Design and Performance Analysis of All Optical Half Adder based on Carrier Reservoir SOA -Mach Zehnder Interferometer (MZI) Configuration.

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***Abstract*—In this manuscript, Carrier reservoir SOA (CR-SOA) based half adder is proposed and simulated at 100 Gb/s. CR-SOA has fast carrier recovery, due to presence carrier reservoir which enables its use at higher data rates on the other hand conventional SOA suffers from slow carrier recovery which leads to unequal amplification of pulses. The obtained results confirm that proposed design can be realized effectively at target data rate with acceptable Q factor.**

Keywords: Carrier reservoir Semiconductor Optical Amplifier, XOR logic gate, AND logic gate, Half adder

I. INTRODUCTION

Semiconductor optical amplifier has been used extensively in the design of logic gates as it possesses desirable nonlinear characteristics along with other suitable features such as smaller footprint, power efficient, low cost, wide gain spectrum and ease in integration with other photonic devices [1], [3]. Conventional SOA suffers from inherently slow gain recovery time which limits its applications at higher data rate i.e. 60 Gb/s or above [2].

Very recently Carrier reservoir SOA (CR-SOA) based logic gates were proposed and performance analysis showed their capability to operate above 100 Gb/s [4]-[5]. For the first time to our knowledge, CR SOA performance will be verified, in the design of all optical half adder as until now CR SOA has been used either as an classic amplifier or as a logic gate. CR-SOA has fast gain and phase recovery as compared to conventional SOA. CR-SOA works on similar principle as that of QD-SOA. Desired features of CR-SOA has been achieved by growing carrier reservoir layer in the vicinity of active region [5] which is also known as wetting layer. Quasi-Fermi level governs electron densities in the Active region and Carrier reservoir layer. Input optical signal depletes carriers in the active region due to stimulated emission which is quickly replenished by carriers from Carrier reservoir layer. The CR-SOA dynamic model can be expressed by following two nonlinear coupled equations representing time dependent gain of AR (active region) and CR (carrier reservoir) region [5]:

$$\frac{dh_{AR}}{dt} = \frac{I_1}{eV_{AR}} + \frac{\Delta N}{\tau_t(1+\eta)} - gP(t,z) \tag{1}$$

$$\frac{dh_{CR}}{dt} = \frac{I_2}{eV_{CR}} - \frac{N_{CR}}{\tau_C} - \frac{\eta \Delta N}{\tau_t(1+\eta)} \tag{2}$$

$$\Delta N = N_{CR} - N_{AR} \tag{3}$$

Where function h_{AR} and h_{CR} represents Active region and carrier reservoir region gain integrated over its length , N_{CR} and N_{AR} are carrier density of active and carrier reservoir region, I is injected current, V represents volume of each region, τ_t is the transition time for carrier from CR to AR, τ_c is the carrier lifetime in both AR and CR, η denotes population inversion factor expressed as carrier densities ratio of AR and CR i.e. $\eta = N_{AR}/N_{CR}$, g represents gain of SOA, P(t,z) stand for optical pulse power at a distance Z from the input facet of SOA.

II. PROPOSED ALL OPTICAL HALF ADDER AND ITS ANALYSIS

Fig 1 demonstrates proposed optical half adder circuit diagram consisting of CR- SOA as nonlinear element in MZI configuration. The input data signal of wavelength 1500 nm is generated with return to zero format at 100 Gb/s with input power of 10 dBm and FWHM of 1MHz. Continuous wave signal of 8 dBm is generated by mode locked laser at 1555 nm. Data and CW signal act as a pump and probe respectively. CW wave and data signal are multiplexed in CR-SOA which act as a nonlinear element. Data signal causes variation in refractive index of SOA, inducing phase shift in CW signal, however in the absence of data pulse (logic 0) no phase shift is induced. This phenomenon is known as cross phase modulation (XPM) [1]. At the output of interferometer, CW signal travelling in upper and lower arms of interferometer are overlapped to form either constructive (logic 1) or destructive interference (logic 0). Fig 2 depicts satisfactory quality factor of sum and carry which is above 10 followed by fig 3, which confirms logical correctness of output signal. All possible data inputs and corresponding output have been discussed :

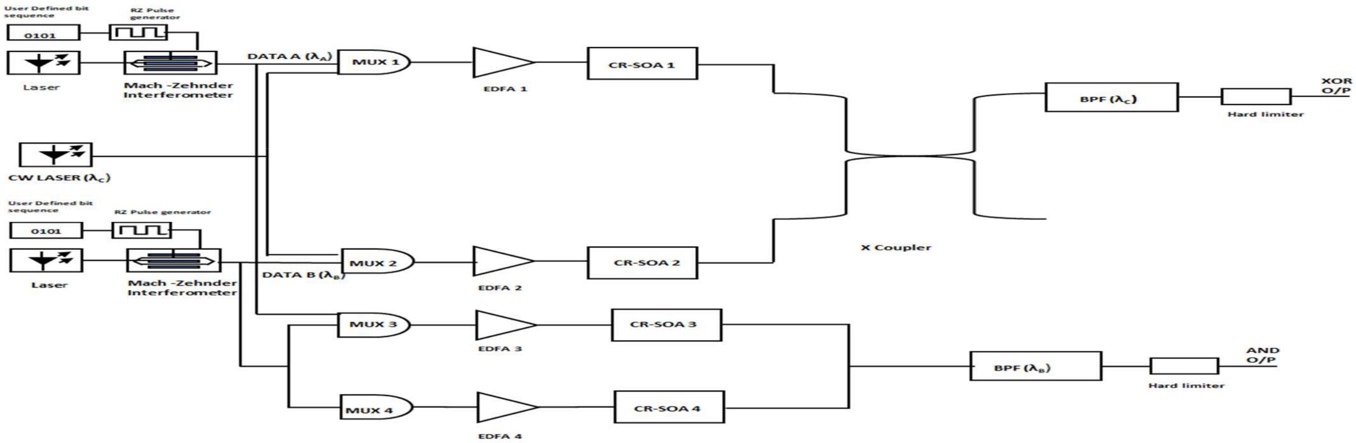

Fig 1. Half adder based on CR-SOA-MZI

Case I For A=0 and B=0

In this case XOR (sum) output will be 0 because no phase shift is induced on CW signal, due to absence of input data. For AND gate operation data signal B is split and launched in upper and lower arm of interferometer whereas data signal A is multiplexed along with Data B. A both data A and B is absent so output obtained is zero.

Case II For A=1 and B=0

Data signal A is present so in XOR operation, upper SOA refractive index will be varied due to A, which induces phase in CW propagating in upper arm of interferometer whereas no phase is induced in lower arm CW. In this scenario CW propagating in upper and lower arm meets at output of interferometer constructively producing logic 1. For AND gate operation due to absence of B, the output of AND gate is 0 as output is sampled using band pass filter tuned at λ_B.

Case III A=0 B=1

This operation is similar to A=1 and B=0 and CW interferes constructively at the output of interferometer, generating logic 1. Considering AND gate operation, due to absence of Data A, no phase is induced on B propagating in upper and lower arm of interferometer. As phase difference is 0 in CW, the interference at the output occurs destructively producing logic 0.

Case IV A=1 B=1

In this case Data A and B will induce equal phase to CW which will cause destructive interference at the output for XOR logic. For AND logic operation, A will induce phase shift in data B such that data B propagating in lower and upper arm of interferometer interferes constructively at the output of interferometer producing logic 1.

III. Conclusion

This work presents design and performance analysis of all optical half adder based on carrier reservoir SOA at 100 Gb/s. Obtained simulation results validates that proposed half adder can be realized practically, with satisfactory Q factor of output signals i.e. above 10, at target data rate.

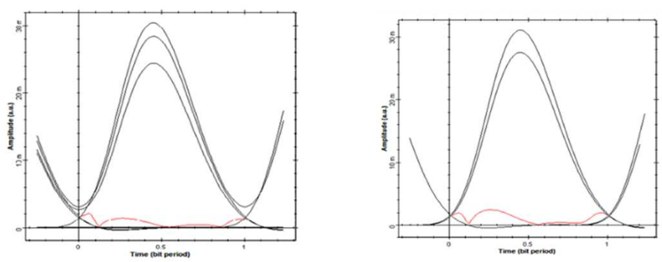

Fig 2: Eye diagrams of Half adder (a) Sum with quality factor 11.1 (b) Carry with quality factor 10.2

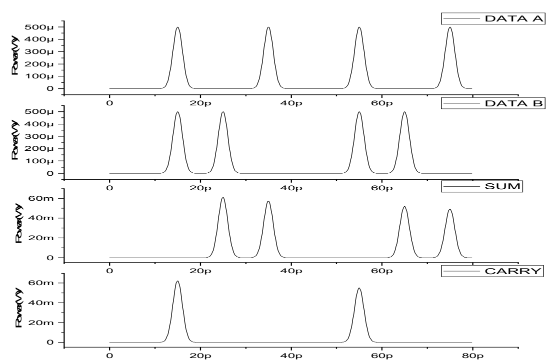

Fig 3: Half adder waveforms (a) Input data A, (b) Input data B, (c) Sum Output, (d) Carry output

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