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OPTICAL COMPUTING

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ABSTRACT

With the growth of computing technology the need of high-performance computers (HPC) has significantly increased. Optics has been used in computing for a number of years but the main emphasis has been and continues to be to link portions of computers, for communications, or more intrinsically in devices that have some optical application or component (optical pattern recognition etc.). Optical computing is the use of optical systems to perform numerical computations or process information. It is the science of making computing work better using optics and related technologies. Optical computers are computers of the future that use of light particles called photons. They come as a solution of miniaturizing problem. They are the most feasible devices that can replace electronic computers with impressive speeds. This paper provides a brief introduction to optical computing

INTRODUCTION

Optical computing (also known as optoelectronic computing and photonic computing) is a computation paradigm that uses photons (small packets of light energy) produced by laser/diodes for digital computation. Photons have proved to give us a higher bandwidth than the electrons we use in conventional computer systems. The optical computers would give us a higher performance and hencebe faster than the electronics.

The speed of computation depends on two factors: how fast the information can be transferred and how fast that information can be processed which is data computation. Photons basically use wave propagation and the interference pattern of waves to determine outputs. This allows for instantaneous computation without inducing latency. Data is processed while it's propagating. There is no need to stop the data movement and flow for its processing. This speed factor would transform the computer industry. An optical logic gate is simply a switch that controls so the light beam by another.

It is "ON" when light is being transmitted, and it is "OFF" when it blocks the light. Photons are almost mass less, hence we need a very less amount of energy to excite them. Also, instead of operating in a serial fashion like most classical computers, optical computing operates in a parallel way, which helps it to tackle complex problems using light reflection, as well as have increased bandwidth as compared to electron-based systems. Coming to security, a so optical computing processes data while it is in motion, and very less data is exposed.

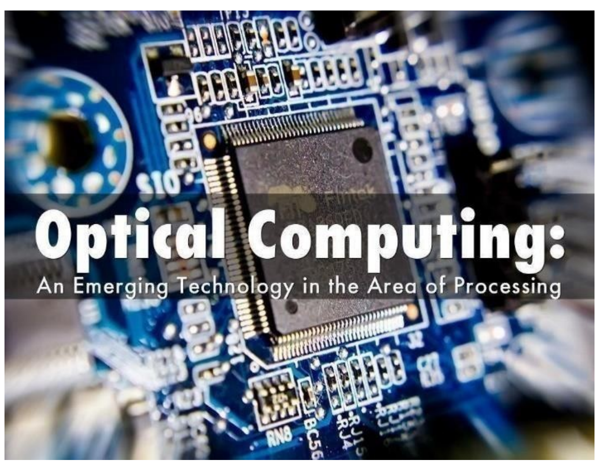

Fig 1 Optical computing [1]

Optical computing technology is, in general, developing in two directions. One approach is to build computers that have the same architecture as present computers but using optics that is Electro-Optical hybrids. The other approach is to generate a completely new kind of computer, which can perform all functional operations in optical mode. In recent years, a number of devices that can ultimately lead us to real optical computers have already been manufactured. These include optical logic gates, optical switches, optical interconnections and optical memory.

Optical technologies one of the most promising and may eventually lead to new computing applications as a consequence of faster processing speed, as well as better connectivity and higher bandwidth. Optical computing is the use of optical systems to perform numerical computations or process information. It is the science of making computing work better using optics and related technologies.

The speed of computers was achieved by miniaturizing electronic components to a very small micron-size scale but they are limited not only by the speed of electrons in the matter but also by the increasing density of interconnections necessary to link the electronic gates on microchips. The optical computer comes as a solution of the miniaturization problem. Optical data processing can perform several operations in parallel much faster and easier than electrons This parallelism helps in staggering computational power. For example, a calculation that takes a conventional electronic computer more than 11 years to complete could be performed by an optical computer in a single hour. Any way we can realize that in an optical computer, electrons are replaced by photons, the subatomic bits of electromagnetic radiation that makeup light.

INSTRUMENTATION

The working principle of the Optical Computer is similar to the conventional computer except with some portions that perform functional operations in Optical mode. Photons are generated b LEDs, lasers, and a variety of other devices. They can be used for encoding the data similar to electrons. Design and implementation of Optical transistors are currently in progress with the ultimate aim of building an Optical Computer. Multi design Optical transistors are being experimented with. A ninety-degree rotating, polarizing ng screen can effectivel block a light beam. Optical transistors are also made from dielectric materials that have the potential to act as polarizers. Optical logic gates are slightly challenging but fundamentally possible. They would involve one control and multiple beamsthat would provide a correct logical output.

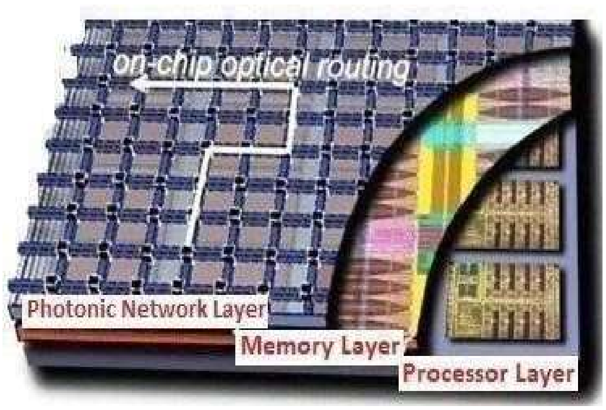

Fig 2: Optical Network on Chip [2]

Electrons have one superior advantage in that, silicon channels and copper wires can be turned and electrons would follow. This effect can be emulated in Optical Chips using Plasmonic Nanoparticles. They are used for turning corners and continuing on their path without major power loss or electron conversion. Most parts of an Optical chip resemble any other commercially found computer chip.

Electrons are deployed in the parts that transform or process information. The interconnects, however, have drastic changes. These interconnects are used for information shuttling between different chip areas. Instead of electron shuttling, which might slow down when interconnects heat up, light is shuttled. This has the advantage of less information loss during travel.

Smart-pixel technology or hybrid-VLSI electronics is emerging as a serious candidate for the fabrication of massively parallel, large throughput bandwidth optoelectronics systems. This chapter attempts to review the current state of the art and the future trends in this field. Basic considerations show that the technology depends on a few parameters in the optical and electronic domains. A system- specific calculation on the optimum throughput is carried out in the case of the bitonics sorter demonstrator which is being built at Heriot-Watt University. The methodology developed emphasizes the need for more compact, high sensitivity, high gain, and low power consumption photoreceiver amplifiers as well as the development of short pulse duration, high modulation rate, and high energy laser sources.

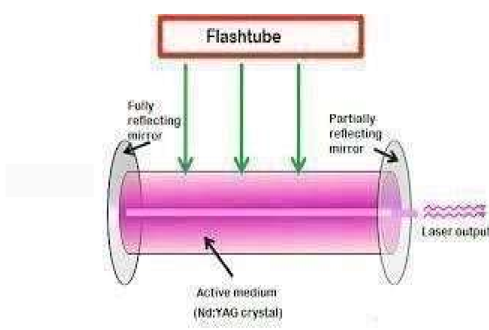

Fig 3: Nd YA Glaser operation [3]

Neodymium: Yttrium Aluminium Garnet solid-state four-level laser system. The optically excited Neodymium ions from the bands E1&E2 quickly decay to the metastable upper laser level. The difference in energy is transferred to the crystal lattice. The upper lifetime is about 230micro second. It is quite long, so the population can be accumulated over a relatively long time during the pumping cycle. At this level (upper laser level), the ions are stimulated by photons due to spontaneous emission, to emit on the main 1.064micrometerlaser. The ions are dropped to a lower laser level. They quickly leave again bytransferring the energy to the crystal lattice.

All-optical computers offer high speed and high levels of parallelism, but problems of miniaturization and manufacturability must be overcome to move ideas out of thelaboratory.

Just as fiberoptic technology, with its tremendous speed and bandwidth, has largely replaced electronics in long-distance telecommunication networks, computer scientists have long strived to develop optical, or photonic, versions of electronic computers. Photons have significant potential advantages over electrons—they can interpenetrate each other unaltered, allowing the use of three-dimensional devices that are difficult or impossible to implement electronically, they are far more energy-efficient, and, of course, they always move at the speedof light.

But researchers trying to make these potential advantages into realities face very significant challenges—optical- computing devices tend to be large and bulky, require careful alignment, and are not easy to miniaturize using existing photolithographic techniques. Such problems are just beginning to be addressed as researchers focus on basic systemdesign ideas, but they are essential to moving technologies outof the laboratory.

Optical computers can potentially overcome all three disadvantages. Light can travel through free space without the need for wires or fibers, and photons can travel through each other without alteration. So optical computers can be designed that are inherently three-dimensional and highly parallel. Elements such as three-dimensional holograms can be accessed by many beams simultaneously, and with other interference effects entire memories can be queried instantaneously, not in serial fashion. Furthermore, energy losses from light traversing free space are negligible, allowing highly energy-efficient devices. And while electro-optic switches can slow down optical computers, some optical computations, again using interference effects, can be performed literally at the speed of light.

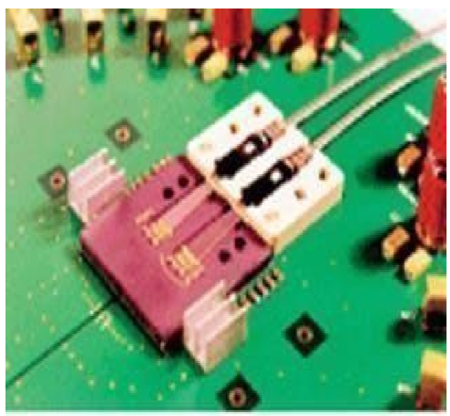

Fig 4: parallel optical computer [4]

But optical computing has serious obstacles, as well. It is difficult to fabricate optical elements that are very small, so most laboratory systems are bench-top-sized, not chip-sized. New techniques have been developed to implement optical elements with silicon photolithography, but they are still relatively immature. In addition, optical elements need tight tolerances to work. And while optical computing can in some cases do what electronic computing does, but better and faster, the truly unique, purely optical capabilities are just now being developed for computing applications. Given the strengths and weaknesses of optical computing, the main applications are not in replacing general- purpose electronic computers but in narrower niches in which optical advantages are the greatest. The most obvious of these are in interconnecting conventional electronic computer chips or boards (see photo). Potentially, optical interconnects canvastly increase connectivity and reduce communication times for machines with multiple processors.

A second important application area is in neural networks. These were first developed to imitate human and animal neural processing and involve self-learning networks for pattern recognition and image processing. Optical methods are ideal for neural networks because they are highly parallel and rely on every unit interacting with every other one. Similarly, shared memory, often in the form of holographic memories, is another way of exploiting the natural parallelism of optical techniques.

Although it is clearly a long-term goal, researchers are also looking at more-general systems of optical logic that could execute any arbitrary program that is implementable on a conventional chip. Even more exciting, a number of groups are looking at new ways of computing, using the quantum and interference properties of light to eliminate many of the intermediate steps involved in conventional Turing-machine computers.

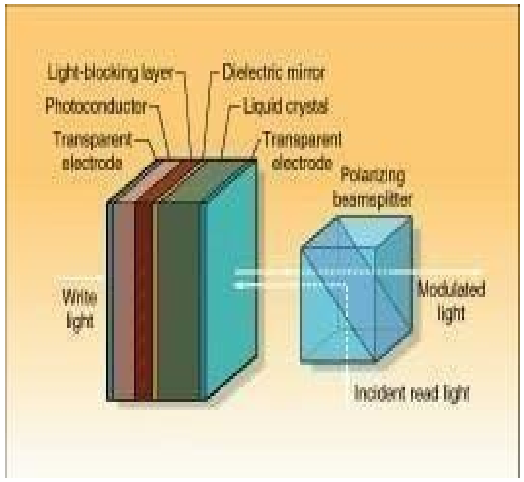

Fig 5: Optical addressable liquid-crystal light valve [5]

Spatial light modulators use a variety of physical principles, essentially all those that are used in any kind of optical modulator. A simple example is a Mach-Zehnder interferometer, in which a beam is split in two and an electric field is applied to one optical path before the two are recombined. By varying the phase of one leg with the applied voltage, constructive or destructive interference can be selected. Using the Kerr effect, the same result can be obtained using an input light to change the refractive index of one leg, making an all-optical switch. Similarly, magneto- optical or acousto-optical effects can be used for other electro- optical SLMs.

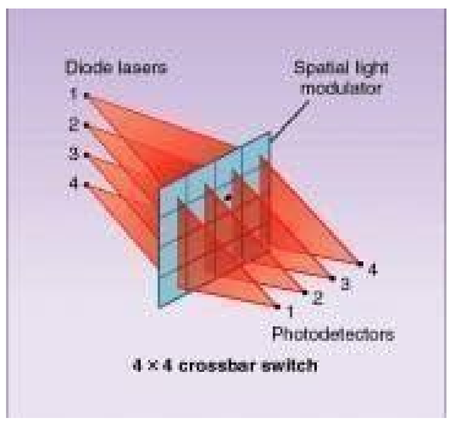

Fig 6: Optical computing with 4*4 arrays [6]

The most developed technology for arrays of spatial light modulators is liquid crystals, which are used in ubiquitous displays. In such liquid-crystal displays (LCDs), an electric field alters the polarization properties of the liquid- crystal molecules, either allowing or blocking light transmission. To create an all- optical switch, a photoconductive layer is added to a liquid- crystal cell. The "write" light signal, coming from one side, changes the potential on the photoconductive layer

APPLICATIONS

1. Storage area network.
2. Fiber channel Topologies.
3. Optical computing in VLSI Technology
4. Optical computing as expanders.
5. Wavelength Amplifiers.
6. High speed communications:

ADVANTAGES

1. Low heating.
2. Can tackle complex computations very quickly.
3. Can be scaled to larger networks efficiently.
4. Increased computation speed.
5. Higher bandwidth with very low data losstransmission.
6. Free from electrical short circuits.

CONCLUSION

Research in optical computing has opened new possibilities in several fields related to high- performance computing and high- speed communications. To design algorithms that execute applications faster, the specific properties of optics is considered, such as their ability to exploit massive parallelism and global inter connections, as optoelectronics and smart pixel devices mature, software development will have a major impact in the future and the ground rules for the computing may have to be rewritten. To design algorithms that execute applications faster, the specific properties of optics is considered, such as their ability to exploit massive parallelismand global inter connections.

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