- Speed of conventional computers-**miniaturizing** electronic components-electrons-travel-very short distances-very short time.
- Very Large Scale Integration (VLSI) technology-smaller device dimensions-greater complexity-300 million transistors on a single silicon chip- number of transistor switches -one chip doubles every 18 months
- Further miniaturization of lithography-
  - dielectric breakdown
  - hot carriers
  - short channel effects
- Optical components
  - no insulators-don't experience cross talk
  - multiple frequencies-without interference
  - process multiple streams of data simultaneously
  - immune to electromagnetic interference
  - free from electrical short circuits
  - low-loss transmission
  - provide large bandwidth
  - multiplexing capability-capable of communicating several channels in parallel without interference
  - no interference or cross-talk
  - compact
  - lightweight
  - inexpensive
- According to KMI corp., data traffic is growing worldwide at a rate of 100% per year
- Phillips Group in London estimates that the U.S. data traffic will increase by 300% annually
- Absence of known efficient nonlinear optical materials that can respond at low power levels. Most all-optical components require a high level of laser power to function as required
- A group of researchers from the university of southern California, jointly with a team from the university of California Los Anglos, have developed an organic polymer with a switching frequency of 60 GHz. This is three times faster than the current industry standard, lithium niobate crystal-based devices
- Another group at Brown University and the IBM Almaden Research Center (San Jose, CA) have used ultrafast laser pulses to build ultrafast data-storage devices. This group was able to achieve ultrafast switching down to 100ps. Their results are almost ten times faster than currently available "speed limits". Optoelectronic technologies for optical computers and communication hold promise for transmitting data as short as the space between computer chips or as long as the orbital distance between satellites.
- A European collaborative effort demonstrated a high-speed optical data input and output in free-space between IC chips in computers at a rate of more than 1 Tb/s.
- Astro Terra, in collaboration with Jet Propulsion Laboratory (Pasadena, CA) has built a 32-channel 1-Ggb/s earth –to –satellite link with a 2000 km range. Many more active devices in development, and some are likely to become crucial components in future optical computer and networks
- NEC (Tokyo, Japan) have developed a method for interconnecting circuit boards optically using Vertical Cavity Surface Emitting Laser arrays (VCSEL)
- Researchers at Osaka City University (Osaka, Japan) reported on a method for automatic alignment of a set of optical beams in space with a set of optical fibers
- Researchers at NTT (Tokyo, Japan) have designed an optical back plane with free –space optical interconnects using tunable beam deflectors and a mirror. The project had achieved 1000 interconnections per printed-circuit board, with throughput ranging from 1 to 10 Tb/s
- **High bandwidth**
- **Parallelism**
  - Cray super computers in the early 1980's

- Two processors were used in conjunction with the computer memory to achieve parallelism and to enhance the speed to more than 10 Gb/ s
- More processors were not necessary to increase computational speed
- More time lost in communication.
- On the other hand, using a simple optical design, an array of pixels can be transferred simultaneously in parallel from one point to another.
- A computation that might require one hundred thousand hours (more than 11 years) of a conventional computer could require less than one hour by an optical one.
- ➢ Photons are **uncharged**-do not interact
- ➢ **Full-duplex** operation
- ➢ In the case of electronics, loops usually generate noise voltage spikes whenever the electromagnetic fields through the loop changes
- ➢ High frequency or fast switching pulses will cause **interference** in neighboring wires
- ➢ Optical integrated channels do not pick up **noise due to loops**
- ➢ Possess superior storage density and accessibility over magnetic materials.

❖ **Nonlinear materials** are those, which interact with light and modulate its properties
Eg: change the color of light from being unseen in the infrared region of the color spectrum to a green color where it is easily seen in the visible region of the spectrum.

❖ Inefficiency of currently available nonlinear optical materials, which require large amounts of energy for responding or switching

❖ Although organic materials have many features that make them desirable for use in optical devices, such as high nonlinearities, Flexibility of molecular design, and damage resistance to optical radiation, their use in devices has been hindered by processing difficulties for crystals and thin films.

❖ Our focus is on a couple of these materials, which have undergone some investigation in the NASA/MSFC laboratories, and were also processed in space either by the MSFC group, or others. These materials belong to the classes of phthalocyanines and polydiacetylenes.

❖ **Phthalocyanines** are large ring-structured porophyrins for which large and ultrafast nonlinearities have been observed. These compounds exhibit strong electronic transitions in the visible region and have high chemical and thermal stability up to 400ºC. We measured the third order susceptibility of phthalocyanine, which is a measure of its nonlinear efficiency to be more than a million times larger than that of the standard material, carbon disulfide. This class of materials has good potential for commercial device applications, and has been used as a photosensitive organic material, and for photovoltiac, photoconductive, and photoelectrochemical applications.

❖ **Polydiacetylenes** are zigzag polymers having conjugated (alternating) mobile π-electrons for which the largest reported non-resonant (purely electronic) susceptibility for switching have been reported. Subsequently, polydiacetylenes are among the most widely investigated class of polymers for nonlinear optical applications. Their subpicosecond time response to laser signals makes them candidates for high-speed optoelectronics and information processing.

❖ We have chosen to study these classes of compounds because growth of these films on ordered organic and inorganic substrates under various processing conditions promise to be useful for preparing highly oriented films. One such processing condition of interest to NASA is the effect of microgravity on the structures and properties of thin films and crystals.

✓ Logic gates are the building blocks of any digital system

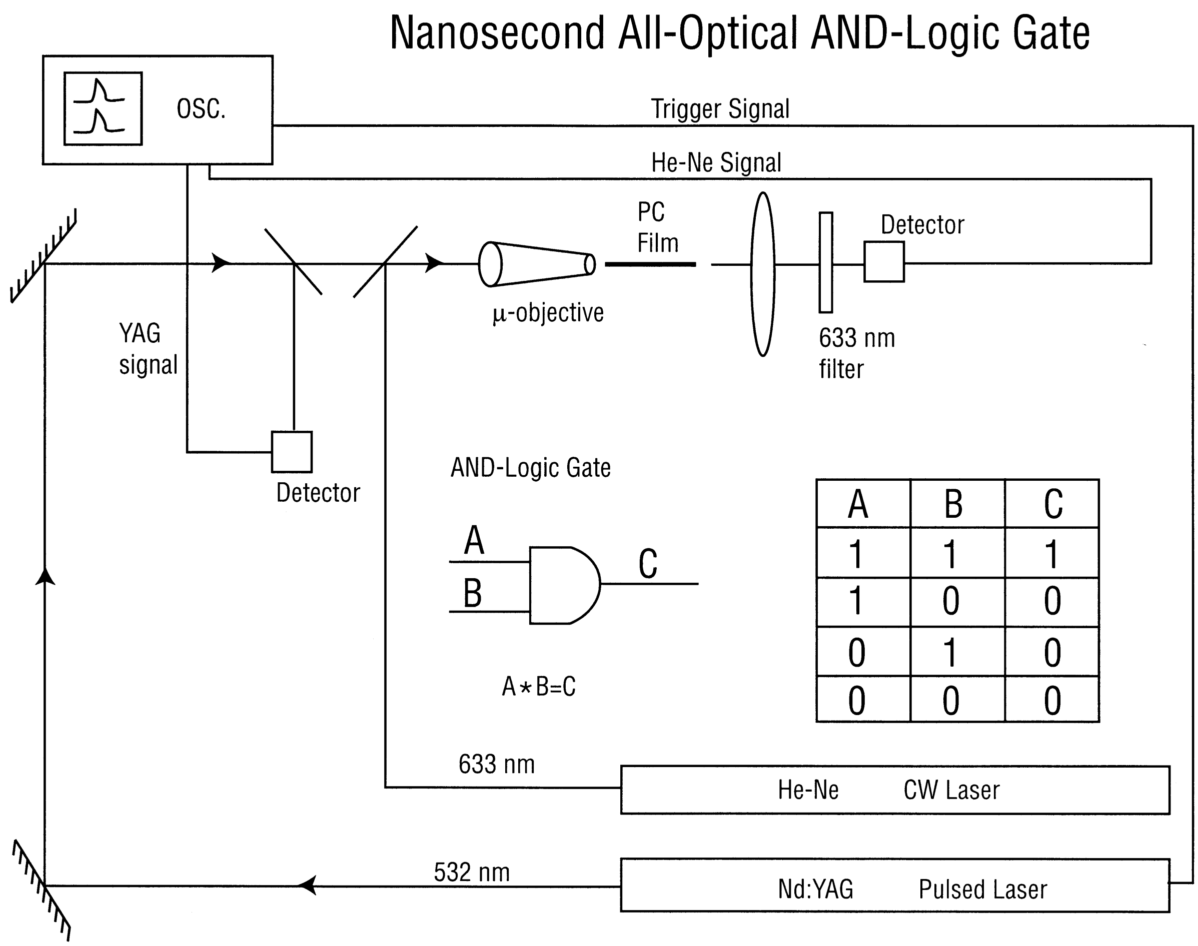
✓ An optical logic gate is a switch that controls one light beam by another; it is "ON" when the device transmits light and it is "OFF" when it blocks the light

✓ Recently we demonstrated in our laboratory at NASA/Marshall Space Flight Center two fast all-optical switches using phthalocyanine thin films and polydiacetylene fiber.

✓ The phthalocyanine switch is in the nanosecond regime and functions as an all-optical AND logic gate, while

✓ The polydiacetylene one is in the pico-second regime and exhibits a partial all-optical NAND logic gate.

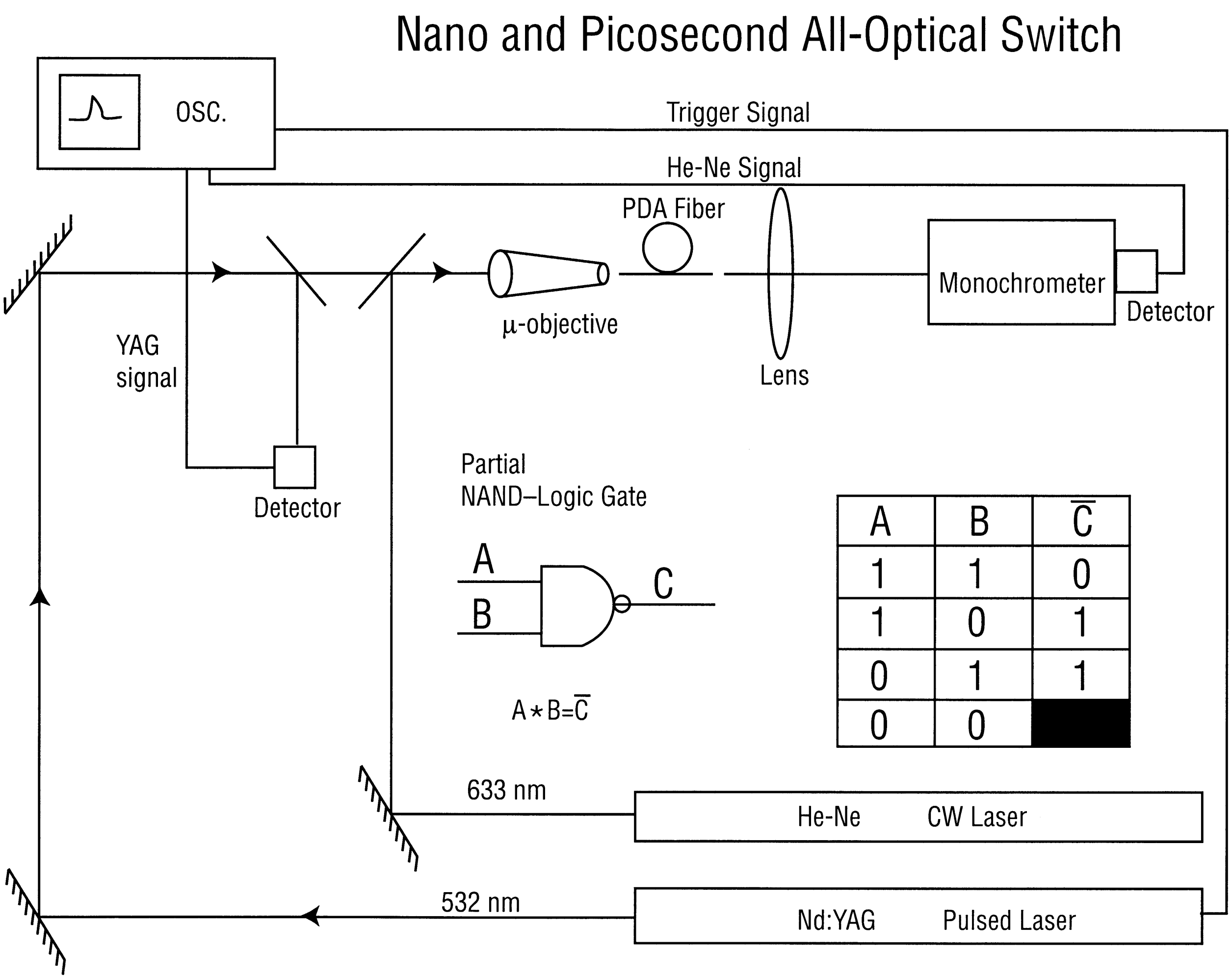
✓ To demonstrate the **AND gate** in the **phthalocyanine** film, we waveguided two focused collinear beams through a thin film of metal-free phthalocyanine film.



- The film thickness was ~ 1 μm and a few millimeters in length
- We used the second harmonic at 532 nm from a pulsed Nd:YAG laser with pulse duration of 8 ns
- Along with a cw He-Ne beam at 632.8 nm
- The two collinear beams were then focused by a microscopic objective and sent through the phthalocyanine film.
- At the output a narrow band filter was set to block the 532 nm beam and allow only the He-Ne beam.
- The transmitted beam was then focused on a fast photo-detector and to a 500 MHz oscilloscope.
- *It was found that the transmitted He-Ne cw beam was pulsating with a nanosecond duration and in synchronous with the input Nd:YAG nanosecond pulse.*

✓ The setup for the picosecond switch was very much similar to the setup in figure 3 except that the phthalocyanine film was replaced by a hollow fiber filled with a **polydiacetylene.**

- The polydiacetylene fiber was prepared by injecting a diacetylene monomer into the hollow fiber and polymerizing it by UV lamps. The UV irradiation induces a thin film of the polymer on the interior of the hollow fiber with a refractive index of 1.7 and the hollow fiber is of refractive index 1.2.
- In the experiment, the 532 nm from a mode locked picosecond laser was sent collinearly with a cw He-Ne laser and both were focused onto one end of the fiber.
- At the other end of the fiber a lens was focusing the output onto the narrow slit of a monochrometer with its grating set at 632.8 nm.
- A fast detector was attached to the monochrometer and sending the signal to a 20 GHz digital oscilloscope.
- *It was found that with the He-Ne beam OFF, the Nd:YAG pulse is inducing a week fluorescent picosecond signal (40 ps) at 632.8 nm that is shown as a picosecond pulse on the oscilloscope.*
- *This signal disappears each time the He-Ne beam is turned on.*
- These results exhibit a picosecond respond in the system and demonstrated three of the four characteristics of a **NAND** logic gate as shown in figure (4).



A	B	$\overline{C}$
1	1	0
1	0	1
0	1	1
0	0	■

<u>A schematic of the all-optical NAND logic gate setup.</u>