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A Novel Nanometric Mach-Zehnder Interferometer-Based All-Optical Fault-Tolerant Reversible Full Adder

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Abstract: According to barriers for the use of electronics in the progress path and with regard to the appearance of new technologies, such as light and quantum, and their numerous benefits, combined light and quantum should be used to enjoy all these advantages. There is no doubt that the changes must also be done in making circuits using base gates based on new design of both the light and quantum technology. Thus, in this study, we propose quantum fault-tolerant reversible MIG gate using the optical components for the first time. Then, by using it, we propose an optical quantum fault-tolerant reversible full adder. Obviously, the design can be applied in the optical computing, quantum computing, DNA computing, as well as genetics and nanotechnologies, considering the increased fault tolerance. All the scales are at the nanometric level.

Key words: All optical switch, mach-zehnder interferometer, MIG gate, optical computing, quantum computing, reversible logic gate

INTRODUCTION

During the twentieth century, electronics industry created a great revolution in human life. A vacuum tube was built for long-distance data transmission, which was used in radio and television. Vacuum tube was also used in computers for processing raw data. Subsequently, the path moved toward the next smaller and faster electronic hardware. First, transistors were introduced to replace vacuum-tube devices, and then thousands and millions of transistors of the same dimensions were integrated on the semiconductor chips. The product of this miniaturization is very easy to use, and as a result, it is now utilized in a variety of modern computer systems, and without which life has become impossible.

Today, a similar revolution is taking place. In this new revolution, electrons that caused the development of electronics industry are not employed; photons play the main role in the emergence of photonics industry. Today, in the advantages of the field of photonics and telecommunications, processing, etc., are evident, and its related technologies have reached their final growth. However, some applications such as optical switches and optical image processing are still in need of many improvements. Optical computing and optical transmitters could be the ultimate goal of photonics research, where process, storage, and retrieval of data are done using light, resulting in the emergence of very fast and efficient computers. However, practical research in the field of optical computers has a long way to achieve this goal (Suhir, 2000; Miller and Ozaktas, 1997).

According to Moore's law, the number of transistors on microprocessors doubles every 18 months. Thus, by 2030, we might witness atomic-scale circuits in microprocessors, and the next logical step will be making quantum computers (QC) to implement the power of atoms and molecules to work in the memory and processing tasks. QC can do any calculations faster than any other silicon-based computer. Quantum technologies are the tool of the fifth generation computers. Quantum computing, nanotechnology, and molecular computers will change the major figures in the coming years. It is worth mentioning that one of the largest and most original design features and benefits of reversible quantum circuits is the reversible state.By using reversible property, one of the most valuable areas of design, i.e., fault tolerance, can be achieved. In other words, if our design is reversible, mechanisms of detect, discover, and fault recovery can be easily utilized and quantum designs with the aim to increase fault tolerant can be made (Bennett and DiVincenzo, 2000; Fredkin and Toffoli, 1982; Haghparast and Navi, 2008; Poustite and Blow, 2000; Karim and Awal, 1992).

However, design weaknesses and problems of quantum design are fan-out and the problem of not having the right to use feedback, which, using light and photonics, can be easily overcome and cover all its weaknesses, in addition to its numerous advantages, such

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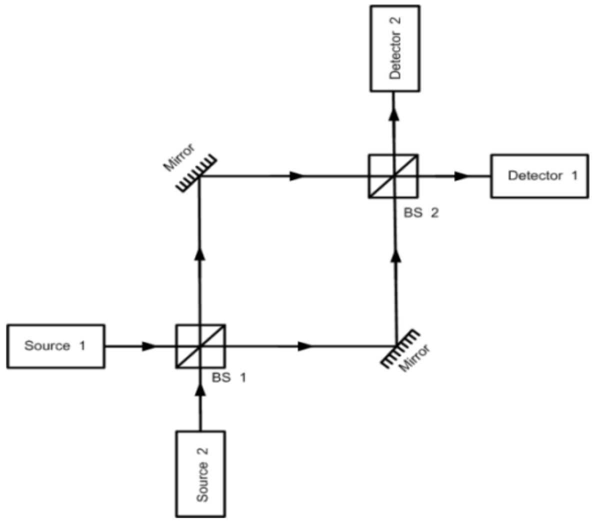

Fig. 1: Internal structure of an MZI

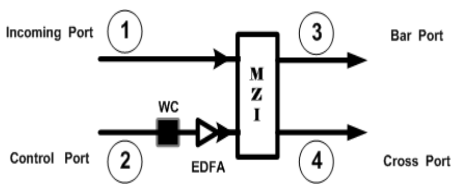

Fig. 2: Symbol of all-optical MZI switch

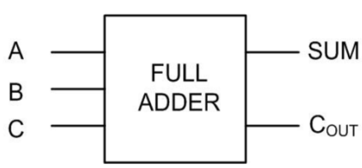

Fig. 3: Symbol of full adder

as light and speed increase, dramatic increase in bandwidth, absence and lack of noise and signal weakness, and substantial reduction in communication volume and dozens of other superior benefits. As the largest and most advanced circuit is always set to include elements and circuits, to achieve quantum structures composed of optical components, we begin with the change in basic circuits and components (Caulfield and Westphal, 2004; Lohmann, 1986; Yatagai, 1986; Jin *et al*., 2005; Chattopadhyay and Roy, 2008).

In this study, we have presented, for the first time, two proposed full adders. The first full adder design is merely provided using MZI optical switches for optimal. Then, in the second project, we will build in the first phase of the MIG quantum gate a gate fault tolerant with properties based on MZI optical switches; in the second phase, adder will be designed using MIG all optical gate design. In the results of our proposed adder, there will be a hybrid circuit structure with all the optical properties with fault tolerance and reversible state.

Introduction of MZI switch structure: The structure of an MZI optical switch is shown in Fig. 1. MZI is used in many optical measuring instruments to detect light and photon signals, and is very useful. MZI components include two 45°-angled reflection mirrors, including one at the top left and another right at the bottom, and two rays Beam Splitters 50:50, one at the top and the other at the lower right and left are two names to the source S1 and S2 and two providers to identify the names of Light Detector D1 and D2 (Gayen and Roy, 2008; Roy, 2009).

Based on the structure of the MZI, four modes of MZI performance are expected. The first case is that the light rays from the source entering Detector 1 could be detected, and the second case is that the light rays from the source entering Detector 2 could be detected and diagnosed. The third mode is that light rays that enter from the second source could be detected by Detector 1, and lastly, light rays entering from the second source could be detected by Detector 2. The symbol of all light switches based on all-optical MZI is shown in Fig. 2.

This is based on incoming signal in optical switches and control signal as a basic input and bar port and cross port as output. Control signal is considered as a signal that has different wavelengths and is stronger than the input signal. WC element provides a different wavelength and EDFA amplifiers play a role as the input signal to these ports.

The structure of optical switches presented in (Agrawal and Olsson, 1989; Eiselt *et al*., 1995; Wang *et al*., 1998; Leuthold *et al*., 1998) is such that if the incoming signal is low as a result of both the bar port

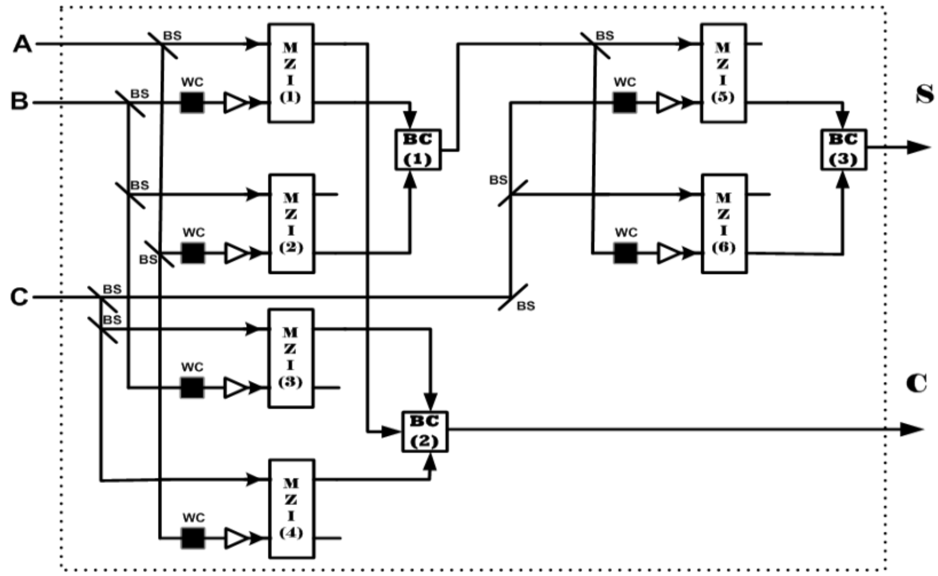

Fig. 4: Schematic diagram of an optimized MZI-based full adder

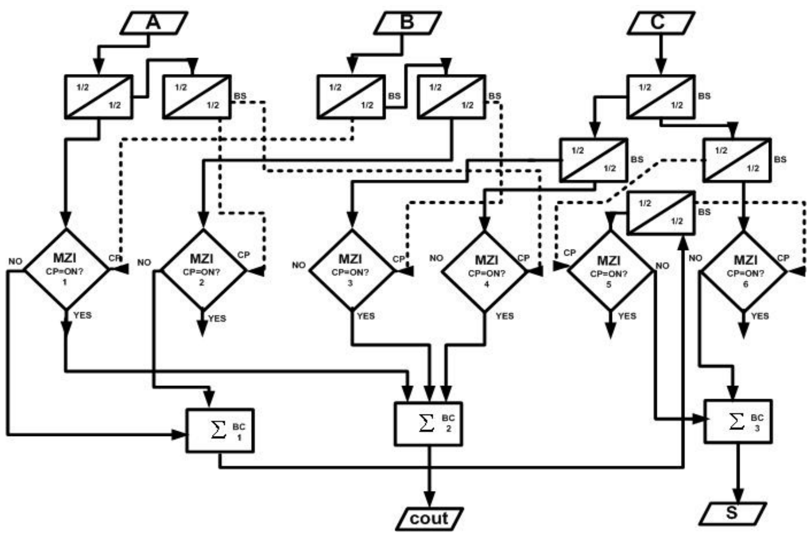

Fig. 5: Block diagram of states of optimized MZI-based full adder

and output port, the cross port will have low or zero value.But if Incoming signal, be high and light rays are present in the input base' then depending on what value a control signal is input signal and some output ports Incoming between Bar and Cross will be so divided Control signal if the value is lowIf the output port will receive no light Bar and value will be zero and 0.83 of the value of the input signal to the output port will be transferred and if Cross Control signal is a high value of 0.45 in this case the input signal at the output base' Bar port and only 0.05 Incoming signal from the input signal at the output base' Cross port. Thus, it can be interpreted that the MZI optical switch, acting as a 2:1 Demax, serves the basic input incoming signal as input and base input selector control signal as if the amount of output signal appears at 0.05 base' cross port output. However, if we exit the base as the cross and bar, then the output of this role will be 2:1 Demax.

Proposed optimized MZI-based full adder: It is known that full adder is one of the basic hybrid circuits having three basic inputs A, B and C and two outputs, Sum and $C_{out.}$ The truth table of a full adder is shown in Table 1 and its symbolic view in given in Fig. 3.

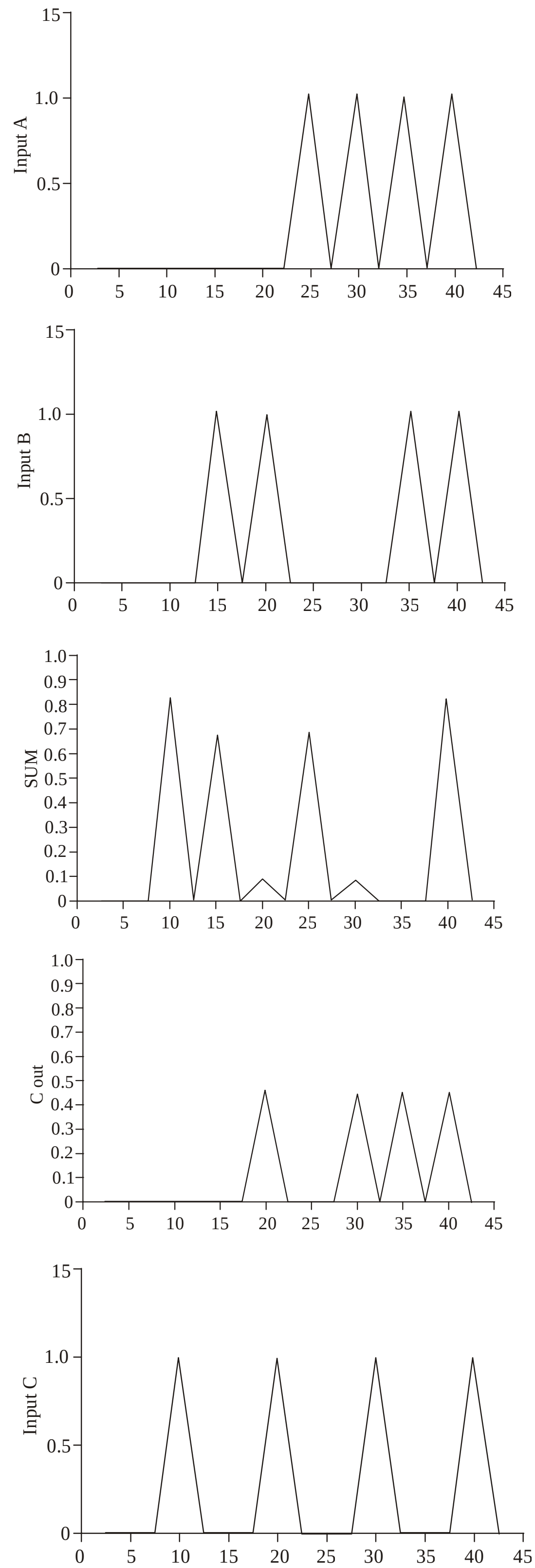

Fig. 6: Performance simulation of optimized full adder

We have designed the full adder hybrid circuit based on MZI optical switch and optimized the design with the lowest number of MZI. Figure 4 shows the schematic diagram of our circuit, in which BS stands for 50:50 splitter, BC stands for beam combiner, MZI represents Mach-Zehnder interferometer, and Cp represents the controlled pulse.

A state diagram of optimized MZI-based full adder is shown in Fig. 5. Owing to the three input circuits, eight modes can be considered, each of which is outlined as follows:

- In case A = B = C = 0, the result is that none of the inputs of MZI has a signal, except MZI-5 . Thus, in both the output ports of the MZI, the output is low; in addition, BC1 and BC2 are low, and the input of MZI-5 depends on the output of BC1, which, in this case, will also be low, and consequently, BC3 output will also be low.
- In this case, the inputs of A and B are low and C is high. As a result, no input signal exists in the MZI-1 and MZI-2, and hence, the output BC1 will be low and none of the output ports of MZI-5 will receive light, provided zero control signal output of MZI-6 cross received the light and light switch causes the BC3 output become high, but considering the lack of any optical signal received at the output port Bar, MZI of 4 and 3 and1 output will be low equal to BC2.
- If only input B is high, then the inputs of MZI-1, -3, -4, and -6 will be low, and none of the MZI output ports will receive the signal. Furthermore, the output of BC2 will be low. However, owing to the MZI-2 low signal, the output of the cross port becomes high and causes output BC1 to become high. Thereby, the control signal of the MZI-5 signal is received in the optical output port of cross, resulting in high BC3 output.
- If the input A is low and C and B are high, as a result of considering the structure function defined MZI switches for optical output port MZI3 bar received light signal and the output of BC2 becomes high, but according to the outputLow to BC1 and considering MZI having control inputs 5 and 6, BC3 output becomes Low.
- The fourth mode is when the only input A is high and inputs B and C are low. As a result, MZI-1 input signal becomes high, and with regard to the control signal that is low, signal light is received in the cross and subsequently, the output and BC1 become high, considering that the output port Bar, MZI 3 and 4 did no t receive any signal light and the BC2 output

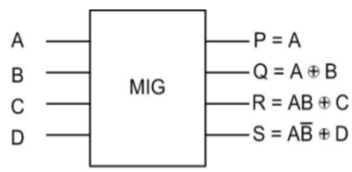

Fig. 7: Schematic of MIG gate

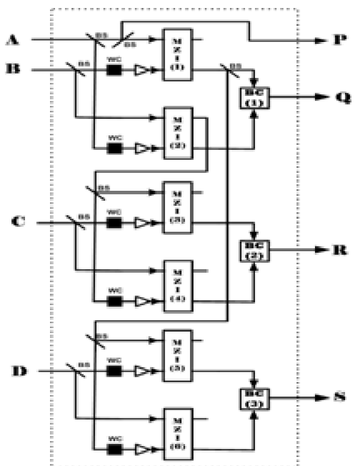

Fig. 8: Schematic diagram of an MIG-based MZI gate

becomes Low, but the situation of MZI-5and MZI-6 output of the BC3 become high.

- In this case, A = C = 1 and input B = 0. Then, input MZI-2 is low and naturally "in the output it will not receive any signal." According to the inputs A and C, the inputs of MZI-1, -3, and -4 will be high and their input control will be low and high. As a result, the output of BC1 and BC2 will be high, and following that, MZI-5 and control signals MZI-6 will become high, and "BC3 output will be low."
- The second case is when the inputs A and B are high, and input C is low. In this case, the input mode of MZI-6, -4, and -3 will be zero and no optical signal at the output of the MZI will be received. Given the control signal being high in MZI-1 and -2, there will be no optical switches in the output of this cross. However, the bar will be receiving its signals, and hence, the output of BC1 becomes low and output of BC2 becomes high. Furthermore, according to the performance of MZI-5 and -6, the output of BC3 will be low.
- When A = B = C = 1, then in the MZI-1-4 and MZI-6, the input and control signals of all MZI inputs will be high, except MZI-5. Therefore, based on the performance of MZI described in the previous sections, the bar port and MZI-1-MZI-4 will receive signal light, given that the cross port, MZI-1, and MZI-2 do not receive the signal. Thus, the output of BC1 will become low and MZI-5 will not have an input signal. Furthermore, the control signal of MZI-6 will be low and owing to the cross port, MZI-5 will receive optical signal, MZI-6 will receive signal, and BC3 output will become high. Also, according to the received signal at the bar port, MZI-1, -3, and -4 and BC2 output will be high.

Table 1: Adder truth table

Input			Output	
A	B	C	Sum	C_{OUT}
0	0	0	0	0
0	1	1	0	0
0	1	0	1	0
1	0	1	1	0
0	1	0	0	1
1	0	1	0	1
1	0	0	1	1
1	1	1	1	1

Analysis table of MZI switches related to the proposed optimal adder circuit is given in Table 2. According to the analysis done, the final output values based on initial inputs as well as a summary table is given in Table 3.

Considering the optical circuit design simulation outputs based on the initial entries of the relevant table done in MATLAB environment, we obtained the results that are shown in Fig. 6.

It must be noted again that this circuit is designed for the first time in terms of the number of MZI switches used in optimization, and it is designed in such a way that use of fewer light switches is not possible. Subsequently, we tried to develop a circuit that combines the ability to design full adder fault tolerance.To do so, the MIG quantum gates have been used.First, the quantum gate structure has been explained, followed by the structure

Introducing quantum gate MIG: MIG gate is displayed in Fig. 7. As shown in the schematic of this gate, four inputs and four outputs comprise the feature of reversible circuits that have equal number of inputs and outputs. For each mode input, a unique output mode can be defined. Each mode of entry is a defined output state and vice versa, and every time, the output mode to input reaches a unique state (Islam *et al*., 2009; Islam *et al*., 2011). The truth table of this gate is shown in Table 4.

Considering that the input and output parity gates in each of the 16 states is equal, the quantum gate is also considered to be full tolerant. Obviously, if every state in the number of input 1 becomes equal to the number of

Table 2: Chart analysis of optimized MZI-based full adder

MZI- 1				MZI- 2				MZI- 3			
A	B	B1	C1	A	B	B2	C2	C	B	B3	C3
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	0	0	0.83C
0	1	0	0	1	0	0	0.83B	0	1	0	0
0	1	0	0	1	0	0	0.83B	1	1	0.45C	0.05C
1	0	0	0.83A	0	1	0	0	0	0	0	0
1	0	0	0.83A	0	1	0	0	1	0	0	0.83C
1	1	0.45A	0.05A	1	1	0.45B	0.05B	0	1	0	0
1	1	0.45A	0.05A	1	1	0.45B	0.05B	1	1	0.45C	0.05C

MZI- 4				MZI- 5				MZI- 6			
C	A	B4	C4	C1	+C2	C	B5	C5	C	C1+C2	B6C6
0	0	0	0		0		0	0	0	0	0 0 0
1	0	0	0.83C	0	1	0	0	1	0	0	0.83C
0	0	0	0	0.83B	0	0	0.68B	1	0.83B	0	0
1	0	0	0.83C	0.83B	1	0.37B	0.04B	0	0.83B	0.45C	0.05C
0	1	0	0	0.83A	0	0	0.68A	1	0.83A	0	0
1	1	0.45C	0.05C	0.83A	1	0.37A	0.04A	0	0.83A	0.45C	0.05C
0	1	0	0	0.83A	0	0	0.68A	1	0.83A	0	0
1	1	0.45C	0.05C	0.83A	1	0.37A	0.04A	0	0.83A	0.45C	0.05C
0	1	0	0	0.83A	0	0	0.68A	1	0.83A	0	0
1	1	0.45C	0.05C	0.05(A+B)	1	0	0	1	0.05(A+B)	0	0.83C

Table 3: Final output values and initial input optimized full adder

Input			Output	
A	B	C	CS = C5+06	C = B1 +B3+B4
0	0	0	0	0
0	0	1	0.83C	0
0	1	0	0.68B	0
0	1	1	0.04B + 0.05C	0.45C
1	0	0	0.68A	0
1	0	1	0.04A+0.05C	0.45C
1	1	0	0	0.45C
1	1	1	0.83C	0.45(A+C)

Table 4: Truth table of MIG gate

Input				Output			
A	B	C	D	P	Q	R	S
0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	1
0	0	1	0	0	0	1	0
0	0	1	1	0	0	1	1
0	1	0	0	0	1	0	0
0	1	0	1	0	1	0	1
0	1	1	0	0	1	1	0
0	1	1	1	0	1	1	1
1	0	0	0	1	1	0	1
1	0	0	1	1	1	0	0
1	0	1	0	1	1	1	1
1	0	1	1	1	1	1	0
1	1	0	0	1	0	1	0
1	1	0	1	1	0	1	1
1	1	1	0	1	0	0	0
1	1	1	1	1	0	0	1

output 1, then this gate is considered to be a conservative gate in which MIG cannot be applied, because the states 9, 11, 15 and 16, despite having equal input and parity, do not equal number of input and output of 1. In the next phase, we design MZI optical switch gate based on the MIG new gate, and its block diagram is given in Fig. 8. in which BS represents 50:50 beam splitter, BC represents beam combiner, and CP denotes control pulse of the MZI.

The schematic of MIG is shown in Fig. 9, in which the gate has four different inputs, and hence, 16 different modes for the inputs of this gate could be considered. Each of these cases of inputs, outputs, and intermediate values of inputs and outputs of MZI has been reviewed:

- When the fourth input of each circuit has zero, in this mode, all inputs of MZI will be low and no signal could be received in cross and bar outputs, resulting in four outputs being low.
- In this case, only input D will be high and the rest of the inputs are zero. In the MZI input results from 1 to 5, there will be no signal and only the input of MZI-6 will be high, considering the amount of control signals, which is equal to zero, and the output of the cross will appear as MZI optical signal, and thereby outputs of the BC3 will become high and the rest of outputs will be zero.
- In this instance, only the C input is high and the rest of the inputs are zero. As a result, both the output ports of MZI, except MZI-4, will be low. Considering that only the control signals MZI-4 are low, the output cross of the MZI will be high and, as a result, only the output of BC2 will be high and the rest of the outputs will be low.

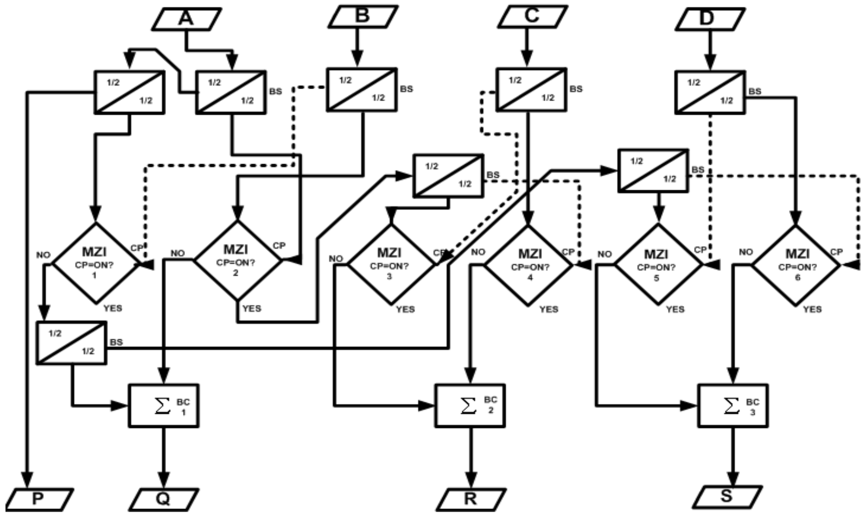

Fig. 9: Block diagram of gate states MIG

Table 5: Table of gate inputs and outputs of MZI optical MIG

MZI- 1				MZI-2				MZI-3			
A	B	B1	C1	B	A	B2	C2	B2	C	B3	C3
0	0	0	0		0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1	0	0
0	0	0	0	0	0	0	0	0	1	0	0
0	1	0	0	1	0	0	0.8,3B	0	0	0	0
0	1	0	0	1	0	0	0.8,3B	0	0	0	0
0	1	0	0	1	0	0	0.8,3B	0	1	0	0
0	1	0	0	1	0	0	0.8,3B	0	1	0	0
1	0	0	0.8,3A	0	1	0	0	0	0	0	0
1	0	0	0.8,3A	0	1	0	0	0	0	0	0
1	0	0	0.8,3A	0	1	0	0	0	1	0	0
1	0	0	0.8,3A	0	1	0	0	0	1	0	0
1	1	0.4,5A	0.0,5A	1	1	0.4,5B	0.0,5B	0.4,5B	0	0	0.3,7B
1	1	0.4,5A	0.0,5A	1	1	0.4,5B	0.0,5B	0.4,5B	0	0	0.3,7B
1	1	0.4,5A	0.0,5A	1	1	0.4,5B	0.0,5B	0.4,5B	1	0.2,B	0.3,2B
1	1	0.4,5A	0.0,5A	1	1	0.4,5B	0.0,5B	0.4,5B	1	0.2,B	0.3,2B
MZI- 4				MZI- 5				MZI- 6			
C	B2	B4	C4	C1	D	B5	C5	D	C1	B6	C6
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	0	0	1	0	0	0.8,3D
1	0	0	0.8,3C	0	0	0	0	0	0	0	0
1	0	0	0.8,3C	0	1	0	0	1	0	0	0.8,3D
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	0	0	1	0	0	0.8,3D
1	0	0	0.8,3C	0	0	0	0	0	0	0	0
1	0	0	0.8,3C	0	1	0	0	1	0	0	0.8,3D
0	0	0	0	0.8,3A	0	0	0.68,A	0	0.8,3A	0	0
0	0	0	0	0.8,3A	1	0.3,7A	0.04,A	1	0.8,3A	0.4,5D	0.8,3D
1	0	0	0.8,3C	0.8,3A	0	0	0.68,A	0	0.8,3A	0	0
1	0	0	0.8,3C	0.8,3A	1	0.3,7A	0.04,A	1	0.8,3A	0.4,5D	0.8,3D
0	0.4,5B	0	0	0.0,5A	0	0	0.0,4A	0	0.0,5A	0	0
0	0.4,5B	0	0	0.0,5A	1	0.0,2A	0.0,2A	1	0.0,5A	0	0.8,3D
1	0.4,5B	0.4,5C	0.8,5C	0.0,5A	0	0	0.0,4A	0	0.0,5A	0	0
1	0.4,5B	0.4,5C	0.8,5C	0.0,5A	1	0.0,2A	0.0.2A	1	0.0,5A	0	0.8,3D

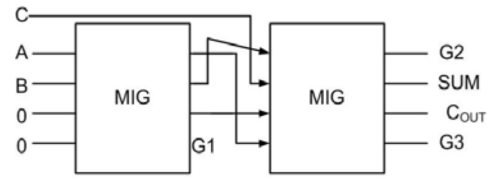

Fig. 10: Full adder made from two gates of MIG

- The fourth case occurs when the two inputs A and B are low and the two inputs C and D are high. As a result of high input MZI-4 and -6, the rest of the MZI will have no signal on the incoming input port. Considering that the control signal inputs MZI-4 and -6 are low, the cross of both the MZI output optical signals are received and this will cause the output of BC2 and BC3 to become high.
- If only input B is high and the rest of the inputs have low value, then only MZI-2 input will receive the input and the rest will have no input signal. Therefore, no optical signal occurs in the output ports, and given that signal MZI-2 control input is zero, the cross MZI output ports have high value; as a result, the output BC1 will become high and the rest will be low.
- In this case, the inputs 0 and B are high, and inputs C and A are low. Therefore, MZI-2 and MZI-6 will have inputs and the rest of the MZI based on the structure described will have no input signal. Thus, the ports will not get light and considering received signal light in optical switches and cross output ports 2 and 6, the output of BC1 and BC3 will be high.
- If the input value of C and B is 1, and inputs D and A are zero, in this case, the output ports of MZI-2 and MZI-4 optical signal will be received, and accordingly, the BC1 and BC2 outputs will become high and the rest of the output gate will be zero.
- If input A is zero and the rest of the inputs are 1, then MZI-2, -4, and 6 have output, and given that the MZI-1, -3, and -5 have no input signal, both the output ports will be zero. As a result, each of the three BC outputs will be high.

Table 6: Table of input and output optical MIG gate

Input					Output		
A	B	C	D	P	Q = C1+C2	R = C3+C4	S = C5+C6
0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0.083D
0	0	1	0	0	0	0.83C	0
0	0	1	1	0	0	0.83C	0.083D
0	1	0	0	0	0.83B	0	0
0	1	0	1	0	0.83B	0	0.083D
0	1	1	0	0	0.83B	0.83C	0
0	1	1	1	1	0.83B	0.83C	0.083D
1	0	0	0	1	0.83A	0	0.68A
1	0	0	1	1	0.83A	0	0.04A+0.05D
1	0	1	0	1	0.83A	0.83C	0.68A
1	0	1	1	1	0.83A	0.83C	0.04A+0.05D
1	1	0	0	1	0.05(A+B)	0.37B	0.04A
1	1	0	1	1	0.05(A+B)	0.37B	0.002A+0.83D
1	1	1	0	1	0.05(A+B)	0.02B+0.05C	0.04A
1	1	1	1	1	0.05(A+B)	0.02B+0.05C	0.002A+0.83D

- In this case, except input A that is 1, the rest of the inputs will be low. As a result, in the output of cross, MZI-1 and MZI-5 optical signal will be present and none of the MZI outputs will have signal. Therefore, BC1 and BC3 will be high and the output of BC2 will be low.
- If the inputs A and D are high, and inputs B and C are low, only the MZI input ports 1-6 will have light signals, and thus, the control input signal exists in the output port of cross and MZI-1 signal. However, considering that the control signal output port MZI-6 is high and cross MZI-6 is low, the output of the BC1 will be high and BC3 output will be zero. Furthermore, the other MZI output will be low.
- In this case, the inputs A and C are high, and inputs B and D are low. As a result, MZI-1, -4, and -5 have received input signal and the optical signal output ports will appear according to MZI input control signals 1, 4, and 5, which, in all three cases, will be equal to zero. Therefore, only three MZI output signals will be received in cross, and ultimately, BC1, BC2, and BC3 outputs will be high.
- In this case, the B input is zero and the rest of the inputs will be high. Therefore, only the input signals

Table 7: Table of correctness of optical fault-tolerant full adder properly made from two optical fault-tolerant MIG gates

INPUT-MIG1				OUTPUT-MIG1				INPUT-MIG2				OUTPUT-MIG2			
A	B	C	D	P = A	Q = C1+C2	R = C3+C4	S = C5+C6	Q = C1+C2	C	R = C3+C4	A	G_2	SUM = Q	Cou r = R	G_3
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0
0	1	0	0	0	0.83B	0	0	0.83B	0	0	0	0.83B	0.83B	0	0.83B
0	1	0	0	0	0.83B	0	0	0.83B	1	0	0	0.83B	0	1	0
1	0	0	0	1	0.83A	0	0.68A	0.83B	0	0	1	0.83A	0.83A	0	0
1	0	0	0	1	0.83A	0	0.68A	0.83B	1	0	1	0.83A	0	1	1
1	1	0	0	1	0.05(A+B)	0.37B	0.68A	0.05(A+B)	0	0.37B	1	0.05(A+B)	0.05(A+B)	0.37B	1
1	1	0	0	1	0.05(A+B)	0.37B	0.68A	0.05(A+B)	1	0.37B	1	0.05(A+B)	1	1	1

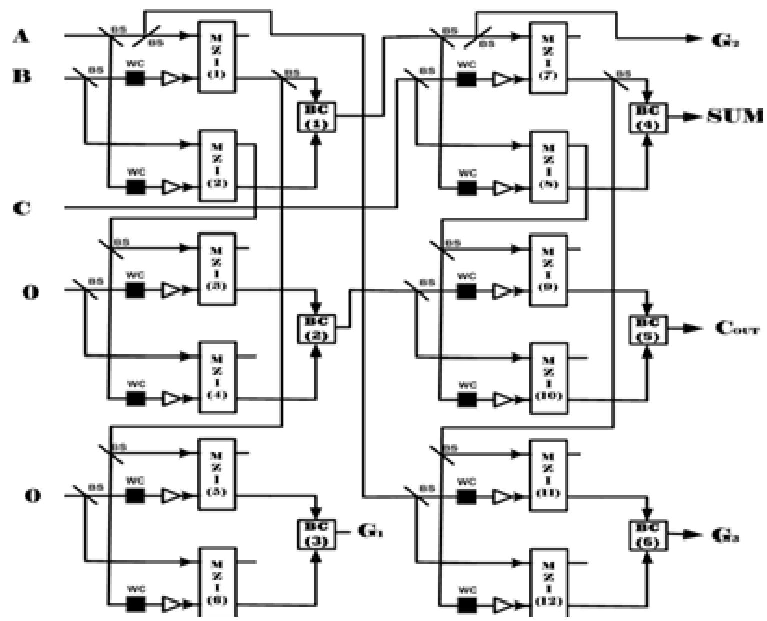

Fig. 11: Schematic diagram of optical fault-tolerant full adder

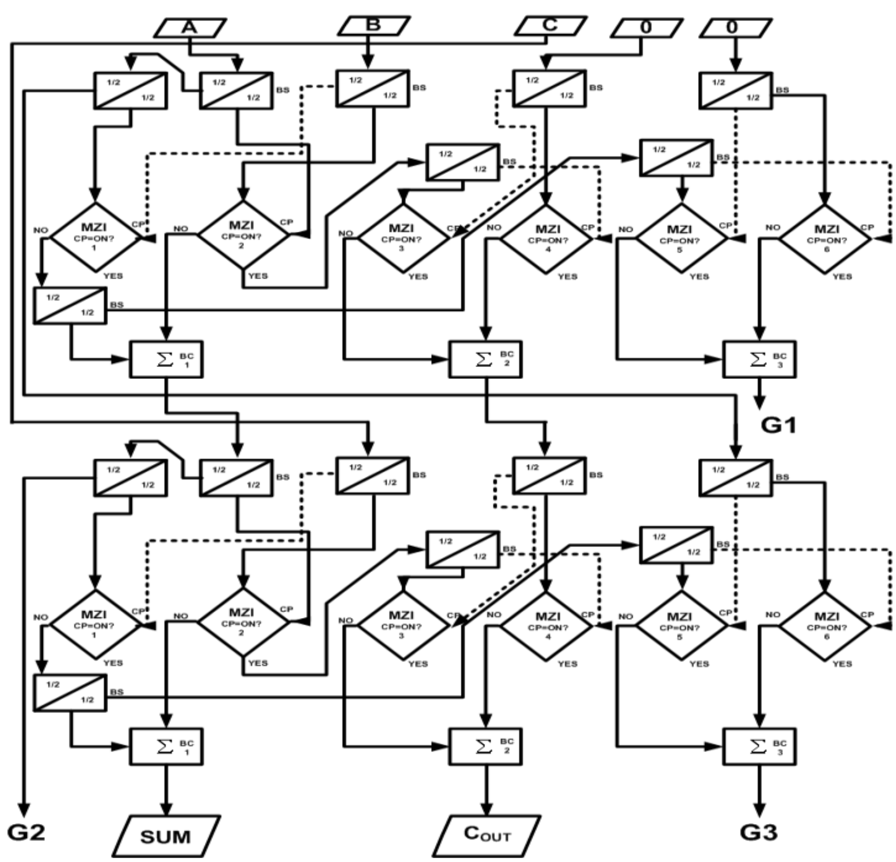

Fig. 12: Block diagram modes of optical fault-tolerant full adder

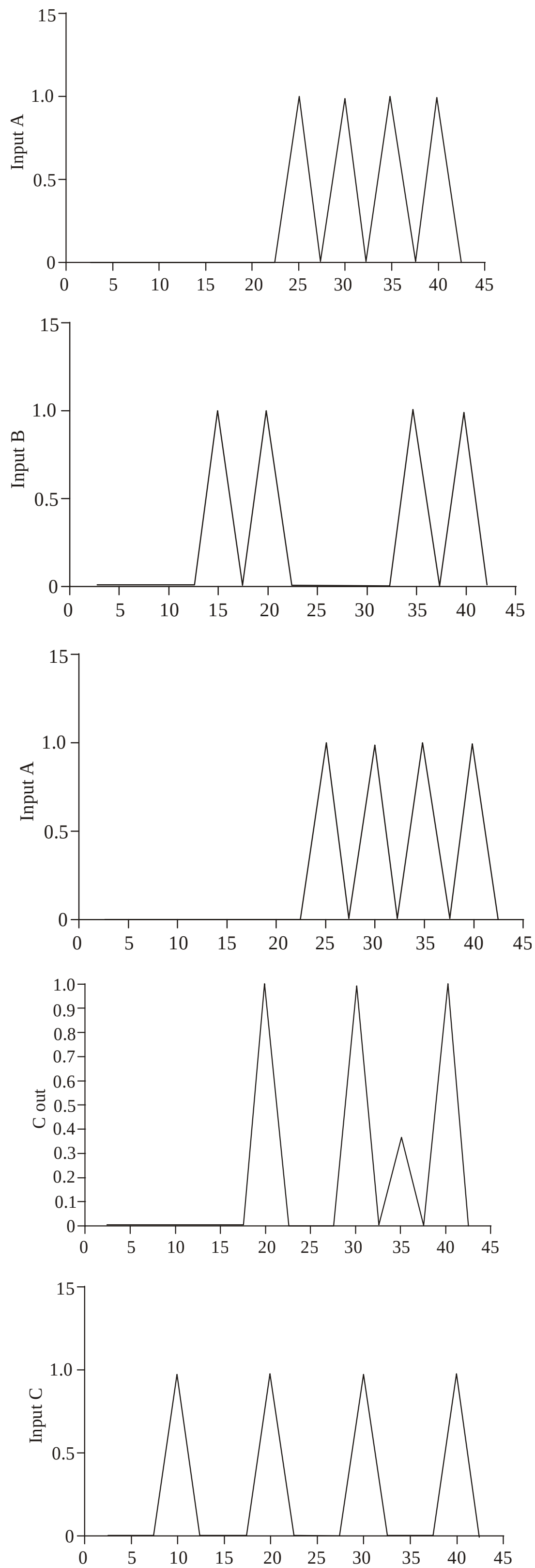

Fig. 13: Simulation results of optical fault-tolerant full adder

2 and 3 will be low and in the rest of the MZI, we will have the input signal. Given that the control input signal of MZI-1 and MZI-4 will be zero, their input signal will be opposite to zero, and cross optical signal output port will only receive signal, but MZI 5 and 6 given that the input control signal is a result of the signal value cross appearing in the port level Low; in general, it can be concluded that the BC1 and BC2 output are high but the BC3 output will be low.

- In this case, inputs of A and B are equal to 1, and inputs C and D are zero. As a result, in MZI-1, -2, and -3, we will have the input signal, but in MZI-4, -5, and -6, we will not have any input signal. The MZI-1 and MZI-2 control signals are high, and hence, only the optical signal output port will have their bar and cross port optical signal , which will be minimal, and thus, the output BC1 will be low, given that MZI-3 control input signal is zero. Therefore, the switch output port cross and high light output makes the BC2 high, and consequently, given the lack of optical signals in the MZI-5and MZI-6, there will be no signal in their output, and obviously, the BC3 output will become low.
- If all the inputs, except C, are equal to 1, then only the inputs MZI-5 and MZI-4 will have no signal. Hence, in any of the two output ports of MZI, the optical signal will be received. However, with a high input MZI-6 and its control input being low, the output of MZI cross receives the light signal and the output BC3 will become high. Likewise, under similar conditions with MZI-3, BC2 will become high. However, the output in MZI-1 and MZI-2 are such that other optical switches in both the input signals have high amounts of MZI output port Cross; so they are very, very weak optical signals that are equal to zero. Therefore, the output of BC1 will be low.
- If only the input D is low and the rest of the inputs are high, then in the mode, both the input signals MZI-5 and MZI-6 as well as the BC3 output will be low. Considering that both the input signals MZI-1 and MZI-4 are the result of high cross in the output, which is related to the appearance of MZI optical signal, the output values of BC1 and BC2 will become low.
- This condition occurs when all the inputs are equal to 1 and the result of a given amount of MZI only inputs signals of MZI-5 and control input signal MZI-6 will be low and the rest of MZI have high value, so the two input signals will have the amount of signal output port Cross MZI-1 to the MZI-4 Low and makes the BC1 and BC2 output equal to Low, but considering the amount of high, output port MZI-6 Cross about the amount of output BC3 will be high.

Table analysis and functional inputs and outputs gate of MIG and MZI switches are shown in Table 5, and the analysis results obtained for the final output based on the primary inputs are presented in Table 6.

Proposed fault-tolerant reversible optical full adder: Figure 10 shows the MIG gate combined with a full adder gate design. Earlier, MIG quantum gate structure, MZI optical design, and analysis were done, and its final output was also determined. If the two gates of MIG are combined, as shown in Fig. 10, then a full adder will have reversible and fault-tolerant properties, and it is also evident that the output gate of the first MIG will be the input gate II.

Table 7 shows the final output of the full adder, based on initial inputs.In this structure, the outputs of the first gate act as inputs in the second gate, and finally, the output of the second gate, which combines the output of the adder circuit, is based on the inputs received from the input of the circuit. The schematic diagram of all optical adders with fault tolerance property and block diagram are given in Fig. 11 and Fig. 12, respectively, while the simulation results are presented in Fig. 13.

CONCLUSION

This article has presented for the first time two structures for all optical adder circuit combinations that any of them in their kind are important because the first project is optimized, and because of the minimum number of optical switches used in its design, The second structure, which is reversible, has the properties of fault tolerance that is remarkable and impressive. According to the results of simulations performed using light signal amplifier circuits in some parts of the proposed combination and the full adder made of two quantum gates, in addition to the MIG benefit of being reversible and having properties of a Fault-Tolerant Like other rates slipped lower output signal and the better and more realistic than the Full Adder is optimal. Although the number of optical switches used in the structure is more stable and the number of entries and exits in front of the Garbage optimization model.

However, due to the advances made in optical switches and the emergence of superfast switches, such as TOAD and the UNI, circuits must be designed using these switches in the near future (Leuthold *et al*., 1998; Li *et al*., 2005; Leuthold *et al*., 1999; Sokoloff *et al*., 1993). Nevertheless, what is certain because the operational structure of optical switches is almost similar to each other and the main difference is the tempo switch and the other with regard to new and emerging technologies being the only justification for the introduction and functioning of gates optical circuits and quantum theory in the limit of gates and circuits using the hybrid MZI we have developed so obviously in the implementation phase should be trying to exploit the latest technologies to the surface of the optical switches have the speed limit Tra-HZ is that we can use them in the laboratory because we simply use Sio_2/Si or in GaAsP/Inp, Integrate. As an adder circuit is considered as the base for many other circuits, future works should examine other components that can be developed as the next provider of many other circuits in the field design and implementation of quantum optics. All the scales are in the nanometric scales.

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