Study on Development and Designing of All Optical Logic Devices for the High Speed Fully Optical Networks

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Abstract--For long, photons have agreed to offer greater bandwidth in comparison of the electrons that are in use in traditional computers. The vista of light wave systems in service at 3.2 Tbps or more are in scene but the restriction essentially occur because of the extreme point's electronics and optical fiber non-linearity. Optoelectronic devices waste 30% power in converting electronic energy into photons and again to electronic back; this exchange also decreases the transmission speed of information. With necessity of high-bandwidth, on-demand triple play and continuous advancement of multimedia applications, next-generation foundation photonic networks will need major enhancement in reconfigurability and extremely fast operations. Current trends in all-optical information processing with the aid of all optical logic devices, possibly for ultrahigh communication systems and networks has been studied in this work. Different technologies are inspected and discussed, different range of theory and ideologies are included.

Keywords: AOLG, Ring Resonator, Mach–Zehnder interferometers

1. Introduction

Fiber Optic Communication systems emerged dramatically in quite little phase of time. Optical fiber has emerged as the potential medium for high speed communication. The maximum capacity of commercially available fiber-optic links was only 2.5 Gb/s in 1992 and now 2001 onwards the vision of lightwave networks with an operating range about 3.2 Tb/s or more are in view[9].Research has shown that the data on a single optical carrier system cannot be arbitrary increased. This limitation mainly comes because of the terminal electronics and non-linearity in the optical fiber. Most networking devices and central operating nodes are still operate on electronic signals and require optical-electronic-optical conversion, which is a significant constraint in fast transmission. This barrier can be removed using all-optical network structure, where absolute switching inside the network would be done by optical signals only. So the field of nonlinear fiber optics catches the attention and along with this optical data processing has exploded as a core research interest to meet the rising demand of complete utilization of optical transmission capacity that can offer an ultra high speed information exchange. So the need of the hour is to migrate from optoelectronic to all optical network, where data is switched and processed transparently in optical form.

All All-optical communication networks system demand for logic components like All Optical Logic Gates (AOLGs) in its all switching knots. All-optical logic gates implementation acquired remarkable interest for fast signal processing using photonic based networks because of their possible applicability in switching, signal reshaping, data encryption, encoding of data, address identification and so on. For designing of the optical gates it is essential to build a nonlinear medium that can modulates the information signal to bring into being the expected results. This nonlinearity can be developed in many ways like using nonlinear loop mirror, waveguide, a fiber with nonlinearity, optical filters, photonic crystal, semiconductor based optical amplifier or ring resonator . All-optical gates may be composed using the nonlinearity effect such as cross-phase modulation, self-phase modulation, stimulated Raman scattering, modulation instability, four-wave mixing, and stimulated Brillouin scattering which can be obtained with or without SOA[8].

II. Need of All Optical Logic Devices

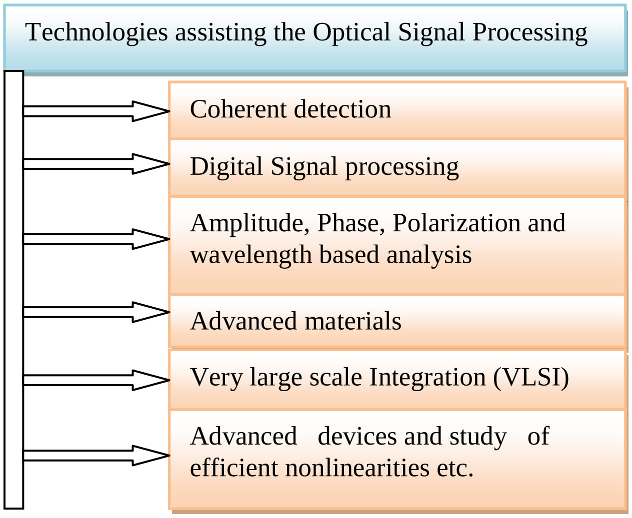

Figure 1. Technical bases for optical signal processing.

Optical data processing conquers the electronic bandwidth restrictions with the reward of lucidity, scalability and transmission rate. We review current development in fullyl-optical signal processing for super fast transmission speed network structure. Along with general idea of optically processed signal for ultrahigh-speed communication to be in picture, we emphasized certain key technologies being adopted for designing of all optical devices for optical logic operations [18].These approaches seems to offer the finest prospects for upcoming commercialization of optical infrastructure, as optical devices are can be incorporated into conventional computers to construct a hybrid of optical and electronics. All-optical computing eliminates the requirement for optical-electrical-optical (OEO) conversions. We resume growth in the facilitating prospects of technology that led to recent examination and development in realization of optical network for signal processing. Digitalized information are first encoded in mentioned size. In this study, we gone through ongoing research in the field of ultrahigh-speed optical networks in diverse areas such as to provide equalization, restoration, generation, and controlling information [19]. Technology has empower society in every aspect to produce, accumulate, and transmit huge information. Current development in technology for rapid speed foundation network structure, increasing drift of bandwidth dependent uses such as distribution of data and video, cloud computing, and data compilation, formed an urge for immense capacities in processing and transmission of signal. on YouTube only, in each single minute, about 100K videos are seen and approx 4320 min new matter is uploaded and about 30% traffic is produced by mobile devices. Such traffic is hopefully add to, as increasing capacity landing infrastructures offer a base that prompt for advancement of novel applications. Due to their moderately huge capacity, optical coupling and transmission have been well thought-out as a probable solution to facilitate an output equal to its electronic counterpart [19]. Current position and infrastructure of all-optical logic circuits is examined in reference of literature. Various schemes are examined and compared.

The optical gates can be divided as per their design structures [4]. During last decade, the outstanding progress, maturity, and economical sense of balance of optical components has inspired and escalate in depth evaluation for the practical implementation and development of fully-optical signal processing systems and science. Complete-optical based processing infrastructure expected to facilitate a performance over cost assistance more than their electronic substitute in optical switching, that is well thought-out as a way toward the assembly of competent, ultrahigh capacity, comprehensive data network[20]. Presently, deployed optical structure function at 10-Gbps (OC-192) or 40-Gbps with 100-Gbps and 400-Gbps links under expansion. To get together with the ever-rising bandwidth supply needs, researchers are continuously driving to increases boundaries of photonic structure capacity. A channel operating at 10.2-Tbit/s was studied in 2011. Befor some time , a 308-Tbps channel based on space division multiplexing andd wavelength-division multiplexing schemes was proposed in literature. Polarization-division multiplexing (PDM) scheme also included to set two fold capacities[18]. Different prototype for different all-optical logics are coming out from research and development centers by researches to make it feasible. For designing an all optical arrangement, it is essential that absolute components employed in optical networks such as multiplexer, couplers, circuit for synchronization, address identification, and signal reformation etc supposed to be fully optically operational. To make the vision come reality the basic necessity is optical gates which are the fundamental necessity blocks to realize all-optical functions. Thus, to realize logic gates in all optical form with the same or better specifications, it is compulsory to build up a number of basic designs. The design is simply doing well when all the gates are designed by the same core technique.

III. Designing approach for Photonic logic

Photonic logic is the application of photons in designing of logical circuits. Switching is achieved by means of nonlinear optical effects obtain when a number of signals are correlated. The literature study reveals that the following approaches can be considered for designing of AOLGs.

3.1. Mach–Zehnder interferometers

Mach Zehnder Interferometer is usually applied to find out the relative phase shift of two coherent beams gathered together. Applying above fundamental concept numerous logical devices can be constructed like fully photonic based sensors, transistor, add-drop multiplexer etc. It is capable to accomplish the urge of high data rates and remarkable bandwidth coverage for dream networks. A number of the advances in photonic networks can be accomplished by the application of Mach Zehnder Interferometer.

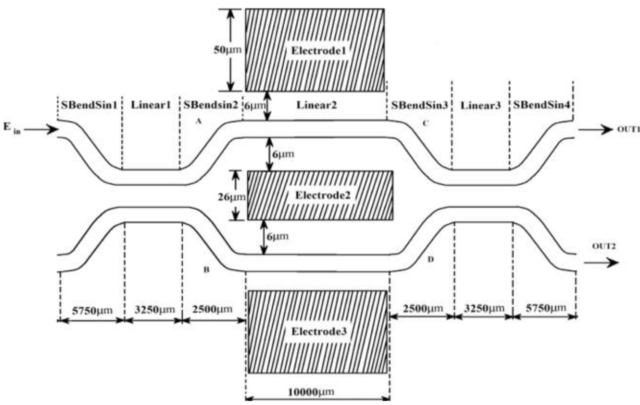

Figure 2. Schematic view of Mach–Zehnder interferometer.

Mach Zehnder interferometric arrangement are employed in lightwave based transformation of signals like switching, modulation, add-drop multiplexing etc. Such devices are of immense need for designing of a network that does not require an unnecessary conversion form electrical to optical and then elcrical [21]. The electro-optic effect is an important fact of Mach–Zehnder (MZI) interferometer .It is elaborated as a switch based on this principle [22].

3.1.1. Applications of Mach–Zehnder interferometers

The switching operation by the Mach–Zehnder interferometer based on the electro-optic effect is elaborated in 2014 by Raghuwanshi et.al. . An optically operable D flip-flop is possible to be constructed on the basis of the electro-optic effect by applying appropriate feedback means and the concept can be extended for the designing of shift register and counters [22]. Yet, Qn (flip flop output) have not shown in the circuit anywhere. Then in 2015, optical switching concept has been applied for construction of D flip-flop and T flip-flop with the help of aforesaid phenomenon of Mach–Zehnder interferometer (MZI) as a base. These flip-flops are designed with the help of MZIs by means of beam propagation method. Three MZI are used to construct D flip-flop and four MZI are used for designing of T flip –flop. Circuits are developed using MZI with feedback. Accurate fiber loops created with lithium niobate produces time delay .So applied to bring into being the necessary amount of time delay [23]. However, a reconfigurable optical D flip flop is modeled and delineated by 2 quantum dot semiconductor based supported Mach–Zehnder interferometers by Chattopadhyay et.al.

The FF (flip flop) enabled for both rising and falling edge triggering with one enable input.[80-24].On the other side, Singh et.al. proposed optical based inverting gate via SOA based Mach-Zehnder interferometer at 1 Gbps by means of the concept of gain saturation in semiconductors. Though, the operation was restricted by SOAs recovery time.

Along with such applications Mach Zehnder interferometric devices are used in modulation, switching ,multiplexing and coupling etc. MZI is under research for designing the potential all optical systems for future networking. For noticeable expansion of optoelectronic technology and remarkable downfall in its cost, the utilization of MZIs will increase as Mach-Zehnder interferometer allow flexibility in fringe localization, which is not possible with other interferometers. A rectangular arrangement is generally used in Mach-Zehnder interferometers, although parallelogram arrangements can also be formed.

3.2. Ring Resonator

Resonators are very constructive choice for building the photonic logical circuits, as they allow an energy build-up from constructive interference, that in turn produces an optical nonlinear effects.

3.2.1. Applications of Ring Resonator

Invention of microstructures predominantly microring resonators (MRRs) present tough optical confinement to devise energy proficient photonic computing. Silicon ring resonators offer quite flexible base for optical networking contributing very low power consumption, high-Q factor, ultrafast switching, easy fabrication and large scale integration. The silicon MRRs providing a striking approach for implementing the fully -optical signal processing using to eliminate tiresome EOE conversions that squeeze the capacity of the network and have more power consumption by utilizing CMOS chips[25].

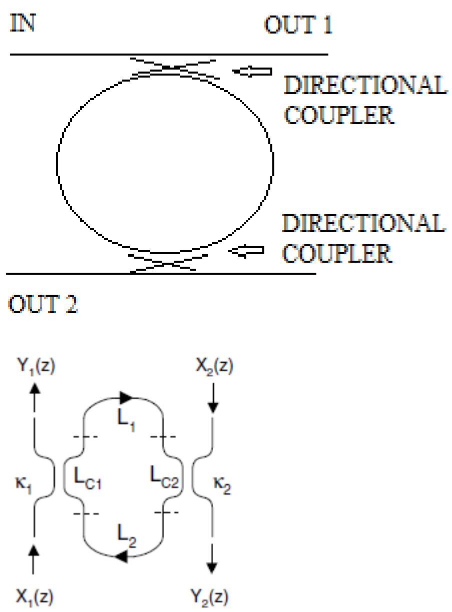

Figure 3. Simplest Optical Waveguide Filter using a Ring Resonator with Two Couplers.

Jalil et.al. in 2011 proposed a new system of concurrent XOR and XNOR logics with phenomenon of dark-bright soliton conversion occur in add/drop optical filter with a phase shift of 90 degree. He used 3 ring resonators. The dark soliton pulses are used for the formation of the input logic and controlling logic [26].
Rakshit et.al. in 2012 proposed a simultaneous operation of XOR and XNOR gates by employing two cascaded GaAs-AlGaAs micro-ring resonator via a pumping source being applied claiming a very high Q factor. The prospect being also used for n-bit.
2014, only one GaAs-AlGaAs ring is fabricated with a feedback loop for the logic of D flip.It was having two stable states .The states was dependent on the phase shift take place in the ring . The synchronization was provided with a clock signal that was opticlly control pump signal. The circuit was quite simple and can be easily mounted with integrated circuit [18]. Exclusive (XOR) logic operation based on two silicon parallel cascaded microring resonators (MRRs) with fabrication on the silicon-on insulator (SOI) platform is designed by Tian et. al. in 2015. PIN diodes constructed about MRRs are applied to attain the carrier injection modulation. Two electrical pulse sequences treated as two operands of logical operations are applied to PIN diodes to provide modulation to two MRRs by the free carrier dispersion effect. The concluding operation outcome of two operands is at the Output port in the form of light. The scattering matrix scheme is employed to found numerical model of the device. Numerical simulator SG-framework is used to simulate and verify the expected electrical characteristics of the PIN diodes. XOR operation with the speed of 100Mbps was established. Although, no waveguide crossing was incorporated in the circuit, this can enhance the signal quality and lessen the insertion loss of the circuit [27].
The performance of ring resonator based Autoregressive filter (AR) for multiple number of rings is analyzed by Kuldeep Singh [39]. The graphical analysis is elaborated for 10 number of rings. The study can be extended for designing of Various logical gates. The simplest optical waveguide filter using a ring resonator with two couplers is shown in figure 2.In such a manner microring resonators have been dominating for their prospective participation in coming-generation optical interconnects. However, the working of microring based devices experience susceptibility to thermal fluctuations that is frequently ignored in their established results, but must be considered and resolved for their implementation in near-term microelectronic applications [28].

3.3. Fiber Non-Linear Effects

Fiber nonlinear effects likes stimulated Raman and Brillouin scattering, self-phase and cross-phase modulation have various pros and cons in optical fiber communication for generation of haigh data rate ,high capacity, fully-optical telecommunication applications.

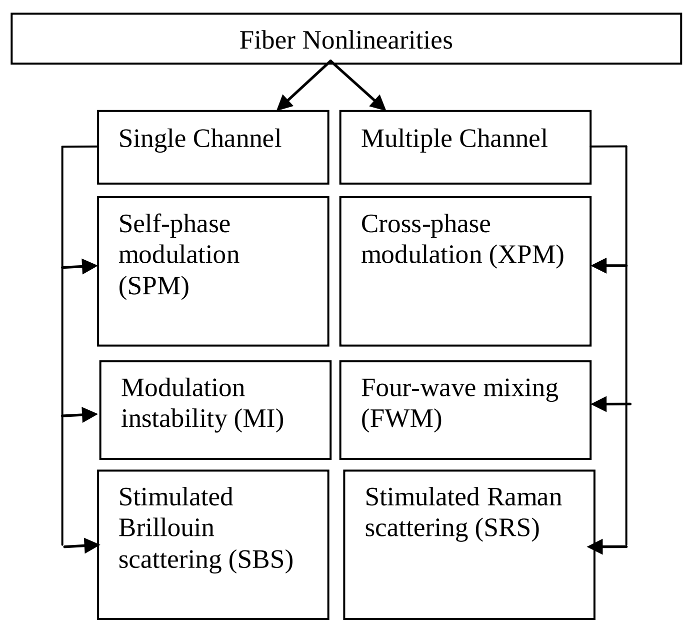

Figure 3. Fiber Nonlinearities

3.3.1. Applications of Fiber Non-Linear Effects

AOLGs working over the concept of polarization characteristic of non-degenerate Four-Wave Mixing are discussed by Bhardwaj in dissertation. An error correction circuit for Hamming Code is illustrated. Performance

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without error (BER < 10-9) at 2.5 Gbps is obtained. The bit-rate is however restricted because of available bandwidth [29].
Aso et.al. analyzed techniques for attaining broadband conversion of wavelength that is completely optical with the help of FWM effect occurring in the fiber, along with techniques for the measurement of the nonlinear coefficient and chromatic dispersion simultaneously[30].
It is found through literature that nonlinear effects do have impactful and important roles in enhancing the fiber performances and generating new functions using lasers, EDFA, RAMAN amplifier, optical switches, optical logic devices, demultiplexers, wavelength conversion etc. Even though, on the other hand these nonlinearity do degrade the performance of the system also. Thus a balance between the advantages and the respective disadvantages of all the nonlinear properties ought to be vigilantly explored and reviewed for utilizing their effects to the fullest extent.

3.4. Photonic Crystal

Nowadays, photonic crystals (PhC) catching considerable attention for applying as a first step to build components working in the wavelength window of light for on demand integrated photonic circuits. Photonic crystals has some exceptional qualities like compactness, very good response time, considerably low power utilization, superior confinement. Such qualities offering it a competitive for future photonic world of communication [31].

3.4.1. Applications of Photonic Crystal

Various logic gates that are being designed using the photonic crystal are elaborated by researchers using the mechanism of bending and splitting of self collimating beam. Here two line defects are formed by dropping the radius of 15 rods in the Γ-X direction[31].
PhC logic gate compiled of four input and output ports. Port 1 and port 2 are used for input and reference signal, port 3 and 4 are used for obtaining the outputs. Reference signal and all incident signals are kept at same polarization, phase and wavelength of 1.55 microm. The coincident having equal path length from the AMS and from BS . The applied input get reflected by the mirror get interfere with another signal at the splitter. Depending on the phase difference occur, this interference can either be constructive or destructive. Port 1 output is destructive and port 2 output is constructive respectively[31]. Thus mostly logical functional device is constructed by non-channel photonic crystal. Self collimation, bending and splitting effects are used to realize logic gates[31].
A design proposal for a completely optical domain functional NOT gate using photonic crystal ring resonator analyzed Ghadrdan et.al.. A photonic crystal composed of 2D square lattice of dielectric rods. Indium phosphide with a refractive index value of 3.1 is used as the material of the rods[32].

3.5. Semi Conductor Optical Amplifier(SOA)

The Semiconductor Optical Amplifier (SOA) potentially can play major role in the acceleration of advancement of the network systems and structure in future demanding communication network. SOAs posses very nonlinear character in optical gain window. The characteristic occurs because of the effect of a huge number of free charge carriers confined in a relatively small active region. The theory also influence refractive index along with gain within the active region. SOAs based photonic logic gates are proficient because of their power efficiency.

3.5.1. Applications of Semi Conductor Optical Amplifier(SOA)

Numerous fundamental logic gates and complex logical system as half and full adder are designed by Kim et.al. .He utilized the theory of non linear effect occur in semiconductor optical amplifier. These concepts provide increased speed and channel capacity for telecommunication systems, as well as various functionalities including optical switching, network decision making, basic or complex computing, and various other optical signal-processing systems[33]. By applying optical filtering and SOA, a number of logical functions are elaborated at around 10 Gbps. Two signals are applied to the SOA, result in a wide spectrum because of carrier density modulation occur due to applied control signal.

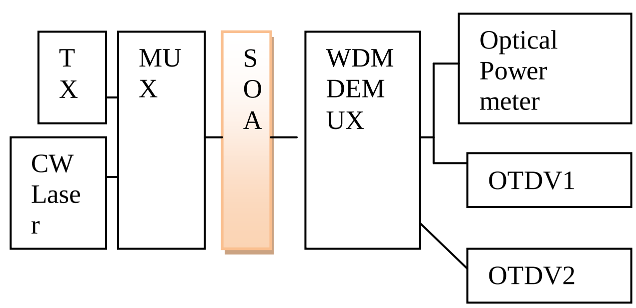

Figure 4. Setup for Switch using SOA[35]

Different operations for NOT, AND, OR and NOR can also be designed successfully using WTW SOA at different constant injection currents and different lengths for different logic functions at 10Gbits because Waveband Travelling Wave Semiconductor Optical Amplifier can work as a switch as proved by Wesley et.al. and setup is shown in Figure 4 [35].

3.6. Terahertz Optical Asymmetric Demultiplexer (TOAD)

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Many researchers have keen interest to put into operation an all-optical flip-flop using SOA-MZIs. The drawback is that SOA-MZIs have a foremost problem of gain saturation. TOAD based designed logic gates have good prospective in coming optical information processing structure. Sokoloff et al. demonstrated a TOAD competent of demultiplexing data at 50 Gbps. It necessitates one picojoule or less of energy to operate and can be easily manufactured as a chip. It contain an optical nonlinear part that placed in the fiber loop. Here the switching time is decided by the off-center position of the nonlinear element within the loop [36]. Mandal et.al. set and demonstrated the TOAD as switch. They also extended the concept to drawing two new all optical reversible NOR gates [37].

The positive aspect of TOAD switches are that they require a small switching power, having a quite easy structure and similar transmission paths for signals of short length fiber loop. The offset value of SOA measured from the central point of the fiber loop decide the size of the switching. Apart from these the key constraints of TOAD based switches is the limited length of fiber loop. However this constraint matters only at lower data rates . At lower data rate it expect some longer length of the fiber loops. The next constraint is the counter-propagation of the control pulse with continuous wave data signal inside the SOA, which generates an asymmetrical window . Increased crosstalk and reduced switching speed is observed in TOAD with asymmetrical switching window profile [38]. Other approaches that are under research at present are photonic logic at a level, with the help of photo luminescent chemicals.

3.7. Critics and Challenges

Over a short distance the power consumption of optical links observed more than the electronic connections. As the shot noise occur in photonic link override the thermal noise of the respective electrical channel .Thus for short distance it is better to implement the commercial electronic structure instead of mounting an optical communication network. The other challenge is that the nonlinearity is necessary to come in seen for implementing logical operations that are all optical, in which multiple signals will interact. The interaction is normally quite week for electromagnetic waves like light. The maintenance of optimality among different performance parameters like power consumption, respective cost, durability, robustness , maintenance , size is a challenge for the dream optical computers, most of which are executing properly by current electronic infrastructure. The research is going on at an exponential speed and hopefully the imaginations will turn to reality by the next decade.

IV. Conclusion

The different technical approach used by researchers for designing all-optical gates are discussed in this paper to obtain digital gates, which are compact, have high speed and easy in coupling. It is studied that Photonic crystals are promising structures for construction of fully photonic processors due to less attenuation and ability of supervise, control and guide the light. On the other hand, microring resonator has inherent positive aspects like compactness and very less power consumption. The Mach-Zehnder interferometer provides fringe localization, which is not possible with other interferometers. Contrary to these devices, SOA designed devices are small in size, steady, do not depend upon wavelength as well as polarization, need low power for switching, low latency and can be integrated. Presented designs in literature provide large operational bandwidth, very less power consumption, fast switching and exceptionally good integration ability along with optimal balance between all designing parameters. The major goal of the ongoing research is increasing the in service bandwidth, declining consumption of power, enhancing response time, increasing contrast ratio of ON to OFF and lastly integration of them for designing of on demand all-optical logic circuits.

References

[1] Jian-Wei Wu,Amarendra K. Sarma, Ultrafast all-optical XOR logic gate based on a symmetrical Mach-Zehnder interferometer employing SOI waveguides, Optics Communications ,2010,283, pp. 2914–2917.
[2] Yonghui Tian et.al. , Demonstration of a directed optical decoder using two cascaded microring resonators, Optics Letters,2013,Vol. 36, No. 17 ,pp. 3314-3316.
[3] Jae Hun Kim, All-Optical Logic Gates Using Semiconductor Optical-Ampli_er-Based Devices and Their Applications, Journal of the Korean Physical Society,2004,Vol. 45,No. 5,pp. 1158-1161..
[4] Pallavi Singh et.al. , All-Optical Logic Gates: Designs, Classification, and Comparison, Advances in Optical Technologies, 2014,Volume 2014, Article ID 275083.
[5] M. Khorasaninejad,S.S.Saini , All-optical logic gates using nonlinear effects in silicon-on-insulator waveguides, Appl Opt. ,2009,48(25):F32-7,DOI: 10.1364/AO.48.000F32.
[6] H. Zhang,P. Wen,S. Esener, Cascadable all-optical inverter based on a nonlinear vertical-cavity semiconductor optical amplifier, Opt Lett. 2007 Jul 1;32(13)pp. 1884-6.

[7] S. Blair,K.Wagner, Cascadable spatial-soliton logic gates, Appl Opt., 2000, 39(32), pp.6006-18.
[8] G. P. Agrawal, Fiber Optic Communication Systems, Wiley & Sons, 1992.
[9] G. P .Agarawal, Nonlinear Fiber Optic ,3rd Edition ,Academic Prees,2001.
[10] A. K. Ghatak and K. Thyagarajan, Introduction to Fiber Optics, First South Asian Ed. Cambridge University Press, Cambridge(1999).
[11] Mohamed Nady, Khalid F. A. Hussein, Abd-El-hadi A. Ammar, "ultrafast all-optical full adder using quantum-dot semiconductor optical amplifier-based mach-zehnder interferometer," Progress In Electromagnetics Research B, Vol. 54, 69-88, 2013.
[12] J.K.Rakshit,J.N.Roy,T.Chattopadhyay, "Design of micro-ring resonator based all-optical parity generator and checker circuit."Optics communication, Volume 303, pp. 30–37,Aug 2013.
[13] J.K.Rakshit,J.N.Roy, "Design of micro-ring resonator-based all-optical logic shifter," Volume 312,pp. 73–79,Feb 2014.
[14] Sanjoy Mandal,Kamal Dasgupta,T.K. Basak,S.K. Ghosh, "A generalized approach for modeling and analysis of ringresonator performance as optical filter," Optics Communications 264,2006,pp 97–104.
[15] Sabitabrata Dey1, Sanjoy Mandal, "Design & Analysis of Integrated Optic Filter:A Digital Signal Processing Approach," Int. Jr. of Advanced Computer Engineering & Architecture Vol. 2 No. 2 (June-December, 2012),pp 313-319.
[16] Sanjoy Mandal and Kuldeep Toppo, "Modeling and Analysis of Triple Micro Ring Resonator as Optical Filter," International Conference on Advances in Transformers and Electronics Engineering (ICATEE'2012) July 28-29, 2012 Pattaya (Thailand),pp 171-173.
[17] T.K.Gangopadhyay, Sanjoy.Mandal, K.Dasgupta, S.K.Ghosh, T.K.Basak ,"Modeling and analysis of an extrinsic Fabry-Perot interferometer cavity,"Applied Optics, New York, Vol. 44, Issue 16, 3192-3196, June 2005.
[18] Lianshan Yan, Alan E. Willner, Xiaoxia Wu, Anlin Yi, Antonella Bogoni, H.-Y. Jiang, "All-Optical Signal Processing for UltraHigh Speed Optical Systems and Networks," Journal Of Lightwave Technology, VOL. 30, NO. 24, DECEMBER 15, 2012,pp. 3760-3770.
[19] Alan E. Willner, Salman Khaleghi, Mohammad Reza Chitgarha, Omer Faruk Yilmaz, "All-Optical Signal Processing," Journal of Lightwave Technology, VOL. 32, NO. 4, Feb 15, 2014,pp. 660-680.
[20] T. Houbavlis, K. E. Zoiros, M. Kalyvas, G. Theophilopoulos et.al. , "All-Optical Signal Processing and Applications Within the Esprit Project DO_ALL," Journal of Lightwave Technology, VOL. 23, NO. 2, Feb 2005,pp. 781-801.
[21] Rekha Mehra, Heena Shahani, Aslam Khan , " Mach Zehnder Interferometer and its Applications," International Journal of Computer Applications® (IJCA) (0975 – 8887) National Seminar on Recent Advances in Wireless Networks and Communications, NWNC-2014,pp. 31-36.
[22] Sanjeev Kumar Raghuwanshi, AjayKumar, Nan-KuangChen, "Implementation of sequential logic circuits using the Mach–Zehnder interferometer structure based on electro-optic effect," Optics Communications333(2014),pp. 193–208.
[23] Santosh Kumar,Gurdeep Singh, Ashish Bishtand Angela Amphawan, "Design of D flip-flop and T flip-flop usingMach–Zehnder interferometers for high-speed communication," Vol. 54, No. 21 / July 20 2015 / Applied Optics,pp.6397-6405.
[24] Tanay Chattopadhyay and Dilip Kumar Gayen, "Reconfigurable All-Optical Delay Flip Flop Using QD-SOA Assisted Mach–Zehnder Interferometer," Journal Of Lightwave Technology, VOL. 32, NO. 23, DECEMBER 1, 2014,pp.4571-4577.
[25] Purnima Sethi, Sukhdev Roy, "Ultrafast All-Optical Flip-Flops, Simultaneous Comparator-Decoder and Reconfigurable Logic Unit With Silicon Microring Resonator Switches," IEEE Journal Of Selected Topics In Quantum Electronics, VOL. 20, NO. 4, JULY/AUGUST 2014,pp. 5900308-5900308.
[26] Muhammad Arif Jalila, Iraj Sadegh Amirib, Chat Teekac, Jalil Alib, P. P. Yupapinc, "All-optical logic XOR/XNOR gate operation using microring and nanoring resonators," Physics Express ,Vol. 1, Issue 1,2011,pp. 15-22.
[27] Yonghui Tian, Yongpeng Zhao, Wenjie Chen, Anqi Guo, Dezhao Li, Guolin Zhao, Zilong Liu, Huifu Xiao, Guipeng Liu, and Jianhong Yang, "Electro-optic directed XOR logic circuits based on parallel-cascaded micro-ring resonators," Optics Express ,5 Oct 2015 ,Vol. 23, No. 20 , DOI:10.1364/OE.23.026342 | 26342,pp.1-14.
[28] Jayanta Kumar Rakshit , Jitendra Nath Roy, Tanay Chattopadhyay, "Design of micro-ring resonator based all-optical parity generator and checker circuit," Optics Communications303(2013),pp. 30–37.
[29] Ashish Ishwar Singh Bhardwaj, "All-Optical Logic Circuits based on the Polarization Properties of Non-Degenerate Four-Wave Mixing," Thesis, Doctor of Philosophy, California Institute of Technology Pasadena, California.
[30] Osamu Aso , Masateru Tadakuma , Shu Namiki, "Four-Wave Mixing in Optical Fibers and Its Applications," Furukawa Review, No. 19. 2000,pp. 63-68.
[31] Kabilan Arunachalam1 and Susan Christina Xavier2, "Optical Logic Devices Based on Photonic Crystal,"

Photonic Crystals – Introduction, Applications and Theory,mar 2012,pp. 64-80.

[32] Majid Ghadrdan, Mohammad Ali Mansouri-Birjandi, "All-Optical NOT Logic Gate Based on Photonic Crystals," International Journal of Electrical and Computer Engineering (IJECE)Vol. 3, No. 4, August 2013, pp. 478-482.

[33] Jae Hun Kim, Young Il Kim, Young Tae Byun, Young Min Jhon, Seok Lee, Sun Ho Kim and Deok Ha Woo, "All-Optical Logic Gates Using Semiconductor Optical-Ampli_er-Based Devices and Their Applications," Journal of the Korean Physical Society, Vol. 45, No. 5, November 2004, pp. 1158_1161.

[34] Z. Li, Y. Liu, S. Zhang, H. Ju, H. de Waardt, G.D. Khoe H.J.S. Dorren and D. Lenstra, "All-optical logic gates using a semiconductor optical amplifier assisted by an optical filter,"pp. 1-12.

[35] Ngetich Wesley, Waswa David, Matere Isaac, "Simulation of NOT, AND, OR and NOR Optical Gates Using Wideband Travelling Wave Semiconductor Optical Amplifier," International Journal of Emerging Technology and Advanced Engineering, Volume 5, Issue 9, September 2015,pp. 20-24.

[36] J. P. Sokoloff, P. R. Prucnal, I. Glesk, and M. Kane, "A Terahertz Optical Asymmetric Demultiplexer (TOAD)," IEEE Photonics Technology Letters, VOL. 5, NO. 7, July 1993,pp. 787-790.

[37] Ashis Kumar Mandal1, Goutam Kumar Maity, " All Optical Reversible NOR Gates using TOAD," International Journal of Computer Applications (0975 – 8887),pp. 18-23.

[38] Hoa Le-Minh, Zabih Ghassemlooy, Wai Pang Ng., and Razali Ngah, "Terahertz Optical Asymmetric Demultiplexer Switch with a Symmetrical Switching Window,"pp. 1-4.

[39] Kuldeep Singh, Sanjoy Mandal, "Designing and Study of Autoregressive Filters based on Multiple Ring Resonator through n-Number of Rings," IEEE International Conference on Communication Systems and Network Technologies (CSNT-2016),Chandigarh, March 2016, Accepted.

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