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GO OPTICAL
ULTRA-FAST PHOTONIC LOGIC GATES FOR THE FUTURE OPTICAL COMMUNICATION AND COMPUTING

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Introduction:

With the increasing number of defense and NASA space satellites deployed every year, and the demand for faster computing and communicating systems for the homeland security, defense, national protection center, and National security agency to mention a few, there is a serious need for much faster computers to handle the high-density flux of data. Optical systems offer several attractive features for future communication, space avionic and computing systems, as an alternative to power-hungry RF systems and conventional digital electronics.

Future communication and computation problems are inevitable since conventional electronics technology will very soon reach its ultimate speed limit. Therefore, a drastic solution to the problem is needed, and unless we adjust our thoughts to a totally different direction from the conventional electronics, we will not be able to further improve our computer performance for the future, nor will we be prepared for the challenges of space exploration.

Optical interconnections and optical integrated circuits are strongly believed to be the most feasible technology that can provide the way out of the extreme limitations imposed on the speed and complexity of present day computations by conventional electronics. Optical devices have been incorporated into many and proved to be reliable and more advantageous. Optics provides higher bandwidth than electronics, which enables more information to be carried simultaneously and data to be processed with ease in parallel. Optical signals in fibers, integrated circuits, and free space do not have to charge a capacitor and are therefore faster. The photons can cross each other without interference, and are immune to space radiation. Such advantage of optical data processing is of extreme interest to the avionics divisions at NASA, and the defense industry, where there will be no need for radiation shielding. An obvious advantage of optical over electronic computing is that optical signal processing promises an impressive increase in speed by several orders of magnitude over conventional electronic signals. This parallelism if associated with fast switching speed would result in a staggering computational speed. For example if a 100 million gates on a chip (Pentium III microprocessor has ~140 million gates) were made optically and assuming on the conservative side each one is operating with a switching time of only 1 ns, the system could perform more than 10^{17} bit operations per second. Compare this to the speed rate of giga (10^9) bits per second which the electronics is now performing. In other words a computation that might can take the conventional computer of today a hundred million hours (more than 11,000 years) might can take the optical computer less than one hour.

Recently, we demonstrated in our laboratory a few ultra fast all-optical switches such as a picosecond switch [1], which functions as an Exclusive OR logic gate and a nanosecond all-optical AND logic gate. An inverter logic gate has already been designed but has not been demonstrated yet. With the combinations of these three logic gates the rest of all other gates can be built to form the core of an all-optical computing system.

Summary and discussion

Recently, we developed two ultra-fast all-optical switches in the nanosecond and picosecond regimes. The picosecond switch is made of a polydiacetylene thin film coated on the interior wall of a hollow capillary of ~50 micron diameter by a photo-polymerization process [2,3]. In the setup a picosecond Nd:YAG laser at 10 Hz and at 532 nm with a pulse duration of ~40 ps was sent collinearly along a cw He-Ne laser beam and both were waveguided through the hollow capillary. The setup functioned as an Exclusive OR gate. On the other hand, the material used in the nanosecond switch is a phthalocyanine thin film[4], deposited on a glass substrate by a vapor deposition technique. In the setup a nanosecond, 10 Hz, Nd:YAG laser of 8 ns pulse duration was sent collinearly along a cw He-Ne laser beam and both were wave-guided through the phthalocyanine thin film. The setup in this case functioned as an all-optical AND logic gate. The characteristic table of the ExOR gate in polydiacetylene film was attributed to an excited state absorption process, while that of the AND gate was attributed to a saturation process of the first excited state. Both mechanisms were thoroughly investigated theoretically and found to agree remarkably well with the experimental results.

An all-optical inverter gate has been designed but has not yet been demonstrated. The combination of all these three gates form the foundation for building all the necessary gates needed to build a prototype of an all-optical system.

Conclusion:

In conclusion, we have reported two all-optical logic gates in nanosecond and picosecond regimes in phthalocyanine and polydiacetylene, respectively. The effect in each has been attributed to a different nonlinear effect. The theoretical predictions, which remarkably agree with the experimental results, will be discussed.

References:

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