Optical Computers

How They Work and
Why We Will See Them

Why We Need Them

- *Moore's Law* states that the number of transistors on a computer chip doubles every eighteen months.
- Traditional transistors can no longer keep up.
  - Too many transistors will slow down processor speeds.
  - Transistors have physical size limits.
- Metallic wires limit the speed of transmission.
- Resistance per unit length in the chip is being increased, causing more power usage and excess heating.

What Is an Optical Computer?

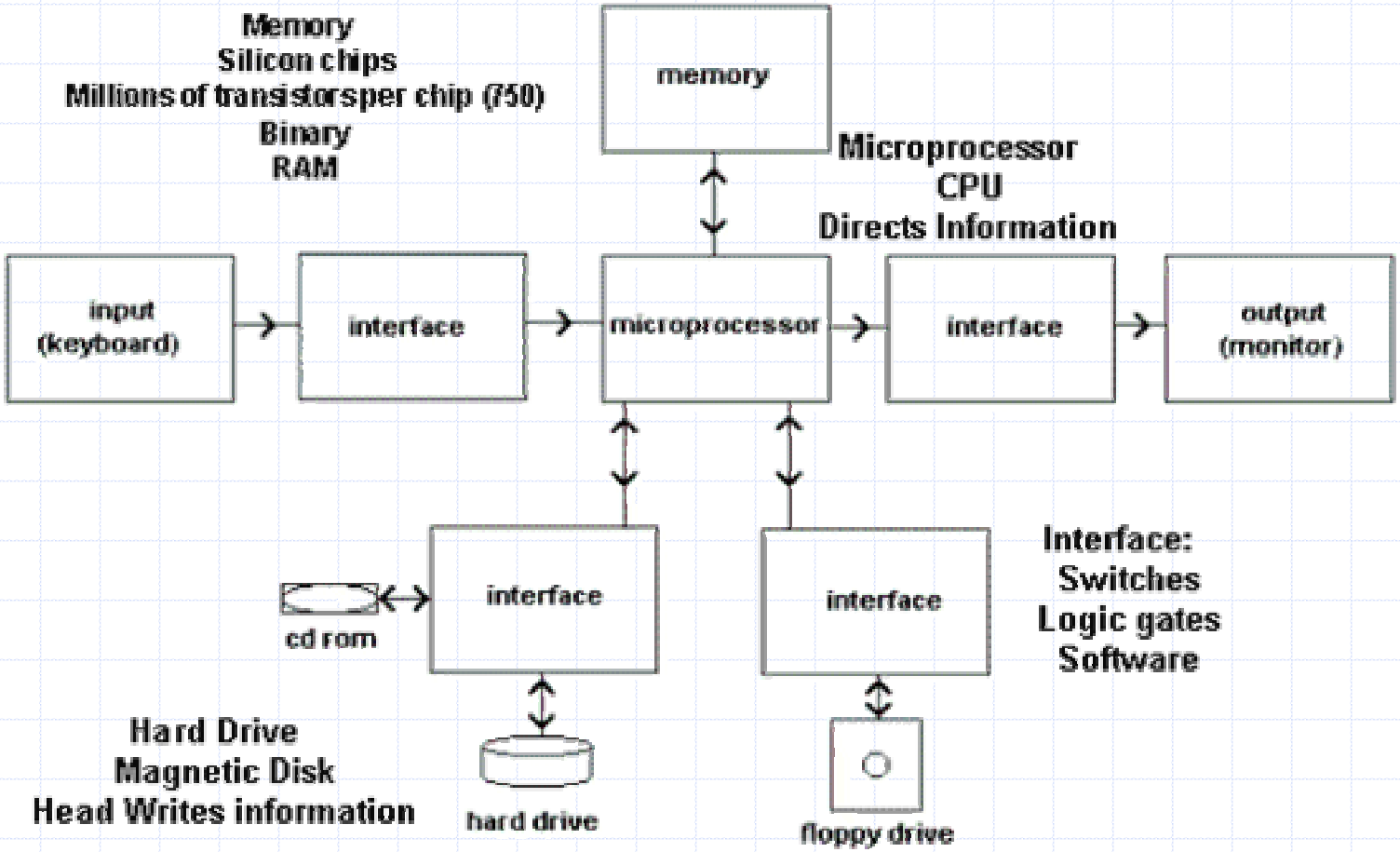
- An optical computer is a computer that performs its computation with photons as opposed to the more traditional electron-based computation.
- There are two different types of optical computers.
  - Electro-Optical Hybrid computers
  - Pure Optical computers

Silicon Vs. Optical Computers

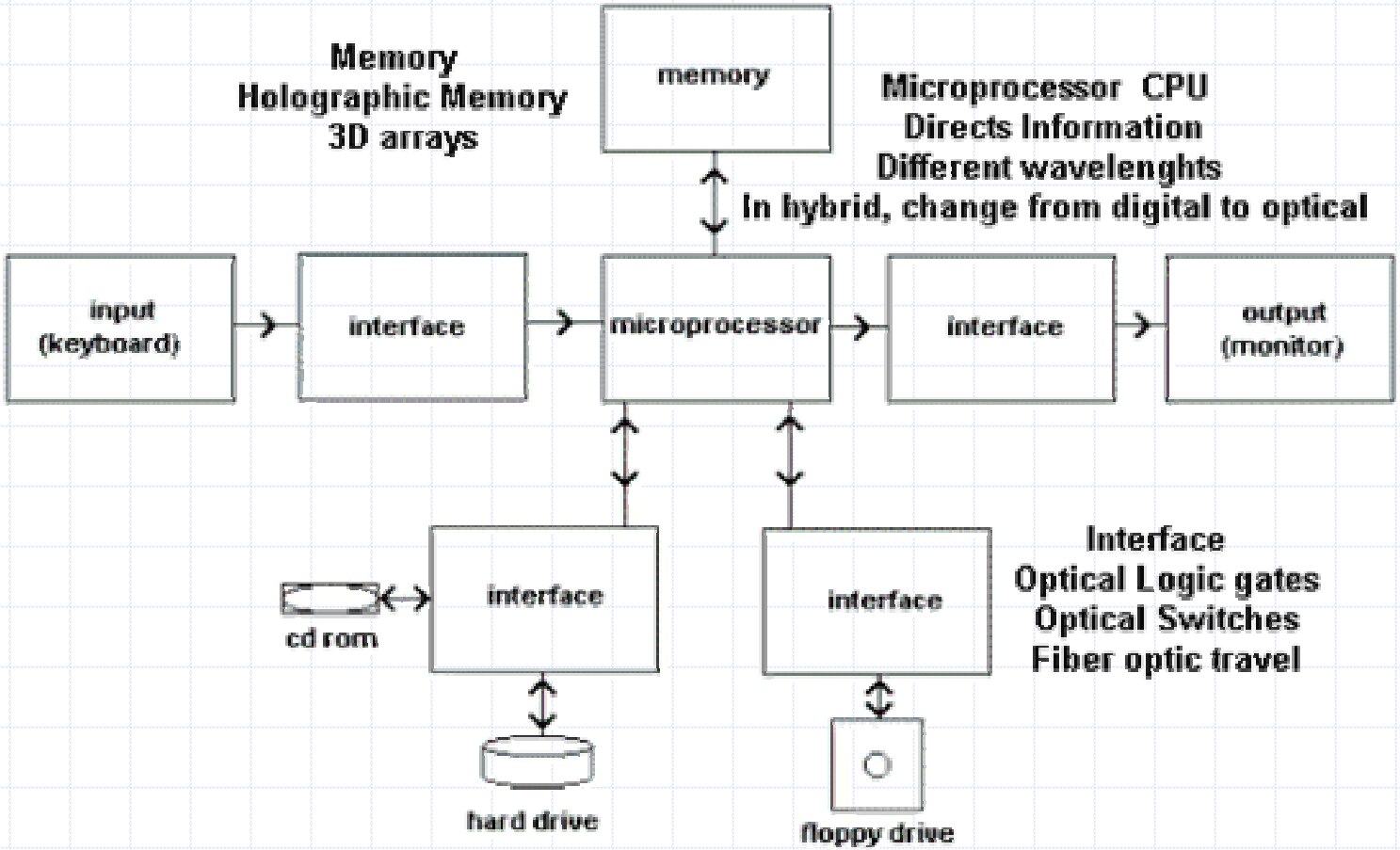
Basic Path of Information Through an Optical Computer

- Information gets sent in from keyboard, mouse, or other external sources and goes to the processor.
- Processor then sends the information through logic gates and switches to be programmed.
- The information is then sent through different fiber optic cables depending on it's final location.
- Some information will be sent to the holographic memory, where it will then be saved.
- After information is saved and the program would like to use it, the program sends a command to the processor, which then sends a command to receive the information.
- The program receives the information and sends a signal back to the processor to tell it that the task is complete.

Electronic Computer



Optical Computer



Electro-Optical Hybrid

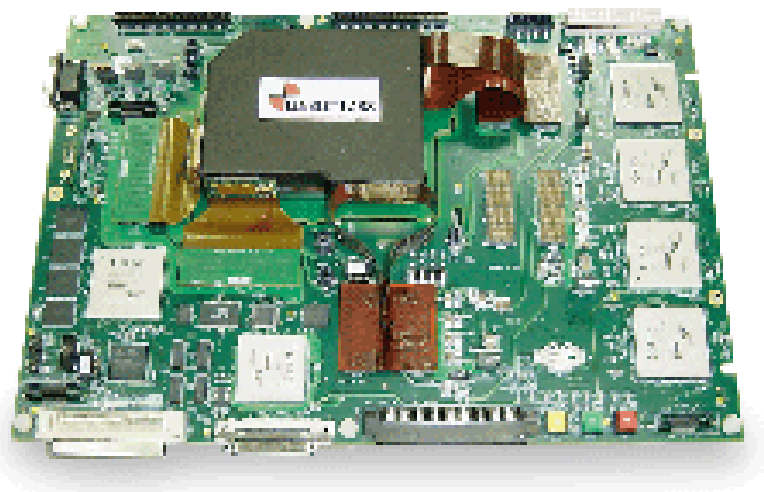
- Use optical fibers and electric parts to read and direct data from the processor
- Light pulses send information instead of voltage packets.
- Processors change from binary code to light pulses using lasers.
- Information is then detected and decoded electronically back into binary.

Pure Optical Computers

- Use multiple frequencies
- Information is sent throughout computer as light waves and packets.
- No electron based systems
- No converstion from binary to optical necessary, greatly increasing the speed.

Lenslet's Optical Processor

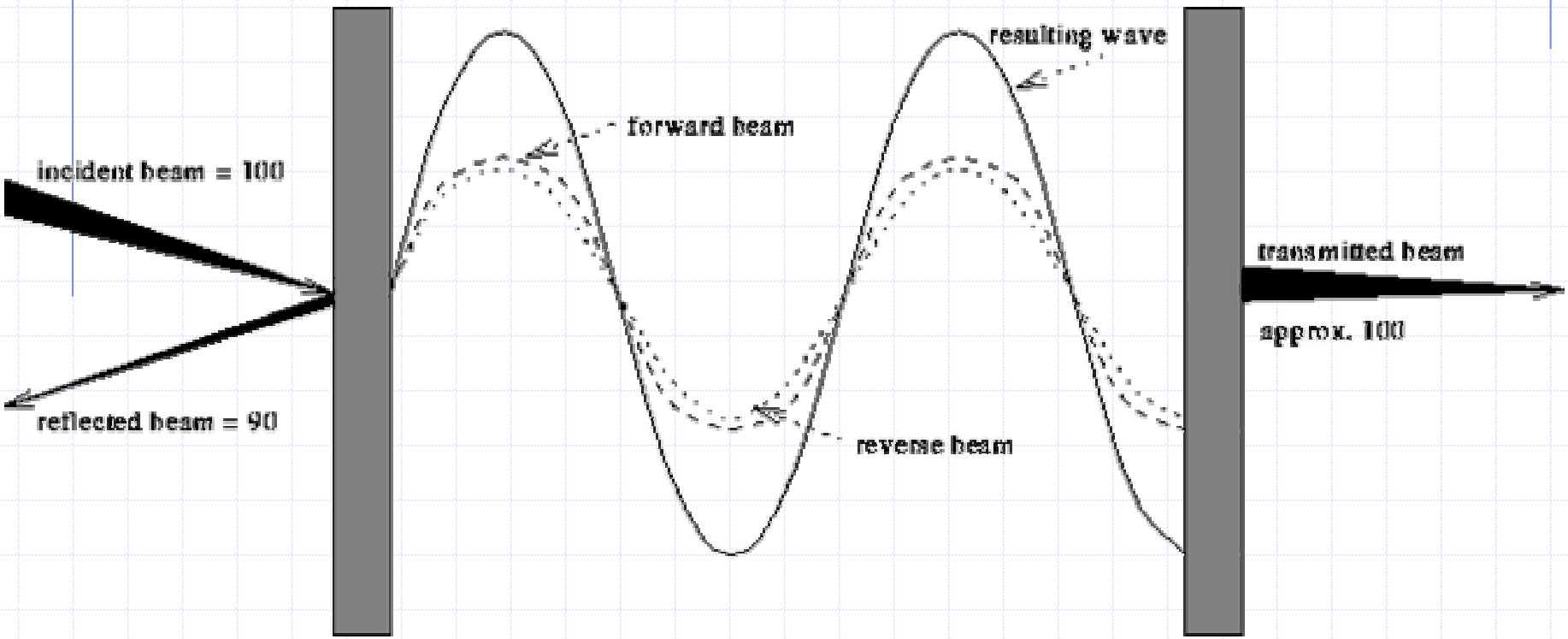
- First programmable optical processor
- Combines optics, silicon, communications, and tools in standard board
- Software tools allow smooth development path



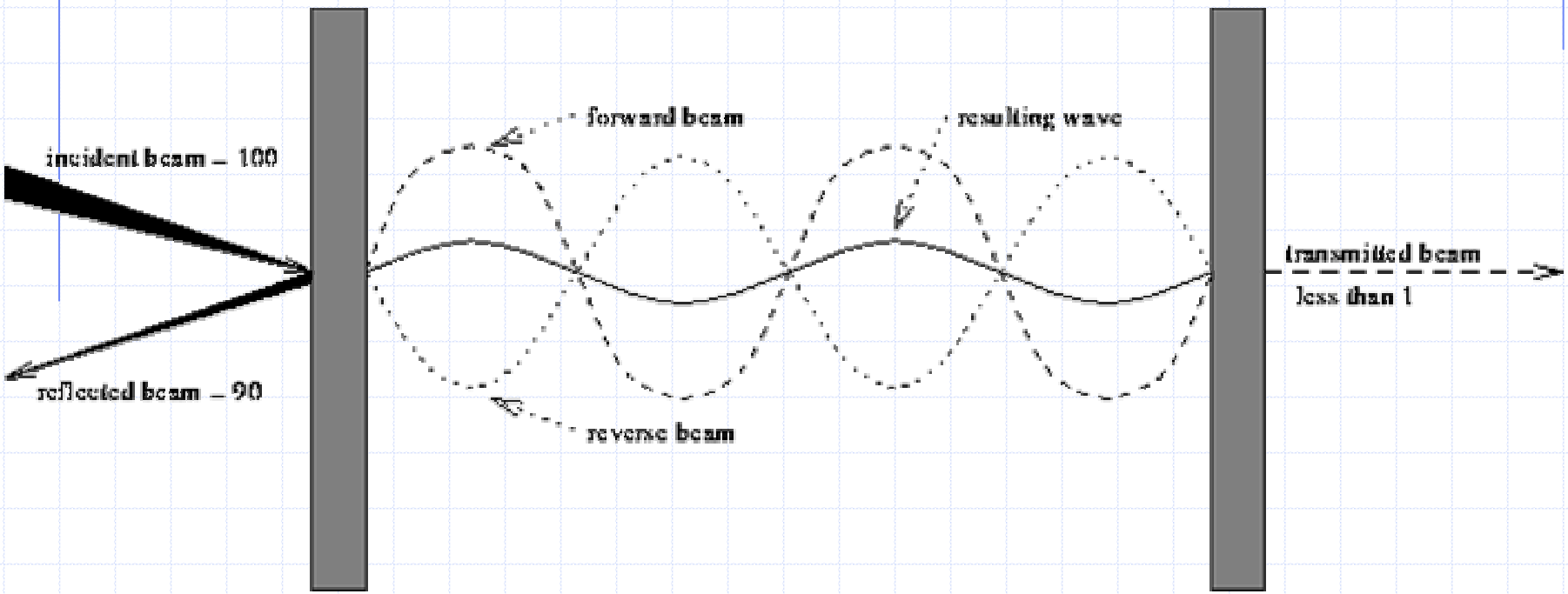
Optical Transistors

- Transistors based off of the Fabry-Perot Interferometer.
  - Constructive interference yields a high intensity (a 1 in binary)
  - Destructive interference yields an intensity close to zero (a 0 in binary)

Constructive Transistor

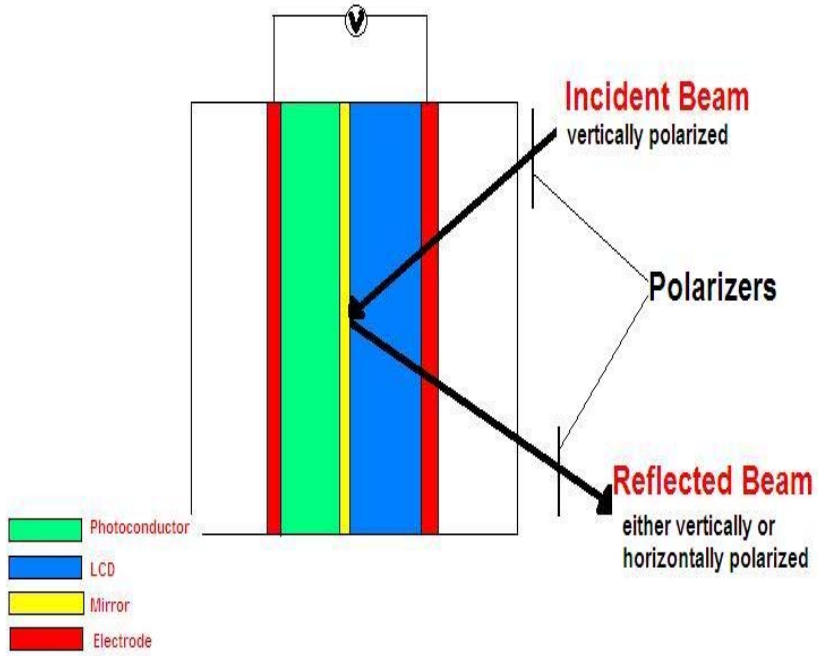


Destructive Transistor



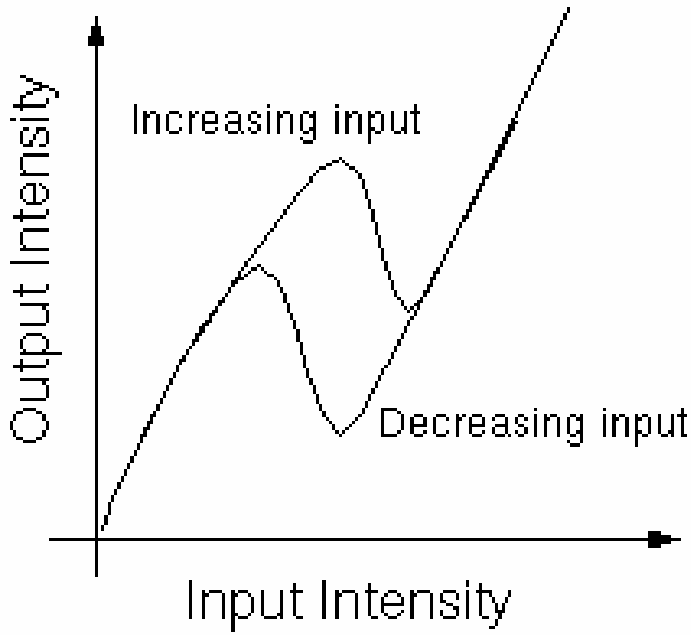
Digital Optical Logic Gates

- Liquid Crystal Light Valve (LCLV)
  - Uses a liquid crystal device and a photoconductor.
  - Programmable through application of a write beam, causing the polarization of the reflected beam to change.

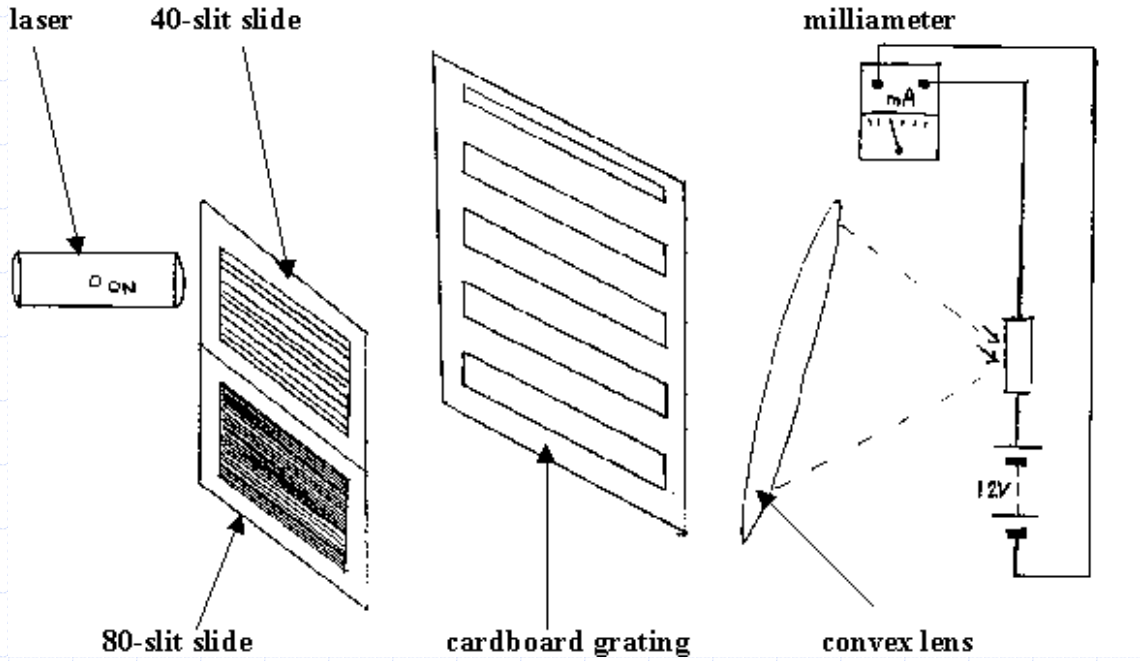


Optical Logic Gate

- Self Electro-optic Effect Device (SEED)
  - Change in voltage changes absorption properties in quantum well layers.
  - Stackable
  - Small size
  - Low power
  - Easily made
  - Compatible with standard fabrication techniques for current logic gates.



All Optical Logic Gate



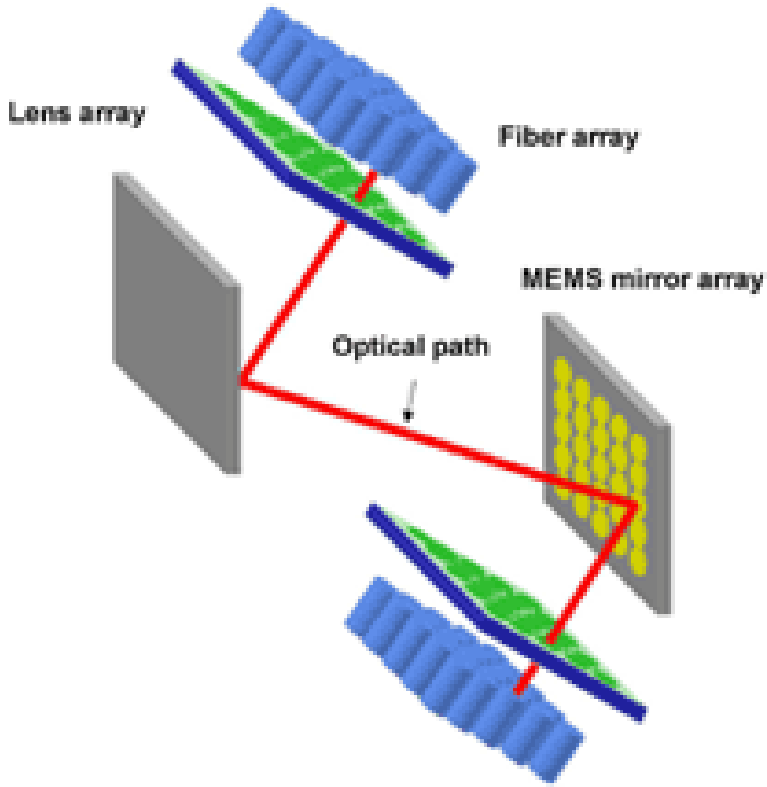
This is an All optical logic gate based on Interference fringes, which the detector reads, and then sends the information through to the correct program.

Optical Vs. Electrical Switches

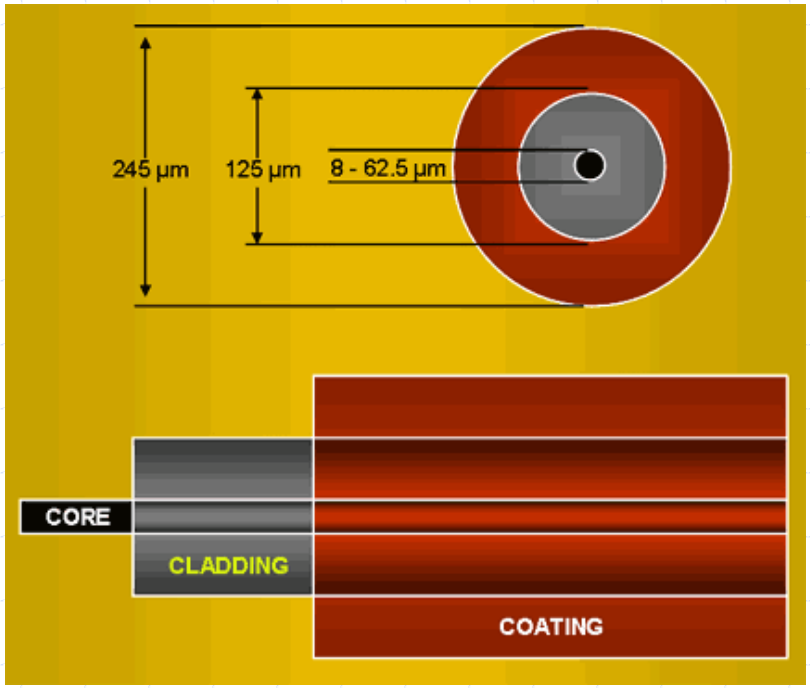
- Change the direction of propagation for the transmitted wave.
- Allow information to be used in other parts of the computer.
- Non-linear optical properties of materials are used to redirect the propagation of one light using another control light.
- Made out of semiconductors.
- Change direction of binary code through wires.
- Toggle Switch (can choose between two directions)
- LAN Switch for networking

All Optical Switches

- Analog Gimbal-Mirror Switch
  - Direct light into higher number of ports without much loss of information
  - No need to waste time converting from optical to digital.
  - Problems include; tightly packed mirrors, mirror-control algorithm, fiber and lens arrays and mechanical packaging.



Optical Fibers



- Advantages
  - Small in size
  - Low transmission losses
  - No interference from radio frequencies, electromagnetic components, or crosstalk
  - Safer
  - More secure
  - Environmental immunity

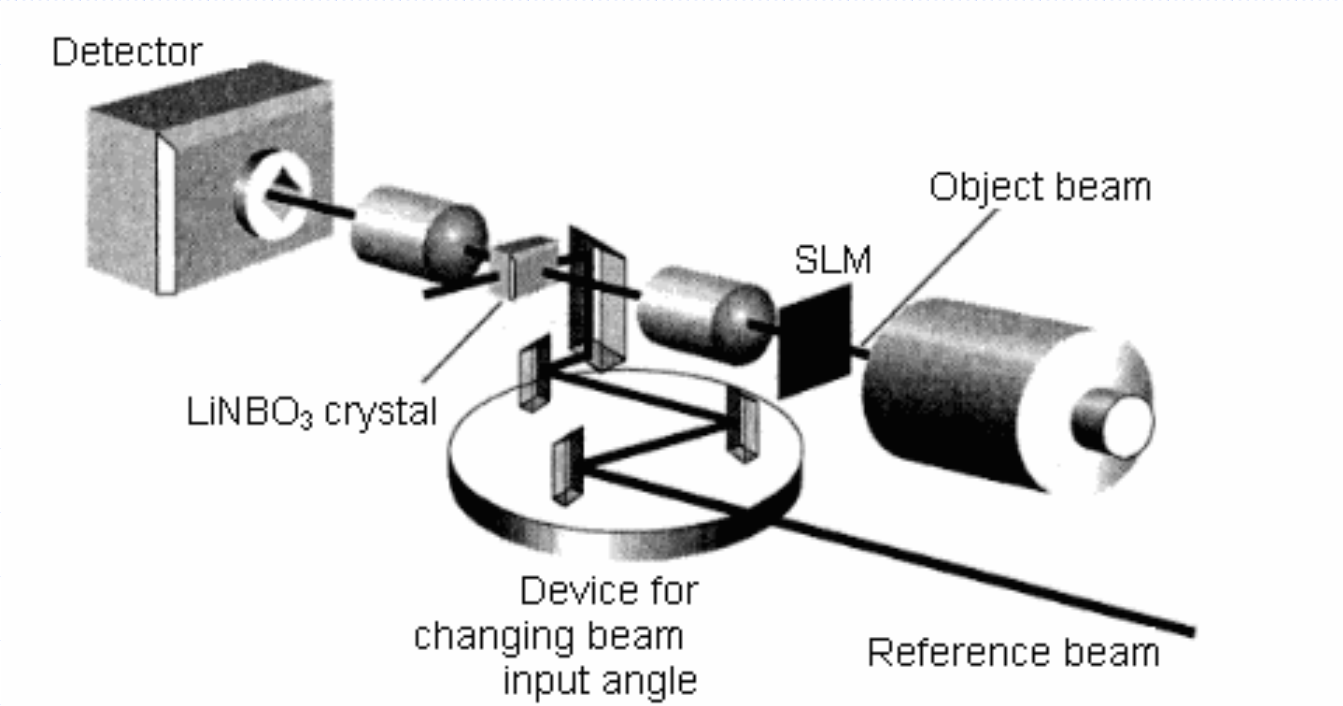
Interconnection of Optical Fibers

- Advantages
  - Bandwidth independence
  - No capacitive effects
  - No interference between parallel waves
  - Low power constraints
  - Increased flexibility
- Disadvantages.
  - Cost
  - Size
  - Alignment precision
  - Thermal stability
  - Fabrication
  - Lack of design software for creation
  - Need ultra low voltages

Holographic Memory

- A holographic memory can store data in the form of a hologram within a crystal.
- A laser is split into a reference beam and a signal beam.
- Signal beam goes through the logic gate and receives information
- The two beams then meet up again and interference pattern creates a hologram in the crystal.

Holographic Memory



Advantages to Optical Computing

- Small size
- Increased speed
- Low heating
- Reconfigurable
- Scalable for larger or small networks
- More complex functions done faster
- Applications for Artificial Intelligence
- Less power consumption (500 microwatts per interconnect length vs. 10 mW for electrical)

Limiting Factors for Optical Computers

- Optical fibers on a chip are wider than electrical traces.
- Crystals need 1mm of length and are much larger than current transistors
- Software needed to design and run the computers.

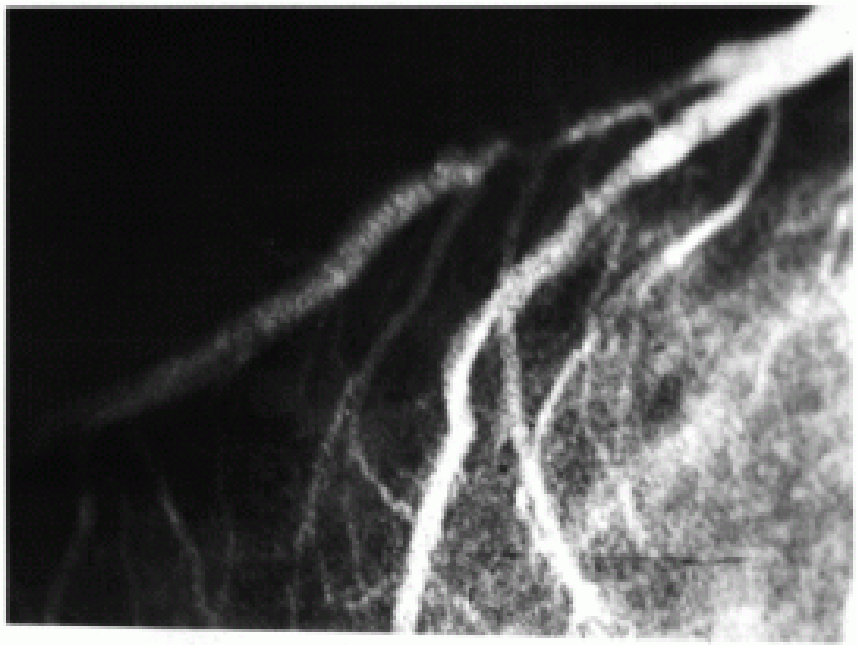
What Exists Already

- Beam splitters which move light in array by silicon being placed at different angles.
- Stacking with banyan switches,allowing for more programming combinations
- Crossover switches which are used in digital cameras.
- Photodiodes which convert light into electrical current.
- A Variable Electro-Optical Mirror, created by Hudson Research, Inc.

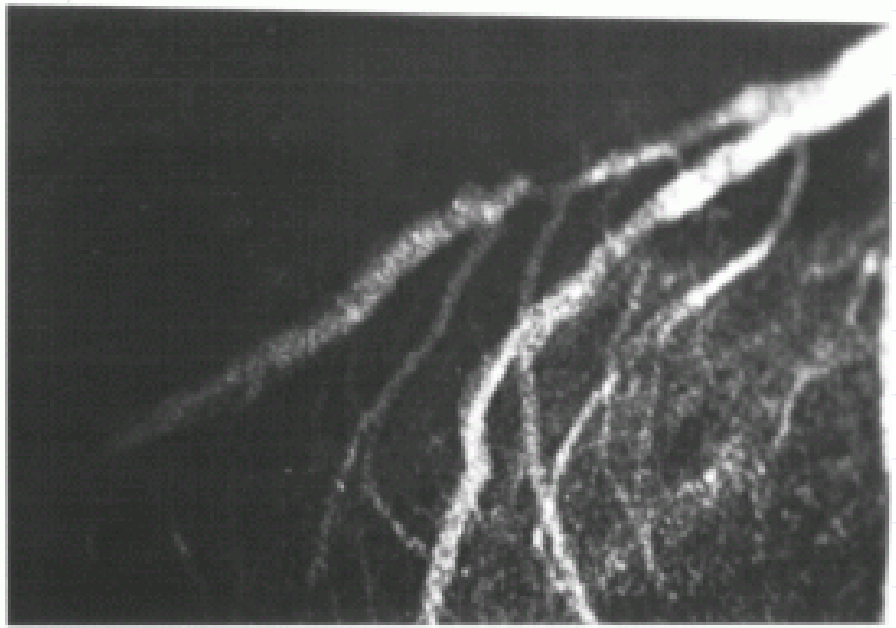
How we use fiber optics now

- We currently use DWDM(dense wavelength division multiplexing) fiber optics for data transfers betweens cities.
- Corning is making fiber optics to the home available for high speed internet connection.
- Optical Spatial Filters are used for medical imaging, using Fourier Analysis to sharpen an image, such as an X-Ray

Images Using Optical Spatial Filters



Unfiltered Image



Filtered Image

What is Probable to See in the Future

- Opto-electronic in nature
- Use direct analogy of presence or absence or signals from a medium.
- Many lasers will be able to travel through one pathway, making the travel time within the computer much faster.

Spatial Light Modulators

- There are six major groups.
  - One-dimensional Optical / Optical
  - One-Dimensional Optical / Electrical
  - One-Dimensional Electrical / Optical
  - Two-dimensional Optical / Optical
  - Two-Dimensional Optical / Electrical
  - Two-Dimensional Electrical / Optical