Synopsis of the Ph.D. Thesis entitled

STUDIES ON DIGITAL ALL OPTICAL PROCESSING USING NON-LINEAR MATERIALS

Thesis Submitted to Vidyasagar University

by

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Under the supervision

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Publications and Presentations

Journal Papers

1. Shantanu Dhar, **Samir Sahu**: All Optical implementation of S-R, clocked S-R and D flip-flops using non-linear material, Optical Engineering. 47(6), 065401-1-6 (2008).

2. **Samir Sahu**, Shantanu Dhar: Implementation of clocked J-K, T and J-K Master Slave flip-flops with non-linear material in All Optical Domain, Optical Engineering. 48(7), 075401-1-7 (2009).

3. **S. Sahu**, R. R. Pal and S. Dhar: A Novel Method of Implementing Nonlinear Material Based All-Optical Binary Half Subtractor and Full Subtractor System, Journal of Electron Devices. 10, 293-298 (2011).

4. **S. Sahu**, R. R. Pal and S. Dhar: All-Optical Binary Counter by using T flip-flop: An Implementation, International Journal of Engineering, Science and Technology. 3(10), 7799-7807 (2011).

5. **S. Sahu**, R. R. Pal and S. Dhar: TeraHertz All-Optical Binary Register using D flip-flop with Non-linear Material: A Proposal, Journal of Electron Devices. 11, 588-595 (2011).

6. **S. Sahu**, R. R. Pal and S. Dhar: Implementation of 1-Bit random Access Memory Cell in All-Optical Domain with Non-linear material, International J. of Optics and Application. 1(1), 8-12, (2011).

7. **S. Sahu**, R. R. Pal and S. Dhar: Ultra-High Speed All-Optical T Flip-Flop Without Preset and Clear Using Non-Linear Material: a Theoretical Study, Vidyasagar University Journal of Physical Sciences. 15, 241-250 (2011).

8. **S. Sahu**, R. R. Pal and S. Dhar: Nonlinear Material Based All-Optical Parallel Subtraction Scheme: an Implementation, International J. of Optoelectronics Engineering. 1(1), 7-11, (2011).

Presentations/ Conference Papers

1. **S. Sahu**, R. R. Pal and S. Dhar, "All-Optical implementation of Binary Subtraction Scheme using nonlinear material based system", Proc. National Workshop on Quantum Perspective of Advanced Materials, 23-25th March, (2011), Vidyasagar University, Midnapore, India.

2. **S. Sahu**, R. R. Pal and S. Dhar, "Ultra-fast all-optical memory cell by nonlinear material", Proc. National Seminar on Recent Trends on Novel Materials, 29-30th November, (2011), Vidyasagar University, Midnapore, India.

3. **S. Sahu**, R. R. Pal and S. Dhar, "All-Optical Toggle flip-flop Implementation with non-linear material", Proc. International Conference on Laser, Materials Science and Communication, 7-9th December, (2011), Burdwan University, Burdwan, India.

4. **S. Sahu**, R. R. Pal and S. Dhar, "Ultra-fast all-optical memory cell by nonlinear material", Proc. National Seminar on Photonics and Nano Sciences, 20-21st December, (2011), Garhbeta College, Garhbeta, India.

5. **S. Sahu**, R. R. Pal and S. Dhar, "Terahartz All-optical D Flip Flop with Preset and Clear using nonlinear material", Proc. National Seminar on 50 Years of LASER: Promises & Challenges, 08-09th January, (2012), Prabhat Kumar College, Contai, India.

Summery, Findings and Contribution of the Thesis

Computerized human life is becoming faster and faster everyday ahead. We need to increase the computational speed and also device reliability to cope with this demand of life. In this context, we have to give up electron as a carrier. The fastest carrier on the world, photon is drawing the attention to carry signal. So optical computation and data processing is now replacing conventional electronic one. Day by day the field of optical communication and computation is on the rise. In last sixty years, the philosophy, science and technical scenarios enriched the scientific communities a lot. Huge device reliability, parallelism, speed of operation, bandwidth, use of several wavelengths at a time, magnetize in many ways to the scientists, researchers and technologists. For these blessing features and not to decay the growth rate of data processing, electron free all-optical processors are obvious. Optical computing is an actively growing research field and also termed optical information processing and now the names of information photonics or information optics are commonly used. An all-optical computing device performs all the computations using only photon as carrier instead of electron. In earlier stage, there was a lot of doubt about the potential of photonics. Several times it was strongly proved that optics can go far and far beyond electronics. Now it is well established that there are a lot of advantages to beat electronics. It is only because of inherent advantages hidden in an optical signal. Our dream goal is to develop an all-optical light-speed super computer.

The thesis have proposed different improved digital circuits which are the components of all-optical computer, by proper accommodation and application of optical non-linear materials. The ten chapters of the thesis are as follows:

Chapter 1: First chapter includes a consolidated review work on chronological development of optical computation from the beginning until today, which describes the relevance and significance of this work of digital all-optical processing, in light of those of the history of optical computation.

Chapter 2: Any type of digital data processing circuits cannot perform without switching circuit and logic gates. We have discussed different aspects of switching operations by optical non-linear materials in view of optical information processing. In several proposals, the switching operation of optical non-linear materials showed some special attractive features. These materials can show switching operation with the application of proper intensity of light. We confined our self in all-optical directional switching by optical non-linear materials which is the building block of all the proposed circuits of this thesis. Several logic gates can be developed by properly selection of input and output terminals of this all-optical directional switch. The thesis has proposed different improved logic circuits by the use of optical non-linear materials. All the digital all-optical circuits are implemented in the whole thesis, by taking the presence of light signal (in a range of intensity level) as 1 and the absence of it as 0, by the use of this NLM based switching and logic gates.

Chapter 3: We have implemented a new method of all-optical half-subtractor which is followed by a full-subtractor. A two bit all-optical binary parallel subtractor has been proposed and which may be elevated to a higher bit parallel subtractor in course. The composite slab of linear medium (LM) and non-linear medium (NLM) discussed in chapter 2 is used to design the all-optical switch that exploits the attractive features of NLM.

Chapter 4: A new methodology on S-R, Clocked S-R and D flip-flop by the use of nonlinear material as optical intensity switch has been proposed. Here we use all-optical NOT and AND gates to implement these flip-flops. Optical nonlinear material plays the most important role to design these circuits.

Chapter 5: An all-optical nonlinear material based switching is utilized in this chapter to developed clock J-K, T and J-K Master Slave (J-K M-S) flip-flops. As the flip-flops are sequential logic circuits, the present states of outputs are dependent not only on the present inputs but also on the past outputs and the sequence of the inputs. Like previous implementation, several all-optical gates are the construction blocks of these flip-flop circuits.

Chapter 6: A non-linear material based all-optical proposal on Binary Register, Counter and Memory has been developed. The ultra-high speed all-optical D and T flip-flop can find application in the development of several complex all-optical circuits of enhanced performances. The all-optical 3-bit binary register and all-optical 1-bit Random Access Memory (RAM) are implemented by the clocked D flip flop. But the all-optical binary 3-bit ripple counter which is realised by clocked T flip flop. At last this chapter elevates these circuits to higher bit different circuits.

Chapter 7: A new concept of arithmetic operation scheme has been described using nonlinear material. Optical tree architectures here convert analog optical signal to the corresponding digital one. First an all-optical true/complement-one/zero circuit is proposed. Then a four bit arithmetic unit has been accessed which is elevated to a higher bit arithmetic unit in course.

Chapter 8: Nonlinear material based all-optical switching mechanism is used here to develop the all-optical logic operation scheme. In the beginning of the chapter an all-optical multi-output gate is proposed. Then a single bit logic unit has been accessed and is elevated to a higher bit logic unit in course. All-optical multiplexing circuit is used to form the logic operation scheme.

Chapter 9: An integrated scheme of arithmetic and logic operations is proposed here. Single stage arithmetic operation scheme and logic operation scheme are combined by an all-optical 2 × 1 multiplexing circuit to form the all-optical arithmetic logic unit (ALU).

Chapter 10: This is basically the concluding chapter of the thesis. Here we have also conveyed our views about our future plan related to the present thesis.

The thesis has dealt mainly the subtraction operations, different types of flip-flop, their application in resister, counter and memory and ALU with optical non-linear material. These circuits are main building blocks in all the data processing architecture. All sorts of computing operations and decision making can be done by the ALU to construct the CPU of an optical computer. Different scientists expressed their views regarding the implementation of optical logic circuits with their own angles. In this work, a special effort is given to implement the operations with ultra-fast speed, fully optical in nature and less architectural complexities. The proposed technique of all-optical implementation of all the schemes is very fast (above THz) as it is fully all-optical. Along with this the circuits being parallel become remarkably fast. These schemes should be the fundamental steps on our dream way to all-optical ultra-fast next generation computer.