CHAPTER 1
CONCEPT OF SILICON PHOTONICS

We all expect fast, free-flowing bandwidth whenever and wherever we connect with the world. However, there is a problem, as newer faster microprocessors roll out, the copper connections that feed those processors within computers and servers will prove inadequate to handle the crushing tides of data. Here is a better way: replace the copper with optical fiber and the electrons with photons. That is the promise of silicon photonics: affordable optical communications for everything. It will let manufacturers build optical components using the same semiconductor equipment and methods they use now for ordinary integrated circuits, thereby dramatically lowering the cost of photonics. Its overarching goal is to develop high-volume, low-cost optical components using standard CMOS processing-the same manufacturing process used for microprocessors and semiconductor device. The only way for photonics to move into the mass market is to introduce integration, high-volume manufacturing, and low cost assembly-that is, to "Siliconize" photonics. By that, we mean integrating several different optical devices onto one silicon chip, rather than separately assembling each from exotic materials.

The researchers believe that with this development, silicon photonic chips containing dozens or even hundreds of hybrid silicon lasers could someday be built using standard high-volume, low-cost silicon manufacturing techniques side by side, communicating with each other to form a supercomputer far beyond the scale of today's fastest computer. Silicon photonics technology has the potential to use the power of optical networking inside computers and to create new generation of miniaturized and low-cost photonic components, among other applications.

In one potential use, many boards containing these Silicon-photonic chips would coexist. Thus one can now see a path to integrating silicon hybrid lasers, photo detectors, modulators, and waveguides into a single highly integrated photonic chip capable of transmitting 1 Tbit/s of information down a single optical fiber all on a piece of silicon the size of your fingernail. The chips will also be well suited for use in general data communications and computing.

CHAPTER 2
INTRODUCTION OF SILICON PHOTONICS

Its overarching goal is to develop high-volume, low-cost optical components using standard CMOS processing the same manufacturing process used for microprocessors and semiconductor device. Despite silicon's shortcomings, researchers have been studying silicon photonics for more than 20 years, starting with Richard Soref's pioneering work in the midioaos at the Air Force Research Laboratory. Since then, there have been a host of silicon photonics breakthroughs at Cornell University, the Massachusetts Institute of Technology, the University of California at Los Angeles, the University of Catania in Sicily, the University of Surrey, IBM, Intel, and elsewhere.

With optical interconnects in and around our desktop computers and servers, we'll download movies in seconds rather than hours and conduct lightning-fast searches through gigabytes of image, audio, or text data. Multiple simultaneous streams of video arriving on our PCs will open up new applications in remote monitoring and surveillance, teleconferencing, and entertainment In theory, you could push fiber up to 150 trillion bits per second a rate that would deliver the text of all the books in the U.S. Library of Congress in about a second. Unlike electronic data, optical signals can travel tens of kilometers without distortion or attenuation. You can also pack dozens of channels of high-speed data onto a single fiber, separating the channels by wavelength, a technique called wavelength-division multiplexing. Today, 40 separate signals, each running at 10 gigabits per second, can be squeezed onto a hair-thin fiber.

Today's devices are specialized components made from indium phosphide, lithium niobate, and other exotic materials that can't be integrated onto silicon chips. That makes their assembly much more complex than the assembly of ordinary electronics, because the paths that the light travels must be painstakingly aligned to micrometer precision. The only way for photonics to move into the mass market is to introduce integration, high-volume manufacturing, and low cost assembly-that is, to "Siliconize" photonics. By that, we mean integrating several different optical devices onto one silicon chip, rather than separately assembling each from exotic materials.

2.1 Photon:

A photon is a discrete bundle of light energy. Photons are always in motion and, in a vacuum, have a constant speed of light to all observers, at the vacuum speed of light. The photon is an elementary particle, despite the fact that it has no mass. It cannot decay on its own, although the energy of the photon can transfer (or be created) upon interaction with other particles. Photons are electrically neutral and are one of the rare particles.

According to the photon theory of light, photons-

- Move at the speed of light in free space
- Have zero mass and rest energy.
- Carry energy and momentum.
- Can be destroyed /created when radiation is absorbed/emitted.
- Can have particle-like interactions (i.e. collisions) with electrons and other particles, such as in the Compton Effect.

2.2 Silicon:

It is semiconductor element which have symbol of silicon is Si and atomic number 14. Second only to oxygen in abundance in Earth's crust; it never occurs free but is found in almost all rocks and in sand, clay, and soils, combined with oxygen as silica. Pure silicon is a hard, dark gray solid with a metallic luster and the same crystal structure as diamond. It is an extremely important semiconductor doped with boron, phosphorus, or arsenic, it is used in various electronic circuits and switching devices, including computer chips, transistors, and diodes.

Silicon presents a unique material for this research because the techniques for processing it are well understood and it demonstrates certain desirable behaviors. For example, while silicon is opaque in the visible spectrum, it is transparent at the infrared wavelengths used in optical transmission, hence it can guide light. Moreover, manufacturing silicon components in high volume to the specifications needed by optical communication is comparatively inexpensive.

Silicon's key drawback is that it cannot emit laser light, and so the lasers that drive optical communications have been made of more exotic materials, such as ‘indium phosphide’ and ‘gallium arsenide’. However, silicon can be used to manipulate the light emitted by inexpensive lasers so as to provide light that has characteristics similar to more-expensive devices. This is just one way in which silicon can lower the cost of photonics.

2.3 Photonics:

Photonics is the science of generating, controlling, and detecting photons, particularly in the visible and near infra-red spectrum, but also extending to the ultraviolet (0.2–0.35 μm wavelength), long-wave infrared (8–12 μm wavelength), and far-infrared/THz portion of the spectrum. The science of photonics includes investigation of the emission, transmission, amplification, detection, and modulation of light. Photonic devices include optoelectronic devices such as lasers & Photo detector, as well as optical fiber and planar waveguides.

2.4 Silicon Photonics:

Silicon photonics is an evolving technology in which data is transferred among computer chips by optical rays. The concept involves combining laser and silicon technology on the same chip. The improved performance results from the greater available bandwidth and high propagation speed of infrared (IR) beams compared with electric current. The effective implementation of silicon photonics technology would dramatically increase the processing speed and power of computers.

2.4.1. Background:

Photonics as a field really began in 1960, with the invention of the LASER (Light amplification by stimulated emission of radiation), and the laser diode followed in the 1970s by the development of optical fibers as a medium for transmitting information using light beams, and the Erbium-doped fiber amplifier. These inventions formed the basis for the telecommunications revolution of the late 20th century, and provided the infrastructure for the internet.

Historically, the term photonics only came into common use among the scientific community in the 1980s as fiber optic transmission of electronic data was adopted widely by telecommunications network operators. At that time, the term was adopted widely within Bell Laboratories. Its use was confirmed when the IEEE Lasers and Electro-Optics Society established an archival journal named Photonics Technology Letters at the end of the 1980s. A huge further growth of photonics can be expected for the case that the current development of silicon photonics will be successful.

2.4.2. Need silicon photonics:

Intel cofounder Gordon Moore projected that the number of transistors on a computer chip will double every 2 years. (1965). Computer chips today have 1.7 billion transistors and growing, The more transistors we can put on a chip, the more information it can process in a given time. There always remains the limit on number of transistors. Multicore processor solves the problem of transistors for now, but it never mean we can keep just adding no. of cores to the processor forever and never limit the speed of our computer. Copper wires are used for the communication in computer. Copper has resistance. Increased resistance increases heat. Increased heat increases resistance that results in loss of information.

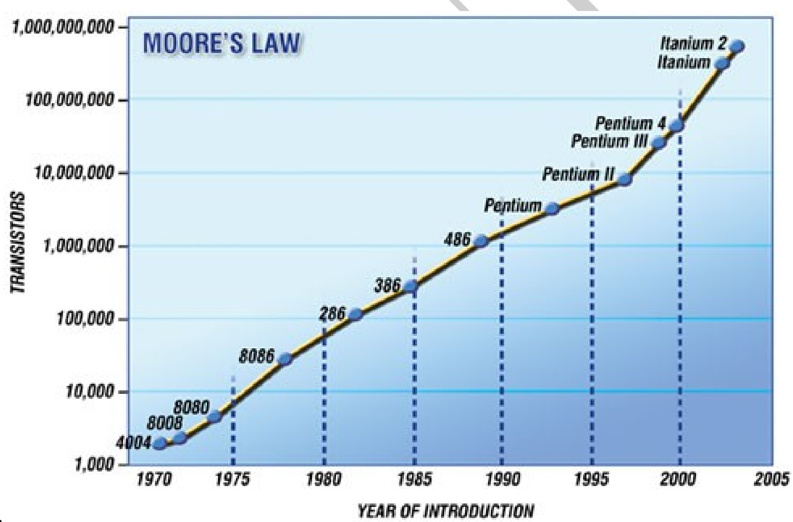

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Fig: (2.1) Moore's Law

Right now, fiber optics is the best way to move large streams of data among computing devices. To find fiber optics, you need look no further than the large-trunk, fiber optic lines that carry telephone and Internet traffic among service providers around the world. what about moving large amounts of data inside your computer?

Computer manufacturers don't use fiber optics to move data from component to component inside your PC because it's expensive to use and implement fiber optics inside computers, which is why they rely on electrical copper links. However, as computer components and chips work faster, those slower copper links will begin to hold back PCs. The copper links won't be able to move data quickly enough to let the chips and other components work at top speed. The chips may be waiting for data to arrive over the copper links, leaving them idle. Fiber optics can carry thousands of times more data than copper cable links.

Silicon photonics may be the answer to these problems. Silicon photonics brings laser technology to silicon, allowing for the use of fiber optic communications from a silicon chip. Because silicon is inexpensive, implementation of fiber optics in many new areas including among servers, across networks, and inside computers may become possible. To understand how optical data might one day travel through silicon in your computer, it helps to know how it travels over optical fiber today.

First, a computer sends regular electrical data to an optical transmitter, where the signal is converted into pulses of light. The transmitter contains a laser and an electrical driver, which uses the source data to modulate the laser beam, turning it on and off to generate 1s and 0s. Imprinted with the data, the beam travels through the glass fiber, encountering switches at various junctures that route the data to different destinations. If the data must travel more than about 100 kilometers, an optical amplifier boosts the signal. At the destination, a photo detector reads and converts the data encoded in the photons back into electrical data.

CHAPTER 3

BUILDING BLOCKS OF SILICON PHOTONICS

3.1. Introduction

Silicon Photonics includes following flow of Process flow

1. *Light source (low cost external laser)*
2. *Guide light (silicon on insulator)*
3. *Modulation (Si MOS capacitor device)*
4. *Photo detection (Si based photo detector)*

A laser generates light this light may be filtered and tuned to a specific wavelength. It is then modulated, which is the process of placing data on the light. If multiple optical channels are desired, the light then passes through a multiplexer that combines it with wavelengths from other lasers and places the resulting light onto a glass fiber. A block diagram of this setup appears in Fig (3.1). On the receiving end, the process operates in reverse. A demultiplexer separates the wavelengths on the fiber to create individual data streams. These are then routed to photo detectors that convert the light into electrical signals

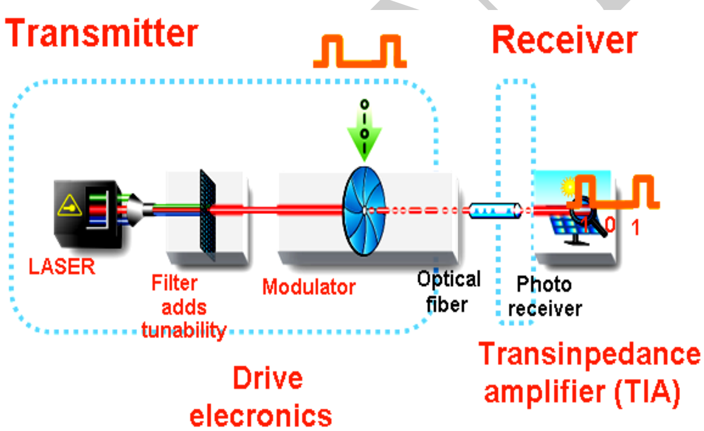


Fig (3.1): Simple block diagram of Silicon Photonics.

3.2. Light source (LASER):

Lasers generate a beam of a single wavelength. Electrical or optical energy is pumped into a gain medium, which is surrounded by mirrors to form a “cavity.” Initial photons are either electrically generated within the cavity or injected into the cavity by an optical pump. they trigger the release of other photons with the same optical properties (wavelength, phase and polarization). As the photons move back and forth between the mirrors, they gather additional photons. And forms strong beam of photon light which is, sufficiently strong to form a coherent laser beam. This stimulated emission is created by changing the state of electrons. As their state changes, they release a photon, which is the particle that composes light which is a LASER.

3.2.1. The Raman Effect:

A phenomenon observed in the scattering of light is, as it passes through a transparent medium the light undergoes a change in frequency, and random alteration in phase due to a change in rotational or vibrational energy of the scattering. By using this effect in silicon, enabling silicon to be used for the first time to amplify signals and create continuous beams of laser light. The Raman Effect is widely used today to make modulators and detectors. These devices are built by directing a laser beam known as the pump beam into a fiber. As the light enters, the photons collide with vibrating atoms in the material and, through the Raman Effect; energy is transferred to photons of longer wavelengths.

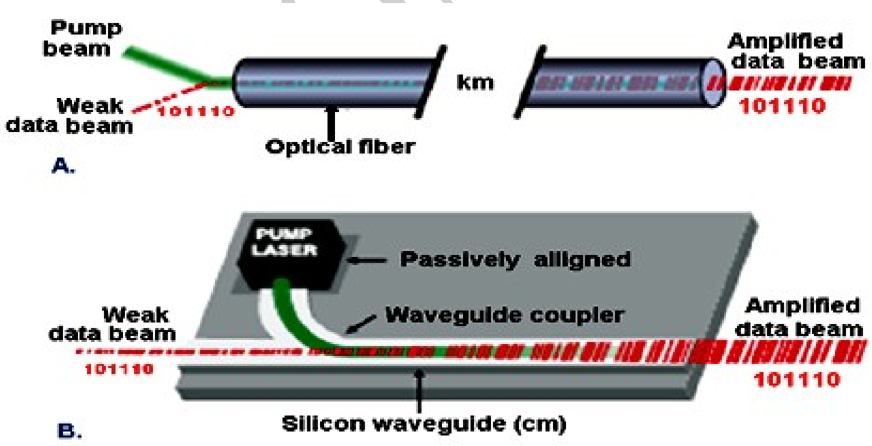


Figure (3.2) LASER through silicon and optical fiber

(a) The Raman Effect allows energy from a pump beam to amplify data at longer wavelengths in glass fiber.

(b) This can now done in silicon as well with small distance.

If a data beam is applied at the appropriate wavelength, it will pick up additional photons. After traveling several kilometers in the fiber, the beam acquires enough energy to cause a significant amplification of the data signal (Figure 3.3 A). By reflecting light back and forth through the fiber, the repeated action of the Raman Effect can produce a pure laser beam.

However, fiber-based devices using the Raman Effect are limited because they require kilometers of fiber to provide sufficient amplification. The Raman Effect is more than 10,000 times stronger in silicon than in glass optical fiber, making silicon an advantageous material. Instead of kilometers of fiber, only centimeters of silicon are required (Figure 3.3b). By using the Raman Effect and an optical pump beam, silicon can now be used to make useful amplifiers and lasers.

3.2.1.1 The Challenge:

The process of building a Raman amplifier or laser in silicon begins with the creation of a waveguide - a conduit for light - in silicon. This can be done using standard CMOS techniques to etch a ridge or channel into a silicon wafer (Figure 1 b). Light directed into this waveguide will be contained and channeled across the chip. In any waveguide, some light is lost through absorption by the material, imperfections in the physical structure, roughness of the surfaces and other optical effects. The challenge that Intel researchers surmounted is making a waveguide in which the amplification provided by the Raman effect exceeds the loss in the silicon waveguide.

3.2.1.2. How Lasers Work:

Lasers generate a beam of a single wavelength by amplifying light. As shown in Figure 2, electrical or optical energy is pumped into a gain medium which is surrounded by mirrors to form a “cavity”. Initial photons are either electrically generated within the cavity or injected into the cavity by an optical pump. As the photons stream through the gain medium, they trigger the release of duplicate photons with the same optical properties (wavelength, phase and polarization). As the photons move back and forth between the mirrors, they gather additional photons. This gain has the effect of amplifying the light. Ultimately, the light is sufficiently strong to form a “coherent” laser beam in which all the photons stream in parallel at the same wavelength. This laser beam is shown exiting the cavity by the red beam at the right of the figure below. The world’s first laser was built by Ted Maiman in 1960. This device used a white flash lamp to optically pump a ruby crystal and generate red laser light

In mid-2004, Intel researchers discovered that increasing the pump power beyond a certain point no longer increased the amplification and eventually even decreased it. The reason turned out to be a physical process called two-photon absorption (see next section), which absorbs a fraction of the pump beam and creates free electrons. These electrons build up over time and collect in the waveguide. The problem is that the free electrons absorb some of the pump and signal beams, reducing the net amplification. The higher the power density in the waveguide, the higher the loss incurred. Intel's breakthrough is a solution that minimizes the extra electrons caused by two-photon absorption - so that an amplified, continuous laser beam can be generated. In fact, Intel recently demonstrated the first silicon device with a continuous net amplification with a gain that more than doubled the input signal power.

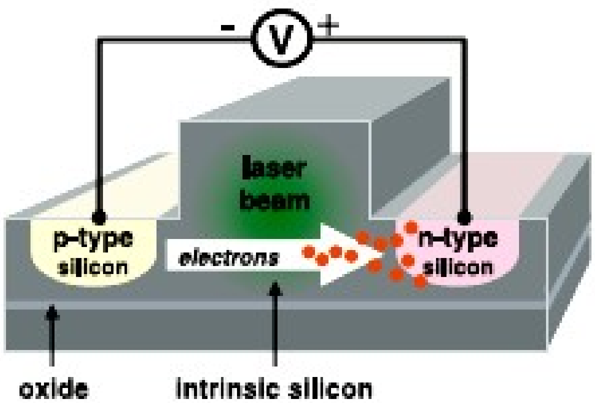


Figure (3.3): By inserting a diode-like PIN device in the waveguide, Intel removed the electrons generated by two-photon absorption and produce continuous amplification

3.2.2. Two-photon absorption:

Usually, silicon is transparent to infrared light, meaning atoms do not absorb photons as they pass through the silicon because the infrared light does not have enough energy to excite an electron. Occasionally, however, two photons arrive at the atom at the same time in such a way that the combined energy is enough to free an electron from an atom.

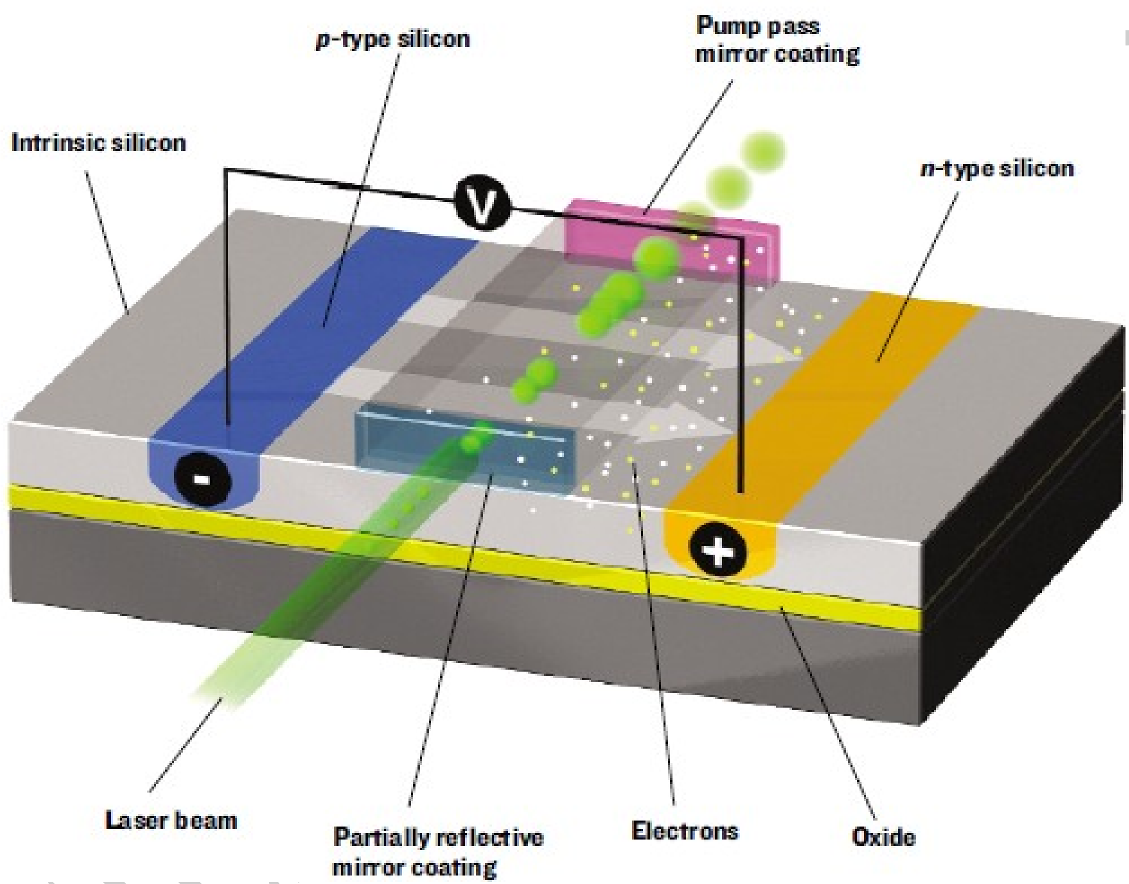


Fig (3.4): PIN (p-type-intrinsic-n-type) diode placed on either side of the light beam

When the pump pulse propagates through the waveguide, free carriers are generated due to the TPA effect. The free-carriers effect not only causes excess absorptions, as mentioned before, it also induces a change in the refractive index of the Silicon (Δn). The phase of the output probe light is therefore modified ($\Delta\varphi$) due to this effect as:

$$\Delta\phi(t) = \frac{2\pi L}{\lambda}\Delta n(t) \propto \int_0^t \beta \cdot \left[\frac{P_p(\tau)}{A}\right]^2 d\tau$$

Where, L= Length of waveguide

λ= Wavelength of the light, β= TPA coefficient

Pp= Intensity pulse of the probe, A =Area of waveguide.

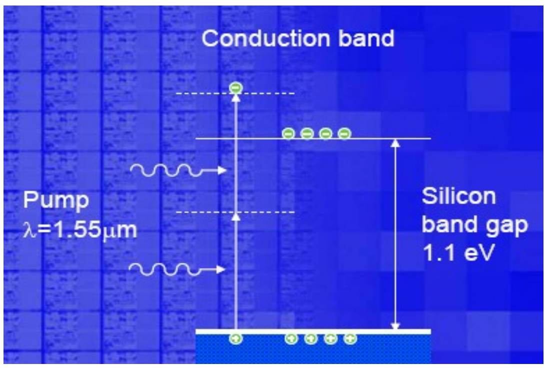


Fig. (3.5): Energy Band Diagram

Usually, this is a very rare occurrence. However, the higher the pump power, the More likely it is to happen. Eventually, these free electrons recombine with the crystal Lattice and pose no further problem. However, at high power densities, the rate at which the free electrons are created exceeds the rate of recombination and they build up in the waveguide. Unfortunately, these free electrons begin absorbing the light passing through the silicon waveguide and diminish the power of these signals. The end result is a loss significant enough to cancel out the benefit of Raman amplification.

3.2.3. Breakthrough Laser:

The solution is to change the design of the waveguide so that it contains a semiconductor structure, technically called a PIN (P-type -Intrinsic - N-type) device. When a voltage is applied to this device, it acts like a vacuum and removes the electrons from the path of the light. Prior to this breakthrough, the two-photon absorption problem would draw away so many photons as to not allow net amplification. Hence, maintaining a continuous laser beam would be impossible. Intel's breakthrough is the use of the PIN to make the amplification continuous.

Figure (3.6) is a schematic of the PIN device. The PIN is represented by the p- and n-doped regions as well as the intrinsic silicon in between. This silicon device can direct the flow of current in much the same way as diodes and other semiconductor devices do today in common electronics. Hence, the manufacture of this device relies on established manufacturing technologies and it reinforces the basic goal of silicon photonics: inexpensive, high-performance optical components.

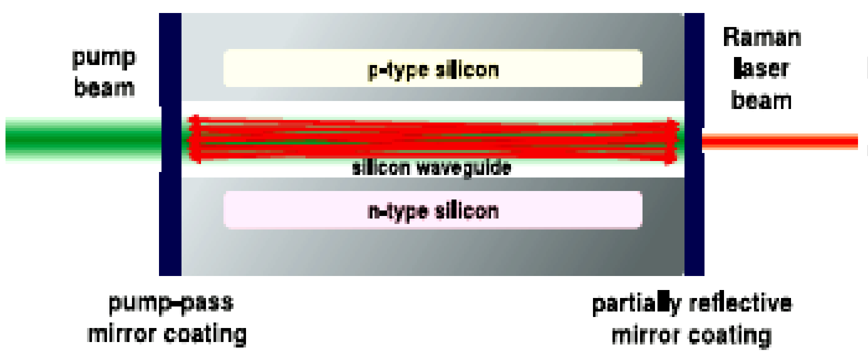


Figure (3.6): The breakthrough silicon laser used a PIN device and the Raman Effect to amplify light as it bounced between two mirrors coated on the waveguide ends, producing a continuous laser beam at a new wavelength.

To create the breakthrough laser, Intel coated the ends of the PIN waveguide with mirrors to form a laser cavity (Figure above). After applying a voltage and a pump beam to the silicon, re-searchers observed a steady beam of laser light of a different wavelength exiting the cavity – the first continuous silicon laser

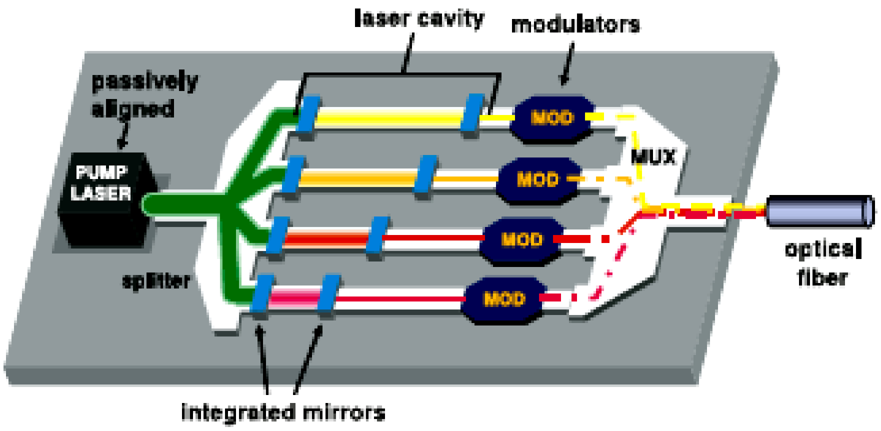


Figure (3.7) An example of creating multiple silicon laser sources from one pump beam

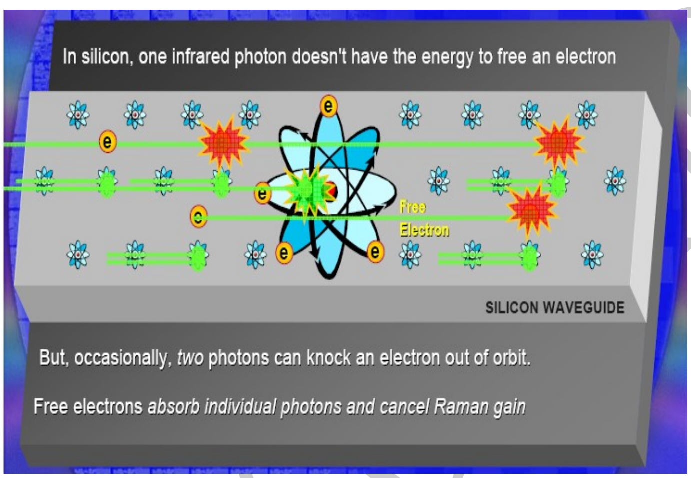


Fig (3.8): Two-Photon Absorption in Silicon

3.2.4. Raman-Based Silicon Photonics

Raman scattering was proposed and demonstrated in 2002 as a mean to bypass these limitations, and to create optical amplifiers and lasers in silicon. The approach was motivated by the fact that the stimulated Raman gain coefficient in silicon is 10^3-10^4 times larger than that in fiber.

The modal area in a silicon waveguide is roughly 100 times smaller than in fiber, resulting in a proportional increase in optical intensity. The combination makes it possible to realize chip-scale Raman devices that normally require kilometers of fiber to operate. The initial demonstration of spontaneous Raman emission from silicon waveguides in 2002 was followed by the demonstration of stimulated Raman scattering and parametric Raman wavelength conversion , both in 2003. Other merits of the Raman Effect include the fact that it occurs in pure silicon and hence does not require rare earth dopants (such as Erbium), and that the spectrum is widely tunable through the pump laser wavelength.

3.3. Silicon Modulator:

3.3.1. Introduction:

Modulation is one of the hottest topics where device scaling and power consumption targets are taking over the race for high modulation speed that occurred in the last few years. The bandwidth has increased from a few tens of MHz to multi GHz in little more than half a decade. Moreover, a CMOS compatible fabrication process optimised to maximize device yield is also highly desirable.

Since the first majority carrier device based on accumulation demonstrated by Liu et al. and the first depletion type device proposed by Gardes et al, later demonstrated by Liao et al with an optical bandwidth of 20 GHz and 30 GHz, a plethora of devices based on accumulation and depletion have been demonstrated. These devices are mostly based on Mach Zehnder interferometers and ring resonators of different sizes. In the case of depletion modulators, the junction is positioned in different ways with a particular trend towards vertical junction implanted in the middle of the waveguide to maximize the optical mode overlap and the depletion region, nevertheless the fabrication of such a junction is subject to alignment tolerance which may impair the device characteristics from wafer to wafer. Efficiency is also a matter of importance as from this, will result the device operating voltage/footprint and ultimately the power consumption.

The optical modulator, which contains two p-n junctions, each in a silicon-on-insulator waveguide that is an arm of a Mach-Zehnder interferometer, is based on the free-carrier plasma-dispersion effect, in which the refractive index changes as a function of electric-field-induced carrier depletion. Optimum electronic performance is crucial; the device is designed so that the electrical and optical signals propagate together down the waveguide.

3.3.2. How Silicon Modulator Works:

To understand how the modulator functions, we need to touch briefly on the nature of light. Light is a form of radiation that occurs at specific frequencies, some of which are visible, and some, like ultraviolet and infrared, that are invisible. When light is emitted it travels in a pattern that looks very much like a sine wave. (See the top row of Figure 1.) The total distance reached by the peaks and troughs of this sine wave is known as amplitude. When the sine wave is nearly flat, the light is at its dimmest and has low amplitude. When the peaks and troughs are very high and deep, the light shines brightly and has greater amplitude.

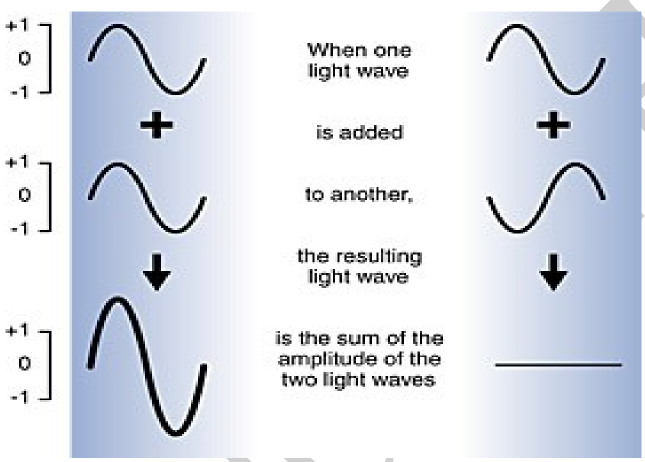


Fig: (3.9) amplification phenomenon

When two wavelengths are combined, the resulting sine wave is the sum of the two constituent sine waves. For example, if two sine waves are perfectly in sync and added together (left column of Figure 3.9), the resulting sine wave has twice the amplitude of the individual waves. In contrast, when two waves are completely out of sync (right column of Figure 3.10) the resulting wave has no amplitude

3.3.3. Mach-Zehnder interferometer:

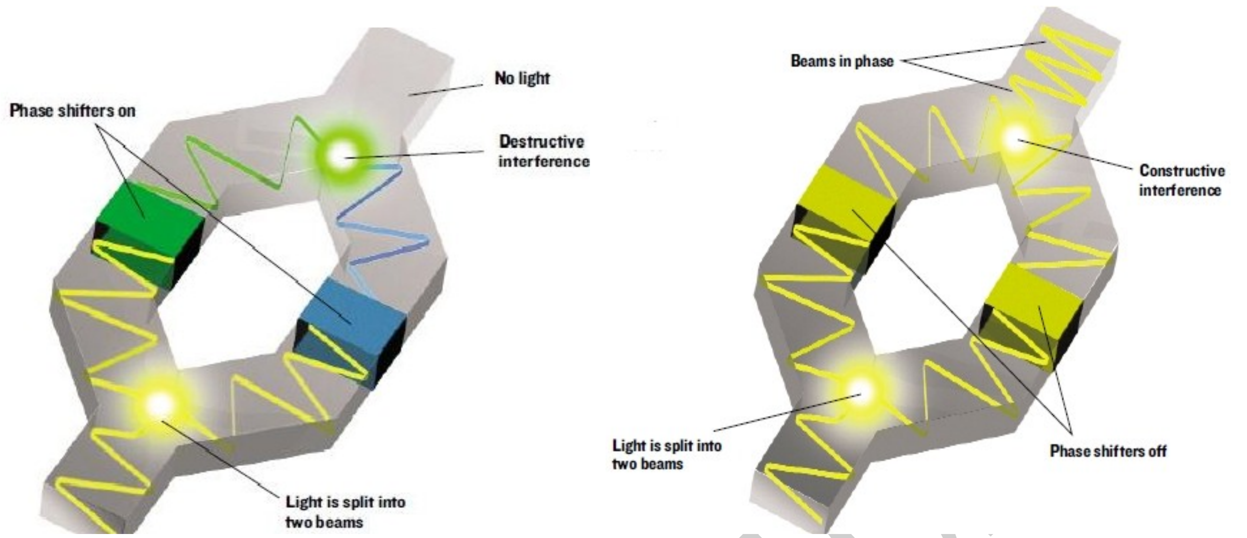


Fig (3.10): Encoding Photons with Data

(a) An optical modulator encodes 1s and 0s by first splitting a laser beam in two and then applying an electric field to the beams, so that one beam is delayed by half a wavelength relative to the other. When the beams recombine, both beams will be out of phase, and they will cancel out.

(b) When no voltage is applied, on the other hand, the beams remain in phase when recombined. Encoding the beam with 1s and 0s then means making the beams interfere (0) or keeping them in phase (1).

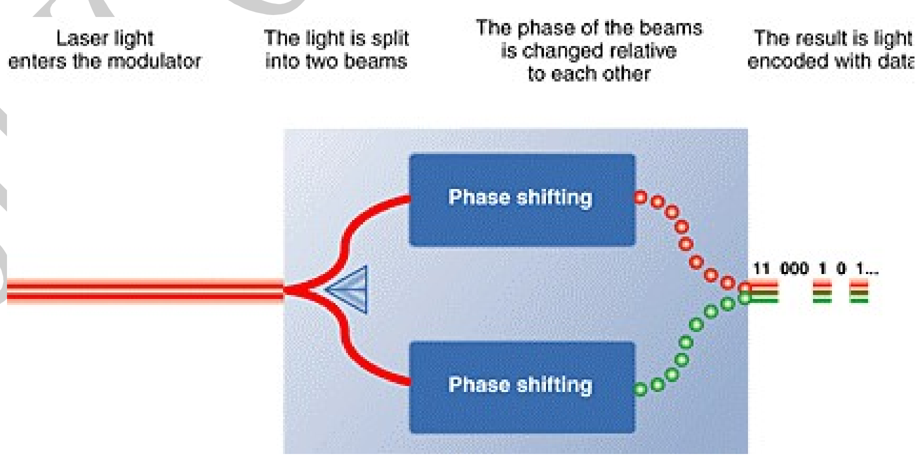


Fig (3.11): concept of phase shifter for silicon photonics

You start by splitting the laser beam in two and then applying an electric field to one beam. If the speed changes enough to delay the beam by half of one wavelength, that beam will be out of phase with its mate. When the beams recombine, they will interfere with each other and cancel out.

If, on the other hand, no voltage is applied, the beams remain in phase, and they will add constructively when recombined. Encoding the beam with 1s and Os, then, means making the beams interfere (0) or keeping them in phase (1).

These resulting changes in amplitude (the strength of the light) are the basis on which the photo-detector recognizes Os and 1s. Because the amplitude is being modulated (to encode the data), this technique is referred to as amplitude modulation (AM).

We expect to achieve even greater bandwidth by multiplexing these data streams. This approach could bring silicon photonics into an age where bandwidths of 40 Gbps bandwidths or more are common.

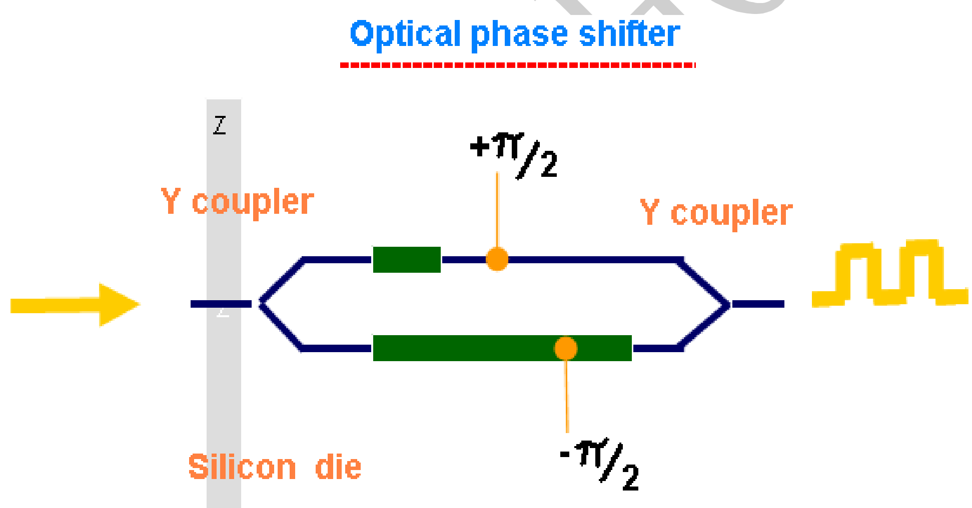


Fig (3.12) Optical Phase Shifter

The Intel modulator is based on a Mach-Zehnder interferometer with a reverse-biased pn junction in each of the arms. When a reverse voltage is applied to the junction, free carriers – electrons and holes resulting from the n- and p-dopants are pulled out of the junction, changing its refractive index via the free-carrier effect. The intensity of the light transmitted through the

Mach-Zehnder interferometer is modulated by modulating the phase difference between the interferometer's two arms. This modulation can be very fast, because free carriers can be swept out of the junction.

The modulator speed is thus limited by, the parasitic effects such as RC time constant limit. The high-speed silicon modulator could find use in various future applications. For example, a highly integrated silicon photonic circuit may provide a cost effective solution for the future optical interconnect within computers and other devices. With the demonstration of the 40 Gbps silicon modulator and the electrically pumped hybrid silicon laser, it will become possible to integrate multiple devices on a single chip that can transmit terabits of aggregate data per second truly enabling tera-scale computing.

3.4. Silicon Based Photodetector:

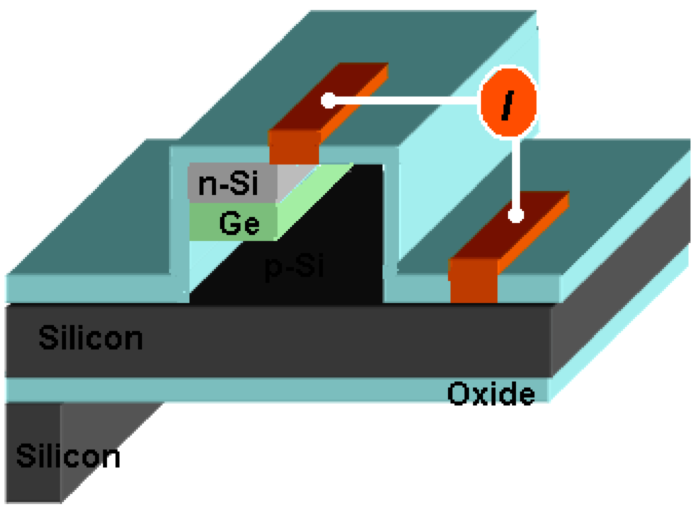


Fig (3.13) Silicon Based Photodetector

Silicon can also be used in photo detection-the process by which incoming wavelengths are converted into electrical signals representing bits. Modulation turns the light on and off to encode the data. When the wavelength is off, a zero-bit is encoded; when the wavelength is on, a one-bit result. The photo detector has the responsibility of converting those incoming bits back into their electrical counterparts. Making a photo detector in silicon, however, has a significant challenge: At the infrared frequencies used by today's fiber-optic lasers, silicon is transparent. It cannot detect incoming light because the photons that make up the wavelengths pass right through it. Interestingly, if the laser wavelengths were in the visible spectrum where silicon is not transparent, silicon would be ideally suited for photo detection. Intel has developed a means of adding the element germanium to silicon to improve its light sensitivity in the infrared spectrum. This approach leverages one of germanium's important properties: It can extend the spectrum of wavelengths at which silicon absorbs light. This achievement enables Intel to build silicon detectors for optical communication.

CHAPTER 4

A TYPICAL ASSEMBLY OF SILICON PHOTONICS

FIG. below shows an assembling structure of silicon photonics in which modulators, electronic chip, optical fiber, photo-detectors, a laser source mirrors etc.

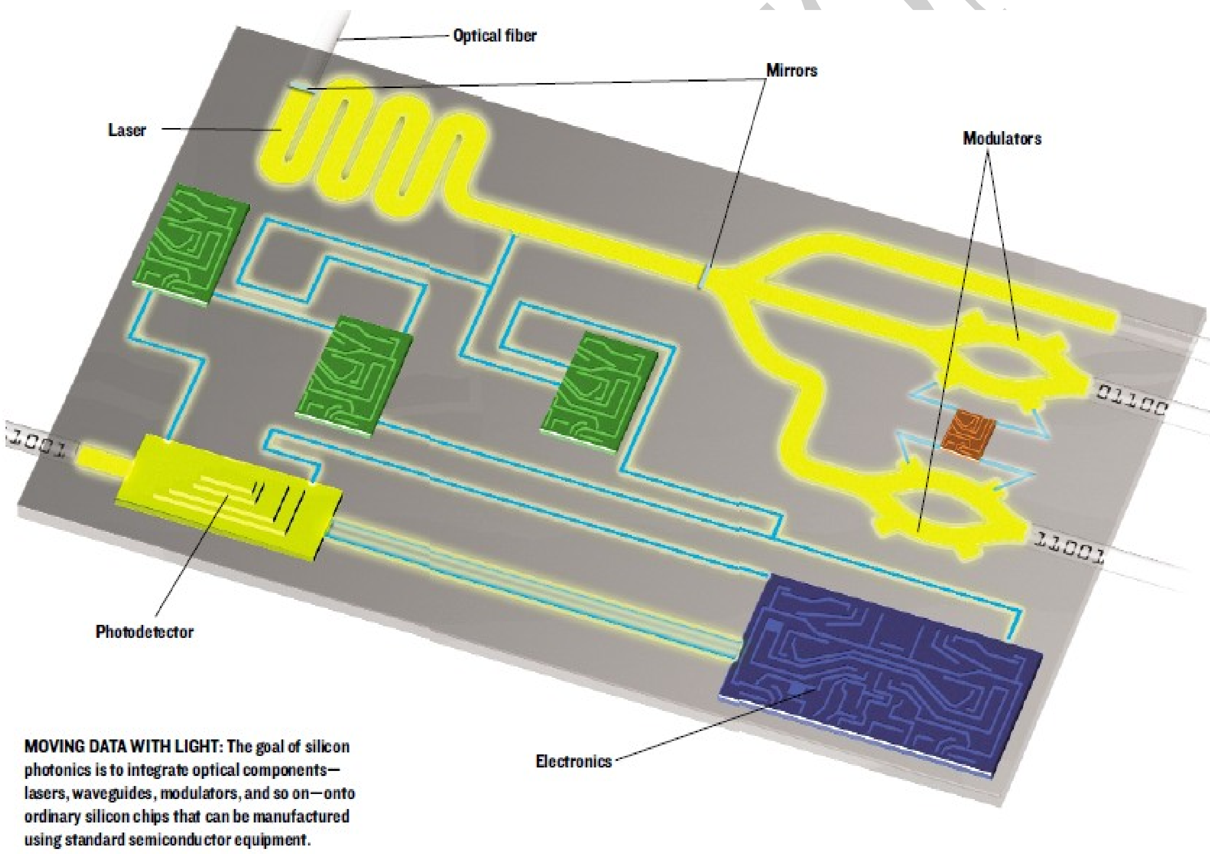


Fig (4.1) Assembly Structure

CHAPTER 5

MICRO-PHOTONICS & NANO-PHOTONICS

Micro-photonics is a branch of technology that deals with directing light on a microscopic scale. It is used in networking. Micro photonics employs at least two different materials with a large differential index of refraction to squeeze the light down to a small size. Generally speaking virtually all of micro photonics relies on Fresnel reflection to guide the light. If the photons reside mainly in the higher index material, the confinement is due to total internal reflection. If the confinement is due many distributed Fresnel reflections, the device is termed a photonic crystal. There are many different types of geometries used in micro photonics including optical waveguides, optical micro cavities, and Arrayed Waveguide Gratings.

Nano-photonics is the study of the behavior of light on the nanometer scale. The ability to fabricate devices in nanoscale that has been developed recently provided the catalyst for this area of study. The study of Nanophotonics involves two broad themes

1. Study the novel properties of light at the nanometer scale.
2. Enabling highly power efficient devices for engineering applications. The study has the potential to revolutionize the telecommunications industry by providing low power, high speed, and interference-free devices such as electro optic and all-optical switches on a chip.

CHAPTER 6

ADVANTAGES AND DISADVANTAGES

Advantages:

1. It is inexpensive to use.
2. Implementation is easy.
3. Speed is so high (1 Tbit/sec).
4. Implementation of the transistors on computer chips will increase
5. It can send & receive 100 billion bits per second.
6. Computer components will become very small in size.
7. The speed of light can also be controlled using photonic crystal waveguides. (up to 1/300th of usual speed of light)
8. Optics is destined to be utilized in data centers since optical communications can meet the large bandwidth demands of high-performance computing systems by bringing the immense advantages of high modulation rates and parallelism of wavelength division multiplexing.
9. Silicon photonics offers high density integration of individual optical components on a single chip.
10. Strong light confinement enables dramatic scaling of the device area and allows unprecedented control over optical signals.
11. Silicon Nanophotonics devices have immense capacity for low-loss, high-bandwidth data processing. Fabrication of silicon photonics system in the complementary metal-oxide-semiconductor (CMOS)-compatible silicon-on-insulator platform also results in further integration of optical and electrical circuitry.

Disadvantages:

1. Circuit Complexity is more.

CHAPTER 7

APPLICATIONS AND PRACTICAL IMPLEMENTATIUON

Applications

1. Computers, Servers, Storage systems
2. Continue high speed data processing from source to CPU - potential processing in the Tb/s range
3. Smaller computers, less heat, elimination of motherboards (by today's standards)
4. High performance for data/computation intense applications.

Practical Implementation

1. First Electrically Pumped Hybrid Silicon Laser (Sept 18th 2006 by INTEL)
2. Optical microelectromechanical system (MEMS) devices

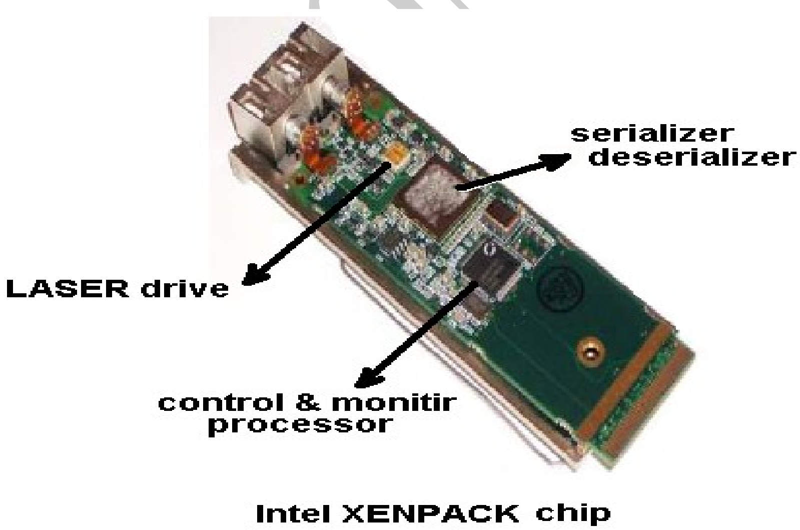
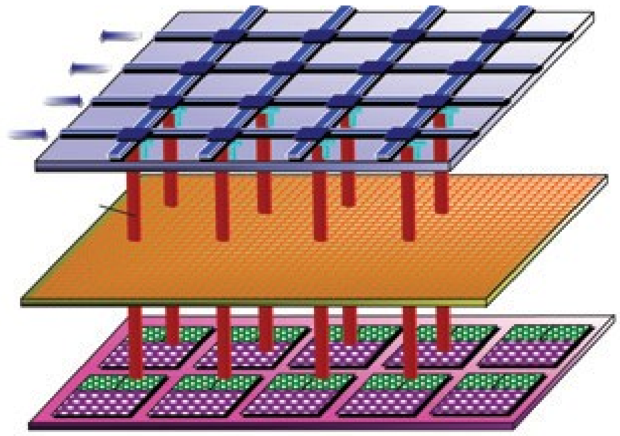


Fig 7.1 Silicon laser



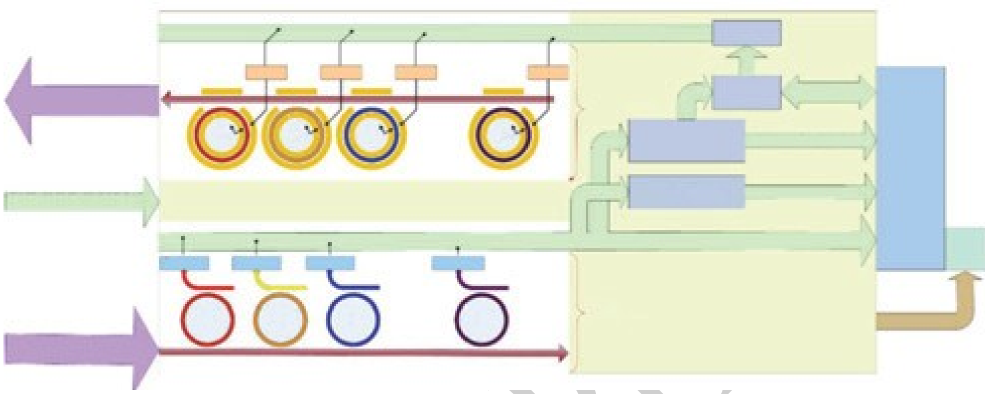


Fig 7.2 optically interconnected future multicore processors with three planes: CPU, memory and optical planes interconnected by vias and optically connected dual inline memory module (OC-DIMM) with optical memory controller (OMC)

CONCLUSION

Silicon will not win individual devices, but with integrated modules that brings total functionality & intelligence at a lower cost. What is certain is that this technology will once again revolutionize the technological world, which is already growing at an exponential rate. The high-speed silicon modulator could find use in various future applications. For example, a highly integrated silicon photonic circuit may provide a cost effective solution for the future optical interconnect within computers and other devices.

Silicon photonics offers high density integration of individual optical components on a single chip. Future monolithic ICs will get manufactured by this technology which help to increase BW, Speed, and thus reduces Cost.

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