Research Article Impact Factor: 0.621 ISSN: 2319-507X
Prafull Padghan, IJPRET, 2014; Volume 2 (9): 238-245 IJPRET

INTERNATIONAL JOURNAL OF PURE AND APPLIED RESEARCH IN ENGINEERING AND TECHNOLOGY

A PATH FOR HORIZING YOUR INNOVATIVE WORK

EXPERIMENTAL REALIZATION OF MULTIPLE ALL OPTICAL UNIVERSAL LOGIC GATES USING ARRAY ILLUMINATOR

PRAFULL P PADGHAN, KAMLESH ALTI*

Department of Physics, Sant Gadge Baba Amravati University, Amravati – 444602, Maharashtra, India.

Accepted Date: 27/02/2014 ; Published Date: 01/05/2014

Abstract: This paper describe the experimental realization of multiple all optical NOR and NAND logic gates using array illuminator. Two Michelson interferometers in tandem were used to produce four nearly collinear beams. Interference of these four beams yield square arrays of equal illuminating light spots. Detectors placed at strategic locations in the interference pattern for sensing light have truth table matching with NOR and NAND logic gates when the beams from the interferometers were blocked and unblocked sequentially. Previous reports of the fabrication of optical logic gates utilize various nonlinear optical phenomena whereas in this work only linear optics was used.

Keywords: Array Illuminator, multiple beam interference, optical logic gates.

Corresponding Author: MR. PRAFULL P PADGHAN

Access Online On:

www.ijpret.com

How to Cite This Article:

Prafull Padghan, IJPRET, 2014; Volume 2 (9): 238-245

PAPER-QR CODE

INTRODUCTION

An array illuminator (AIL) is a device, which redistributes the energy of a collimated, uniformly distributed wide beam into an array of bright spots with high efficiency. Array Illuminator has gained widespread applications in the last two decades in the fields of data storage with high temporal bandwidth [1], optical signal processing [2], image processing [3] particularly in coded aperture imaging, optical switching [4], optical interconnections [5], focusing of atomic beam to produce the nano-deposition [6], online optical testing, etc. Different applications require different types of array illuminator. Various methods have been proposed to produce AIL using diffraction techniques [7, 8] and interference technique [9]. In all, these diffraction based techniques the geometry and size of the arrays are dependent on the diffracting element, without having much scope of online control. To realize the arrays of different configuration, different diffractive elements have to be designed and used accordingly. An array illuminator can be achieved via interference of multiple nearly collinear beams. In this technique the spot size, the array size and the compression ratio of the array pattern can be varied in real time. By the relative orientations of the appropriate mirror, the geometry of arrays can be easily controlled. Recently there has been a proposal to use interferometer array illuminator for the realization of all optical logic gates [10]. An optical logic gate is a switch that controls one light beam with another. It is "on" when the device transmits light, and "off" when it blocks the light. All optical transistors and logic gates similar to electronic transistors and logic gates respectively are the basic building blocks of a photonic chip. Generally optical logic gate can be realized via two methods; one is using semiconductor optical amplifier (SOA) with Mach-Zender interferometer (MZI) [11] and other is using the nonlinearity of optical fibre [12]. Other variants utilize various kinds of nonlinearity to realize the optical logic gates. Processing, storage, transport and visualisation of huge amounts of data at ultra high speed have been possible using photonics technology.

This paper discusses an experimental realization of all optical multiple universal logic gates using array illuminator obtained via four beam interference method.

Experiment Set up:-

Experimental set up used to generate square arrays of equal illuminating light spots is shown in Fig. 1. It comprises of a two Michelson interferometers in tandem producing the four nearly collinear beams in the output.

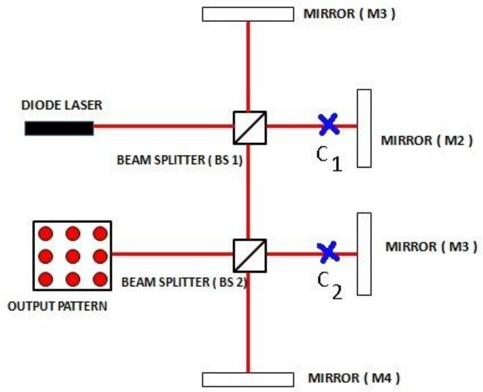

Fig.1: Schematic of experimental set up

Beam splitters BS_1, and mirrors M_1 and M_2 form the Michelson interferometer giving the two interfering beams. These two beams can be launched into the second stage, a second Michelson interferometer, comprising of beam-splitter BS_2 and mirrors M_3 and M_4. Thus the output of BS_2 consists of four nearly collinear interfering beams. The mirror tilts can be adjusted in such a way that the interference patterns of individual stages were oriented perpendicular to each other. Interference pattern can be recorded using CCD camera. Characterization of interference pattern such as number of spots, periodicity and their contrast can be measured using the image captured in CCD camera. Four beams interferometer can be easily brought down to a two beam interferometer by blocking the beam at appropriate locations using electronically controlled two mechanical choppers C_1 and C_2. The resultant intensity distribution of four beam interference pattern generated by using such a set up is given by [4-5]

$$I = I_0[4 + 4\cos(kx) + 4\cos(ky) + 2\cos(kx + ky) + 2\cos(kx - ky)] - - - (1)$$

Where k=2πμ spatial frequency $\mu = \frac{\sin\theta}{\lambda}$, ϑ is angular separation between the two interfering beam and it is of the order of 1 mrad. λ is the wavelength of laser light used. Fig. 2 shows the computed plot of intensity distribution of Eq.1. Beam profiler (BC 106-VIS, Thorlabs Beam 4.0) was used to record the interference pattern/output of the BS_2. Imagine there are four zones in the pattern of Fig.2 and detectors are placed at these locations namely D_1, D_2 D_3 and D_4. The light intensity at these points is of interest to us and we will discuss them in detail in following section.

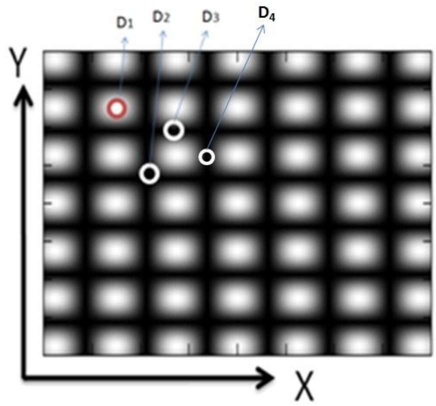

Fig. 2: Simulated Four beam interference pattern.

Results and Discussions:-

Fig. 3 shows the resultant pattern of four beam interference. Arrays of equal illuminating light spots in the square geometry are seen in Fig. 3.

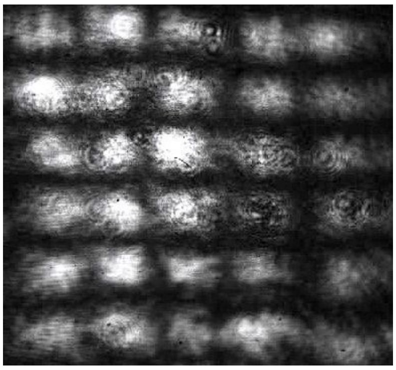

Fig. 3: Four beam interference pattern.

Now if chopper kept in the front of M_2 is blocked then, we will get interference of only two beams as shown in Fig.4.

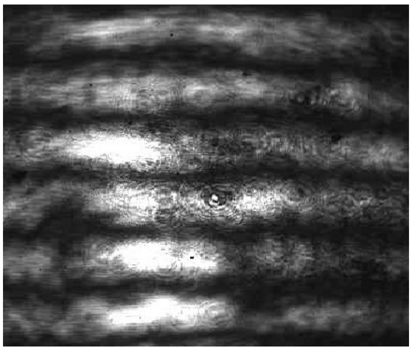

Fig.4: Interference pattern obtained when the beam going to M_2 is blocked.

Similarly when the beam going towards M3 was blocked we obtained again two beam interference pattern as shown in Fig. 5.

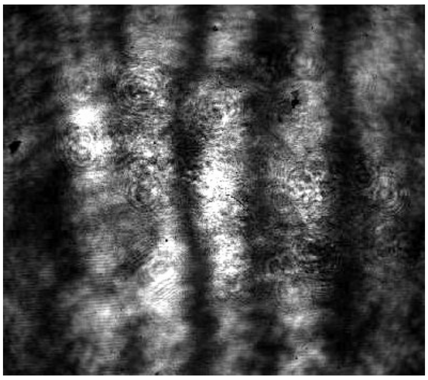

Fig.5: Interference pattern obtained when the beam going to M_3 is blocked.

If both the beam going towards M_2 and M_3 were blocked no interference pattern was obtained and the entire CCD sensor got equal illumination as laser beam itself shows up at the output. It is as shown in Fig.6.

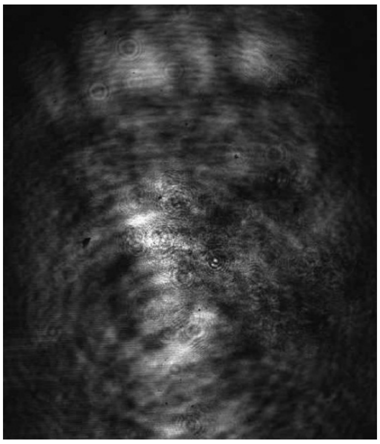

Fig.6: CCD output obtained when both choppers were blocking the beam.

Now we will probe the intensity of light at the zones marked by D_1, D_2, D_3 and D_4 in Fig.2. Imagine there four tiny photo detector kept in these places. Now let us see the intensity variation at these four points.

Starting with imaginary detectors kept at D_1. Now let us consider the output of the detector placed at maxima (bright spots, D_1 as shown in Fig. 3). When C_1 and C_2 both are at OFF position i.e. they allow laser beam to pass through them (1, 1), this will yield four beam interference pattern as shown in Fig. 3. Light will get detected at D_1 and hence it implies to 'ON' state (1). Suppose one of choppers is blocking the beam (1, 0) or (0, 1), then it will yield two beam interference which again corresponds to light at D_1 and hence a 'ON' state (1). Even if both choppers C_1 and C_2 are blocking the beams still D_1 will get illuminated with laser beam reflected from M_2 and M_4. Hence (0, 0) will yield 'ON' state (1). This discussion is tabulated in Table 1. Hence outputs of D_1 do not correspond to any logic gate.

Table No. 1: Output of the imaginary detector placed at D_1

Input		Output
1	1	1
1	0	1
0	1	1
0	0	1

Consider the output of the detector D_2 placed at the horizontal minima as shown in Fig.2. For all the combination i.e. (0, 1) (1, 0) and (1, 1) except (0, 0), detector D_2 output will imply to 'OFF' state (0). When both the choppers are blocking the beam, laser beam will get reflected from mirrors M_2 and M_4 and D_2 will get illuminated. This discussion is tabulated in Table 2.

Table 2: Output of the imaginary detector placed at D_2

Input		Output
1	1	0
1	0	0
0	1	0
0	0	1

Hence output of D_2 corresponds to NOR logic gates. Now let us consider the output of the detectors D_3 and D_4 combined together. When both choppers are not blocking the beams coming towards mirrors M_2 and M_3, light will not get detected at D_3 and D_4. Hence output for will be (0, 0) and combined output will be zero. At (1, 0) detector D_3 will get illuminated with light since two beam interference pattern will be vertical as seen in Fig. 5 and hence output at D_3 will be 1. Whereas output of D_4 will be 0 for (1, 0) output and combined output of D_3 and D_4 will be 1. At (0, 1) detector D_4 will get illuminated with light since two beam interference pattern will be horizontal as seen in Fig. 4 and hence output at D_4 will be 1. Whereas output of D_3 will be 0 for (1, 0) output and combined output of D_3 and D_4 will be 1 again. For (0, 0), output of combined D_3 and D_4 will be again 1 as both the detectors will receive light.

Table No. 3: Output of the imaginary detectors placed at D_3 and D_4 combined together.

Input		Output
1	1	0
1	0	1
0	1	1
0	0	1

CONCLUSION:-

Utilization of such interference pattern to realize optical logic gate has some advantages. First of all several optical logic gates can be realized simultaneously in a single interferometer beam without using any nonlinearity. It is reported [9] that one can generate the matrix of around 20×20 tiny spots with very good contrast. The highest recorded spot density in the patterns was around 900 mm^2. So an interference pattern is equivalent to an optical chip having many logic gates.

REFERENCES:-

1. Streibl N, Prise ME. Digital optics-architecture and system requirements. Phys Stat Sol 1988;150:447–54.

2. Francis T, Yu S, Suganda Jutamulia. Optical signal processing, computing and neural network. New York: Wiley; 1992.

3. Liren Liu, Xiaoben Liu, Bo Cui. Optical programmable cellular logic array for image processing. Appl Opt 1991;30(8):943–9.

4. Morrison RL, Walker SL, Cloonan TJ. Beamarray generation and holographic interconnections in a free-space optical switching network. Appl Opt 1991;32(14):2512–8.

5. Liao TD, Stephen Sheard. Integrated-optic array illuminator: a new design for guided-wave optical interconnections. Appl Opt 1998;37(13):2729–34.

6. Sandoghdar V, Drodofsky U, Schulze Th, Brezger B, Drewsen M, Pfau T, Mlynek J. Lithography using nano-lens arrays made of light. J Mod Opt 1997;44:1883–98.

7. Hamam H. Talbot array illuminator: general approach. Appl Opt 1997;36(11):2319–27.

8. Lohmann AW, Thomas JA. Making an array illuminator based on Talbot effect. Appl Opt 1990;29(29):4337–40.

9. A S Patra and Alika Khare, Optics & Laser Technology, 38, (2006) 37.

10. K Alti, P Chapate, K Singh, Simultaneous Realization of Multiple NAND Optical Logic Gates using four Beam Interferometer, International Journal of Basic and Applied Research, 103-105 (2012).

11. Joo-Youp Kim, Jeung-Mo Kang, Tae-Young Kim, and Sang-Kook Han, "All-Optical Multiple Logic Gates With XOR, NOR, OR, and NAND Functions Using Parallel SOA-MZI Structures: Theory and Experiment," J. Lightwave Technol. 24, 3392 (2006).

12. J.-M. Jeong, M.E. Marhic, "All-optical logic gates based on cross-phase modulation in a nonlinear fiber interferometer", Optics Communications, 85, 430 (1991).