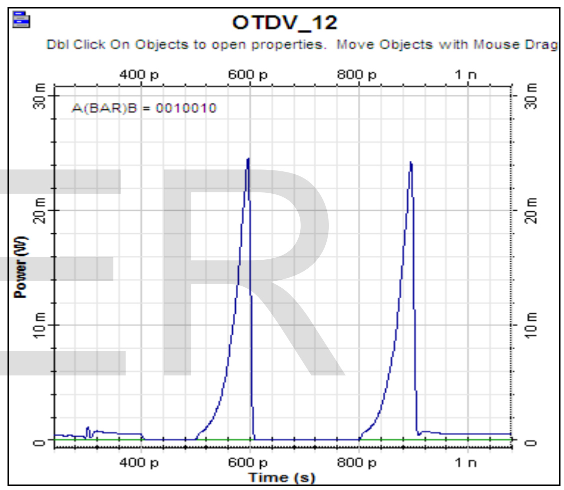

Figure 4. $\overline{A}B$ = 0010010

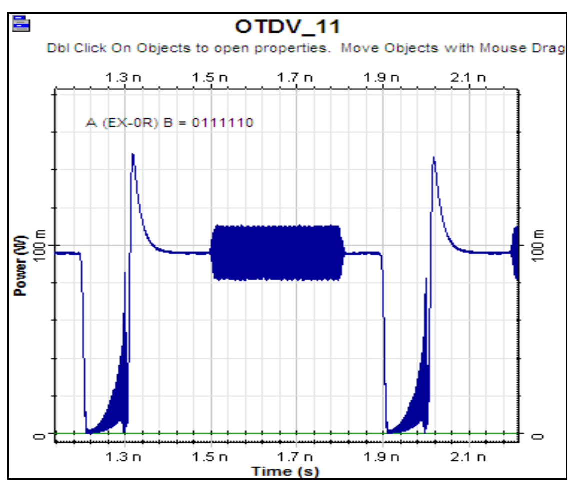

Figure 5. A XOR B = 0111110

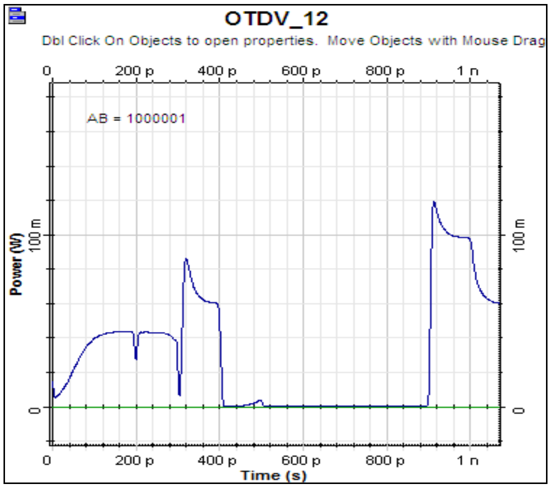

Figure 6. AB = 1000001

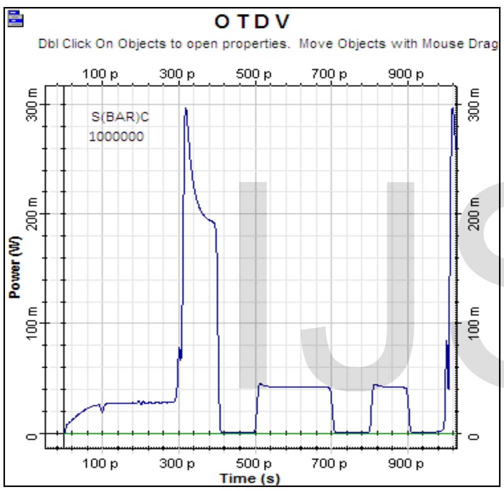

Figure 7. $\overline{S}C_{in}$ = 1000000

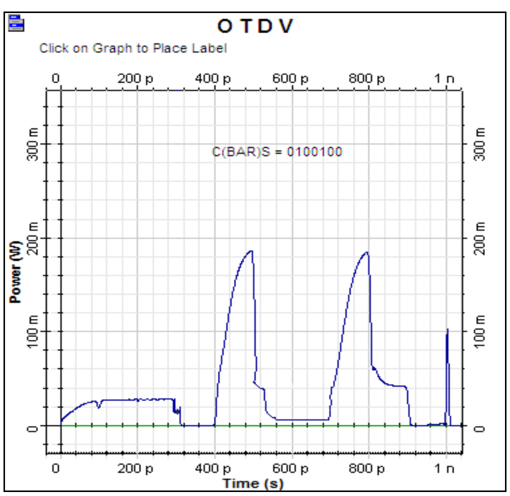

Figure 8. $S\overline{C}_{in}$ = 0100100

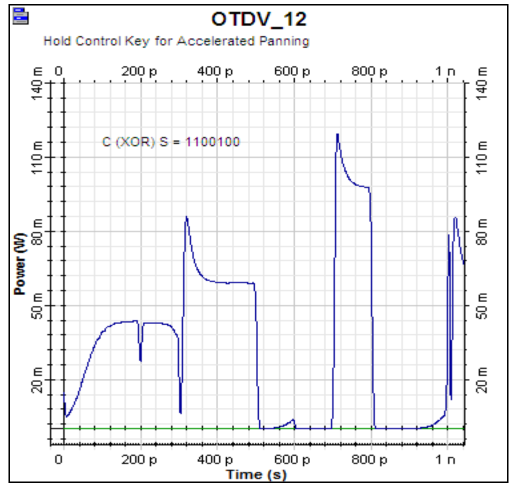

Figure 9. S XOR C = 1100100

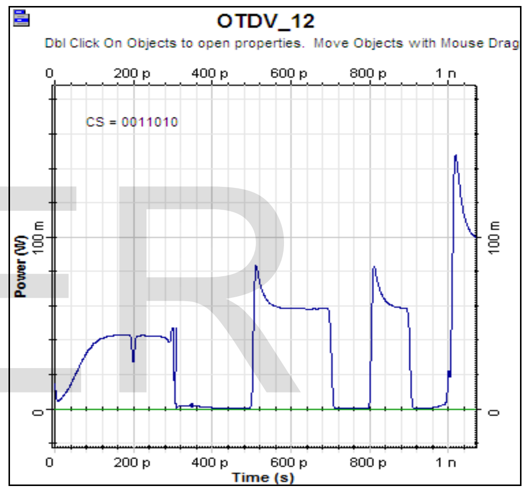

Figure 10. SC_{in} = 0011010

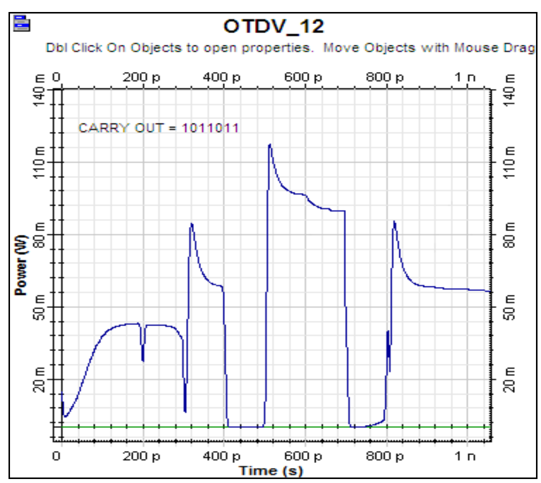

Figure 11. CARRY OUT = 1011011

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