Recent Advances in Photonic Devices for Optical Computing and the role of Nonlinear Optics-Part II

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Introduction

The twentieth century has been the era of semiconductor materials and electronic technology while this millennium is expected to be the age of photonic materials and all-optical technology. Optical technology has led to countless optical devices that have become indispensable in our daily lives in storage area networks (SANs) [1], parallel processing [2,3], optical switches [4,5], all-optical data networks [6], holographic storage devices [7] and biometric devices at airports [8].

This chapter is meant to bring some awareness to the state-of-the-art of optical technologies, which have potential for optical computing and demonstrate the role of nonlinear optics in many of these components. It is a continuation of our earlier article [9], which expresses a far limited development then in the area of optical computer. An optical computer is a system that uses photons instead of electrons to perform appropriate mathematical calculation. In the optical computer of the future, electronic circuits and wires will be replaced by laser diodes, optical fibers, tiny crystals, micro-optical components, and thin films, which will make the systems more efficient, more cost effective, lighter, and more compact. Optical components would not need insulators, as those needed between electronic components, because they do not experience cross-talk or suffer from short circuits. Multiple frequencies of light can travel concurrently through optical components without interference, allowing photonic devices to process multiple streams of data, in parallel, with ease. Optical computing can enhance our computing speed by more than seven orders of magnitude than our current computing speed. This means that an hour of computation by an optical computing system is equivalent to more than eleven years by a conventional electronic computer. Researchers at the University of Rochester have built a simple optical computer, demonstrating the feasibility of such a system, which was able to conduct huge computations nearly instantly. In the last five years, significant advances have been achieved in the field of optical communication to improve upon our communication technology and have a great impact on the development of the optical computing technology. The efforts in trying to avoid the conversion of an optical signal traveling through a fiber to an electronic signal and vise versa and build an all-optical system enhances to a great extent the communication performance and serves very well the optical computing technology. Although recent years have shown a great deal of progress on all fronts in the field of optics, there are still certain fundamental limitations to be resolved in the optical computing technology, such as cascading, size of optical circuits, integration of components, nonlinear optical processes, laser sizes and powers, etc. Widespread intensive research on the national and international levels is currently progressing at a fast base in academia, industry, and government laboratories to develop the means of processing those light encoded signals without the need for optical conversion to electronic forms. Recent developments in developing all-optical processors, optical switches, optical materials, optical storage media, and optical interconnects have brought all-optical systems closer to reality than ever before as will be shown below. The concept of optical computing stems from the advent of lasers. This promising new technology exploits the advantages of photons over electrons, which include ultrafast information processing and communication. Although an optical computing system is not yet in existence, many related recent developments have been demonstrated which bring the optical computing technology closer to reality. Our intent, in this Chapter, is to present an overview of the current status of optical computing, and a brief evaluation of the recent advances and performance of the following key components necessary to build an optical computing system.

1. All-Optical Logic gates.
2. Adders.
3. Optical processors.
4. Optical Storage
5. Holographic storage.
6. Optical interconnects.
7. Spatial Light Modulators.
8. Optical Materials

1. All-Optical Logic Gates:

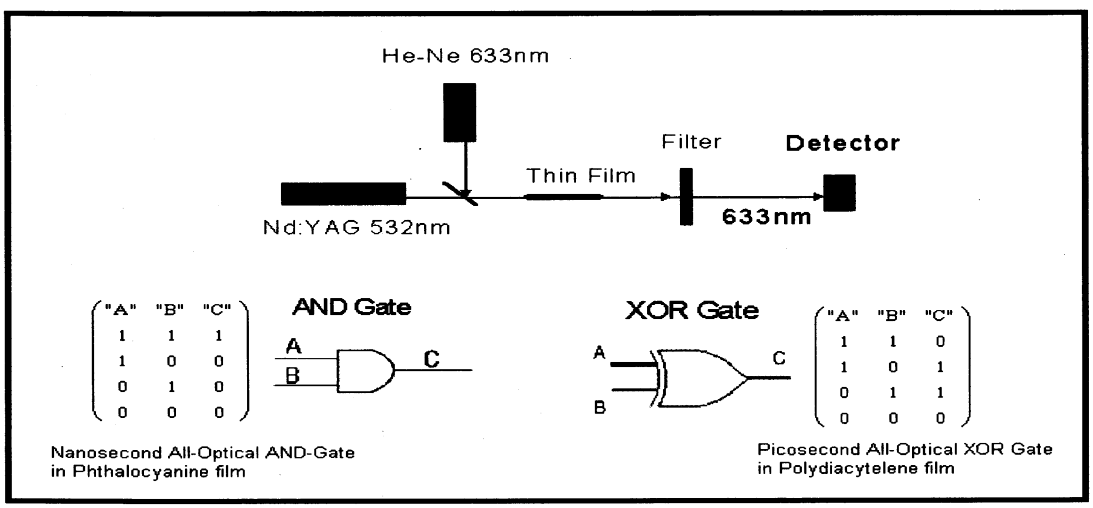

Figure 1. A schematic of all-optical AND and XOR logic gates, which were demonstrated in phthalocyanine and polydiacetylene thin films in the nanosecond and picosecond regimes, respectively.

Logic gates are the building blocks of any digital system. An all-optical logic gate is a switch that controls one light beam by another without the need for an electrical signal; it