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THE USE OF SOA-BASED MACH-ZEHNDER INTERFEROMETER IN DESIGNING/IMPLEMENTING ALL OPTICAL INTEGRATED FULL ADDER-SUBTRACTOR AND DEMULTIPLEXER

[1,2]Stanley A. I., [3]Eke James&[2]Nweke F. U.
[1]Department of Electronics and Communication Engineering, MNIT, Jaipur, India, (Visiting Research Scholar).
[2]Department of Industrial Physics, EBSU, Abakaliki, Nigeria.
[3]Department of Electrical and Electronic Engineering, ESUT, Enugu, Nigeria.
Corresponding Author's E-mail: stanleyanyigor@gmail.com

ABSTRACT
By exploiting nonlinear effects in a semiconductor optical amplifier, different functionalities for all-optical digital signal processing are implemented. In particular we demonstrate the logic functions of integrated addition-subtraction and demultiplexing. The all-optical realizations are based on semiconductor optical amplifier (SOA) and Mach–Zehnder interferometer (MZI), which represent one of the most promising solutions due to their compact size, thermal stability and low power operation. Numerical Simulations confirming the described logic devices is done at 40Gbps and for different input combinations.

KEYWORDS: Adder–Subtractor, SOA-MZI, Tree architecture, Demultiplexer.

INTRODUCTION
The demand for faster optical communication networks has been on the rise in recent years. To accommodate this demand, the new generation of optical communication networks is moving fast per second data rates. Such data rates can be achieved if the data remain in the optical domain eliminating the need to convert the optical signals to electronic signals and back to optical signals. Therefore, to successfully be able to achieve higher data rates, advanced optical networks will require all optical ultra-fast signal processing such as wavelength conversion, optical logic and arithmetic processing, add–drop function, etc [1,2].

All -optical combinational circuits are required for managing of the contentions and the switch control in a node of an optical packed switched network. Calculating the addition of Boolean numbers an important functionality to perform packet header processing [3].

Many approaches have been proposed to implement all-optical digital logic function based on the nonlinear effects, either in optical fiber or in semiconductor optical amplifier (SOA). Compared with the nonlinearity of optical fiber, SOA-based all-optical signal processing has demonstrated great potential in terms of high speed, low power consumption, and optical integration [4,5].

Various SOA based switching configurations to implement combinational logic circuits have been proposed. These include cross gain modulation and cross polarization rotation in a single semiconductor optical amplifier (SOA)[3], SOA- assisted OBF, one level simplification method, SOA-based Mach-Zehnder interferometer and terahertz optical asymmetric demultiplexer (TOAD)[6,9].

Among different topologies, monolithically integrated MZI switches represent the most promising solution due to their compact size, thermal stability and low power operation. Symmetric MZI structure provides the highest flexibility and shortest switching window [10].

In digital optical computing, optical interconnecting systems are the primitives that constitute various optical algorithms and architectures. Optical tree architecture (OTA) also takes an important role in this regard [11].In this communication we extend the advantage of SOA based MZI switch by including Optical Tree Architecture for the implementation of integrated full adder-subtractor and demultiplexer at high data rates.

Implementation of adder-subtractor and demultiplexer
This project simulated in Opt SIM 4.7.1 specified in Block mode simulation.

- **Integrated full adder -subtractor**

Schematic diagram of integrated all optical full adder -subtractor is shown in Fig.2.

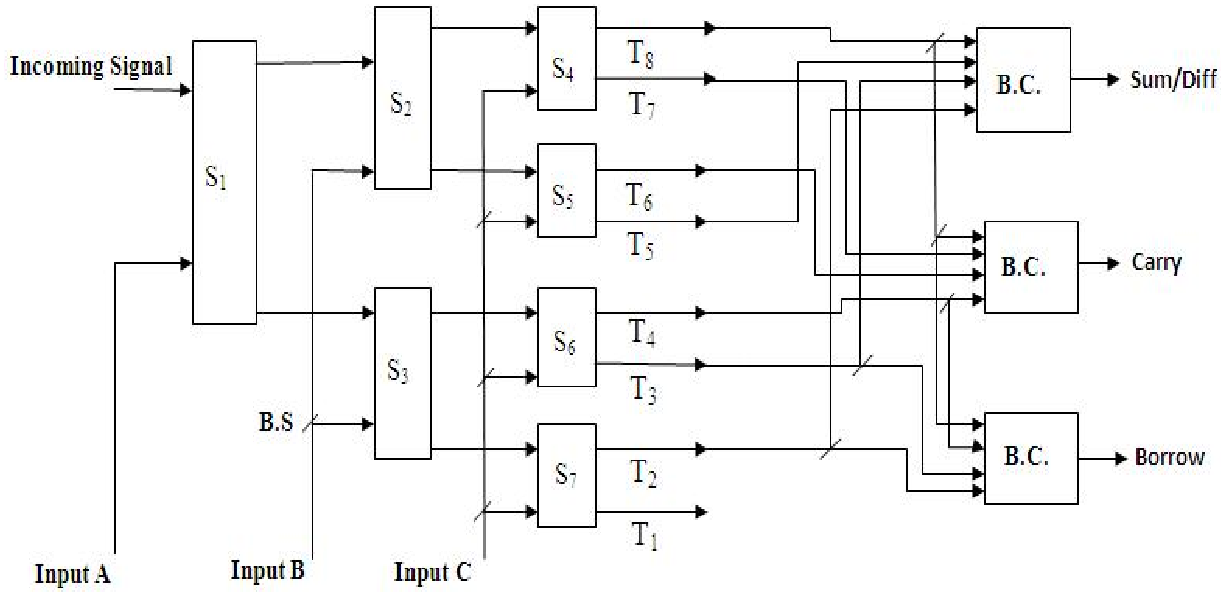
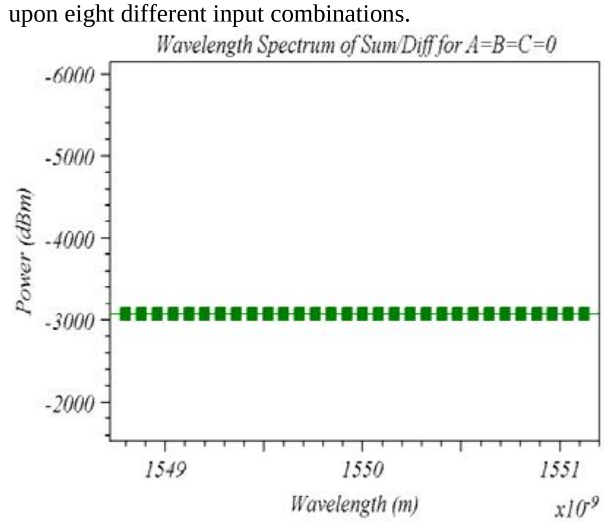


Fig.2.Schematicdiagramoffulladder-subtractorusingSOAbasedMZIswitches
(BC: Beam Combiner, BS: Beam Splitter).

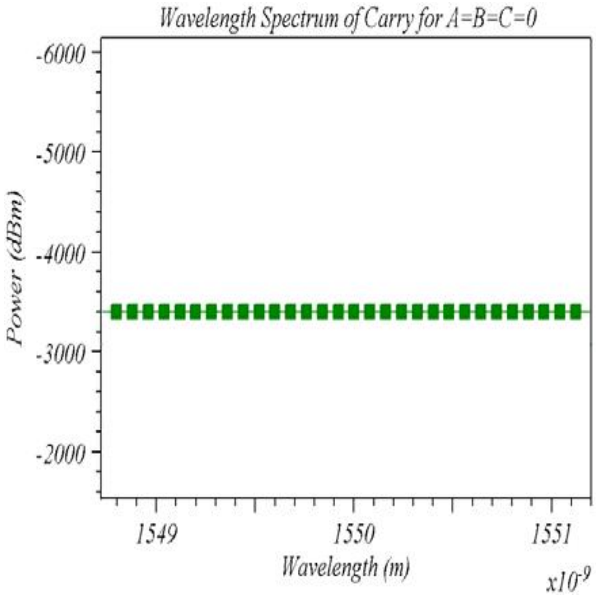
Four signal generators having a frequency of 40 GHz acting as electrical sources for incoming signal and for three inputs of the integrated full-adder and subtractor. Direct modulated semiconductor lasers are directly modulated with the electrical signals. In model considered lasers have 1550 nm wavelength (incoming signal), 1500 nm wavelength (control signal), 0 dBm CW power, ideal laser noise bandwidth, 10 FWHM line width and laser random phase. An input coupler followed by two SOAs then by an output coupler and filters make a single MZI switch [Fig.1]. Outputs of the lasers are fed to input couplers of the MZI switches, which contain two ports named as bar port and cross port. Coupling coefficient α and parameters of the coupling matrix are optimized to obtain the MZI switching. Each arm of the coupler fed to the semiconductor optical amplifier. The SOA is modeled as a travelling wave amplifier. It takes into consideration the time dependence of the gain caused by the saturation effect and the time-dependent phase change due to the gain-index coupling. The semiconductor optical amplifier is assumed to be polarization independent with confinement factor 0.15, noise figure of 6dB, 200mA of pump current, high nonlinearity, and fast transient time.

Outputs of the semiconductor optical amplifiers finally go to other optical couplers. The Gaussian filter type uses a Gaussian filter response to block the control signal at wavelength 1500nm with bandwidth equal to 10m. There are total seven switches, one in first stage, two in the second stage and four in the third stage. Final outputs of four MZI switches in third stage are fed to spectrum analyzers and represent terminals T1 through T8.

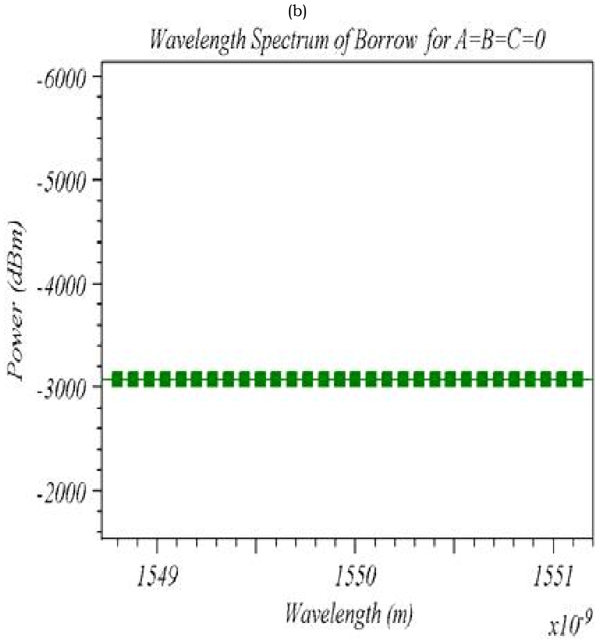
As per the switching operation discussed earlier in theory, when A=B=C=0, in coming signal light is obtained at terminal T1 and all other terminals are in off state. Thus T1 represents logic $\bar{A}\bar{B}\bar{C}$ Similarly terminals T2–T8 give the logical operations of $\bar{A}\bar{B}C, \bar{A}B\bar{C}, \bar{A}BC, A\bar{B}\bar{C}, A\bar{B}C$ and $AB\bar{C}$ respectively. As “sum” as well as “difference” takes the expression $\bar{A}\bar{B}C + \bar{A}B\bar{C} + A\bar{B}\bar{C} + ABC$, therefore output of terminals T_2, T_3, T_5 and T_8 are combined to obtain the result. Combination of results of output of terminals T_4, T_6, T_7 and T_8 gives the result of ‘‘carry’’ ($\bar{A}BC + A\bar{B}C + AB\bar{C} + ABC$)in case of full-adder. Where as the combination of terminals T_2,T_3,T_4 and T_8 gives the result of ‘‘borrow’’ ($\bar{A}\bar{B}C + \bar{A}B\bar{C} + \bar{A}BC + ABC$) in case of full-subtraction. There are eight different cases depending upon eight different input combinations.



(a)



(b)

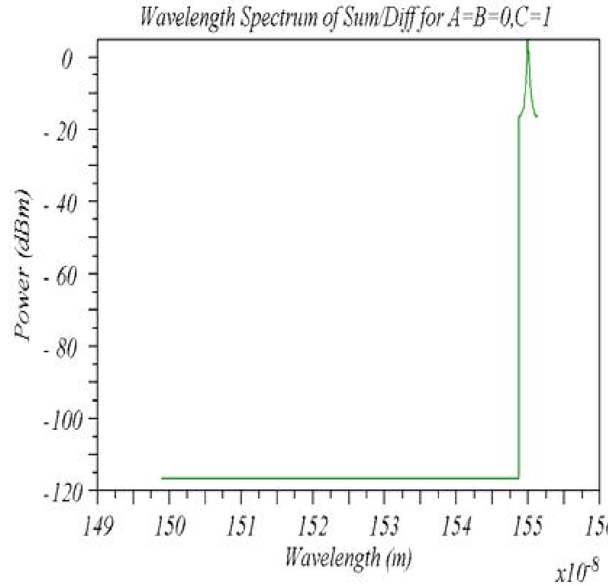


(c)

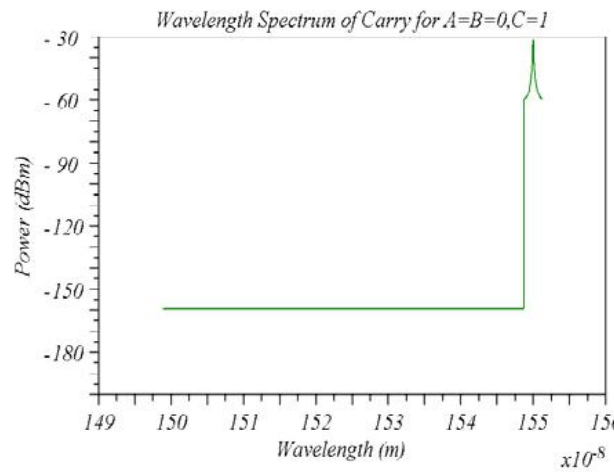
Fig3.Wave length spectrum for logic A=B=C=0
(a) "sum" and " Difference" (b) "carry" (c)"borrow"

When A=B=C=0, output is high at T_1 but this output is not connected to "sum" ("difference"),"carry" and "borrow" so all three outputs give very low power (i.e. gives the 0 output) [Fig.3].

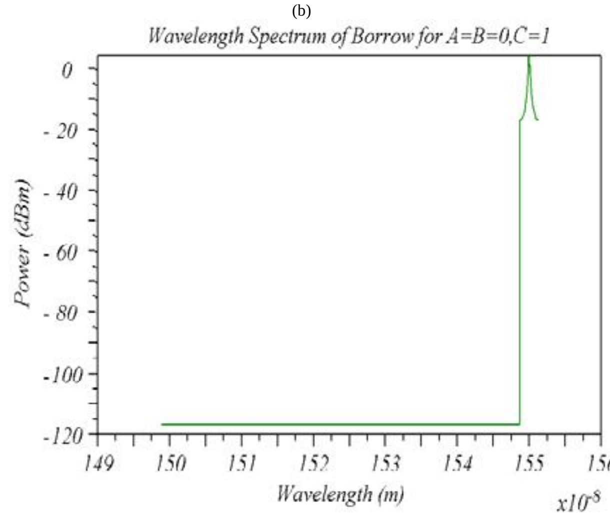
When A=0,B=0,C=1, light reaches at output terminal T_2, which contributes to the "sum" ("difference") and "borrow" output but is not connected to "carry". Positive and negative output powers in the wavelength spectrum are considered as high and low respectively. Fig.4, shows the resulting spectrum for output of "sum" ("difference") and "borrow" is high and for "carry" is low. Similarly, the three outputs are verified for other input combinations.



(a)



(b)



(c)

Fig.4.Wave length spectrum for logic A=0,B=0,C=1. (a) "sum" and "difference". (b) "carry" (c) "borrow"

System Description of Demultiplexer

Demultiplexer operation requires three MZI switches, one in first stage and two in the second stage as shown in Fig.5. Final outputs of two MZI switches in second stage are fed to spectrum analyzers and represent terminals (output ports) T_1 through T_4.

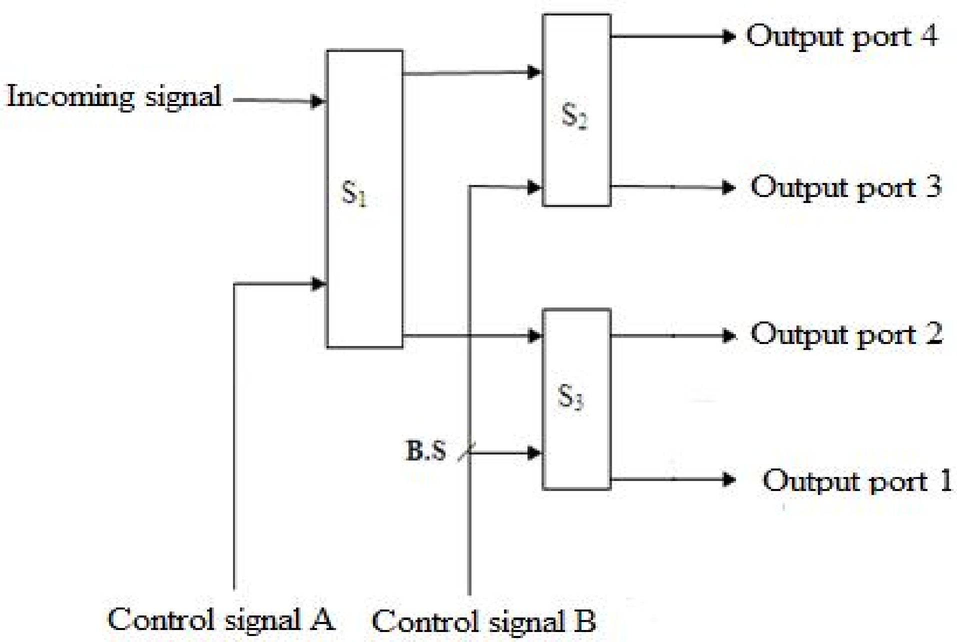
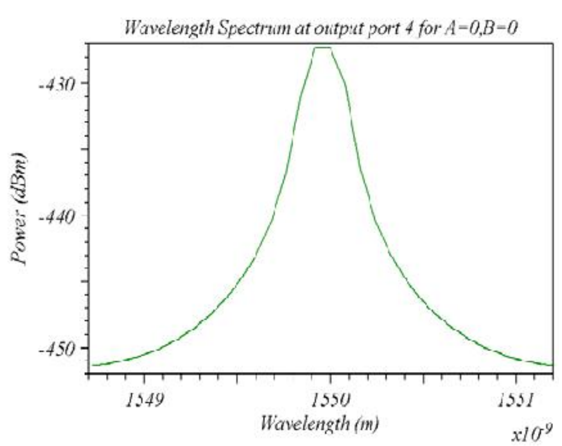


Fig.5.Schematicdiagramofdemultiplexer.

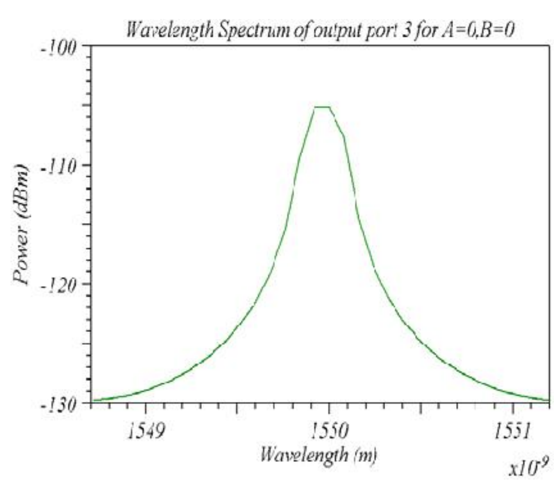
When A=0 and B=0, according to the switching principle discussed earlier, the light reaches T_1 (output port1).In this case, no light is present at other terminals T_2,T_3 and T_4. Fig.6 shows the optical spectrum at four output ports for this condition. As seen in the Fig.6, positive spectrum is obtained only at T_1 and spectrum peaks at other three ports are less than -100dBm.

When A=0 and B=1, light is only present in T_2 (output port2) thus positive spectrum peak is obtained only at this terminal outputs at all other terminals is less than -60dBm. For the case A=1 and B=0, T_3 (output port3) is in the one state and others are in zero state.When both control signals are 1, light is obtained at output port4

Spectrum peaks at other ports are less than 100dBm. As filters block any control signal wavelength at outputs so output spectrums are obtained around 1550nm which is incoming signal wavelength.



(a)



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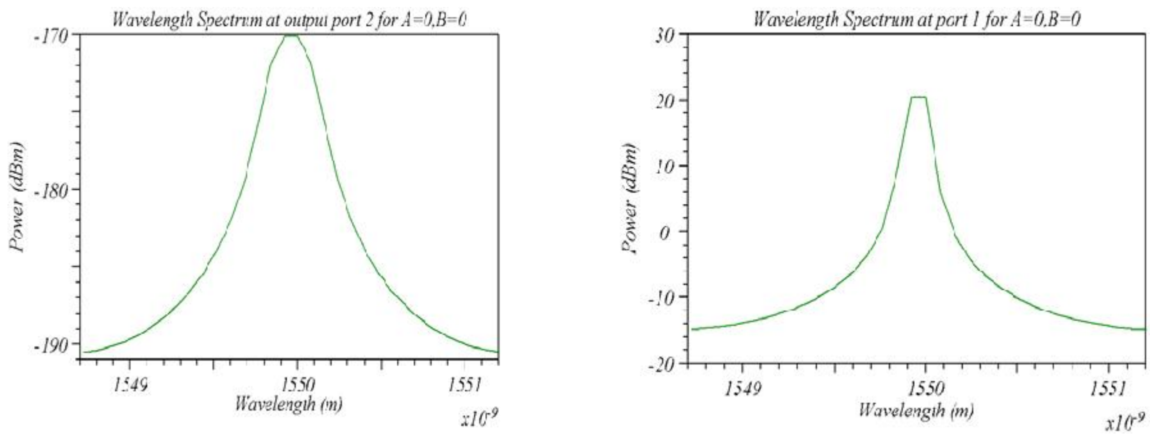

(c) (d)

Fig.6.Demultiplexer output at different ports for A=B=0.(a) Output port 4 (b)Output port3 (c)Output port 2(d)Output port1

CONCLUSION

An all-optical integrated full adder-subtractor and demultiplexer is proposed and implemented using SOA-based Mach–Zehnder interferometer (MZI). As the scheme exploits SOA based MZI switches thus making it suitable for integrated solutions. The simulated system has the potential to operate at above 40 Gb/s.

By combining beam splitters, beam combiners, and cascading SOA-MZI switches, we can implement and realize any complex logical function expressed in sum of the products form. This scheme can be easily and successfully extended for any higher number of input digits by proper incorporation of MZI based optical switches, vertical and horizontal extension of the tree and by suitable branch selection.

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