Optical Computing Outline

- Why?
- Applications
- Power considerations
- Mathematical possibilities
- Logic Gates (Imaginary and real)
- VSLI
- Summary

Why?

- What could possibly be better?
  - Bandwidth
  - Elimination of Interference between connections
  - Power? Are you sure?
    - Optical devices need power as well as electrical devices
    - Capacitive effects of creating threshold voltage and transmission line characteristics.

Applications of Optics

- Networks
  - Network connections are Fiber Optic
- Peripheral Connections
  - Fiber Optic connections are waveguides for the light. A waveguide is needed to channel light whereas without it light would disperse uncontrollably.

Applications of Optics (cont)

- Processor to processor connections.
  - Fiber optics offers wide band width and promotes parallelism.
- Interprocessor connections
  - Such as cache to CPU or to Main memory
- Image processing
  - Laser lend themselves to Image processing because of matrix calculations and convolution are extremely easy to implement.

Power

- Optical Processors need more power than electrical processors called Reactive Power

$$P = \frac{(C)V^2}{t}$$

- =time required to charge a capacitance C to a voltage threshold level V. V=threshold voltage C=capacitance in transmission lines and connections.
  - Interconnection equation

$$Pe = \frac{(C + Cd)V^2}{2t}$$

Power (cont.)

- Taking finite power efficiency and R representing responsivity of the detector usually 25% or so.

$$P = \frac{V(C_D + C_d)}{h_s R t}$$

- Electrical > Optical

$$\frac{(C + Cd)V}{2} > \frac{C_D + C_d}{h_s R}$$

Optical connection is superior when characterisitc resistance is included.

$$\frac{V}{R_0} > \frac{(C_D + C_d)}{Rt}$$

Logic gates (Imaginary)

- Logic gates are implemented optically by controlling the population inversion that occurs to produce lasing. A controlling laser is used to control the population inversion thus causing switching to occur.
  - Sounds brilliant but not likely to be implemented because of power requirements.

Mathematics

- Several methods for mathematical calculations.
  - Conventional ALU
  - Matrix calculations
  - Convolution as a from a arithmetic for pure optical computers

Logic Gates (Real)

- Holographic truth table
  - Destructive interference will light to be emitted or not based on phase relationship
- Logic based on gratings
  - 1 is represented by vertical grating causing light
  - 0 is represented by horizontal grating causing darkness1

VSLI

- Similar to VSLI design with electrical devices by layering glass on top of a substrate to make Thin film waveguides.
- Mirrors can be simulated by using diffraction grating.

VSLI (materials)

- Materials
  - GaAs is most widely used because this material can make modulators,lasers,switches and detectors.
  - Hybrid $LiNbO_3$, best for waveguides, modulators and switches.
  - Silicon based
    - easy to fabricate on single crystal, with a insulating layer of SiO_2.
    - Inferior to devices based $LiNbO_3$

Summary

- Outside to inside lineage
  - From networks to processor, processor to device, processor to processor etc.
- True Optical processing in it’s infancy
- Remember that bandwidth is limited by the wavelength of light whereas electrical connections are primarily limited by size.

References

- Optical Processing and computing, various authors, Academic Press
- Optical Computing, Dror G. Feitelson, MIT Press