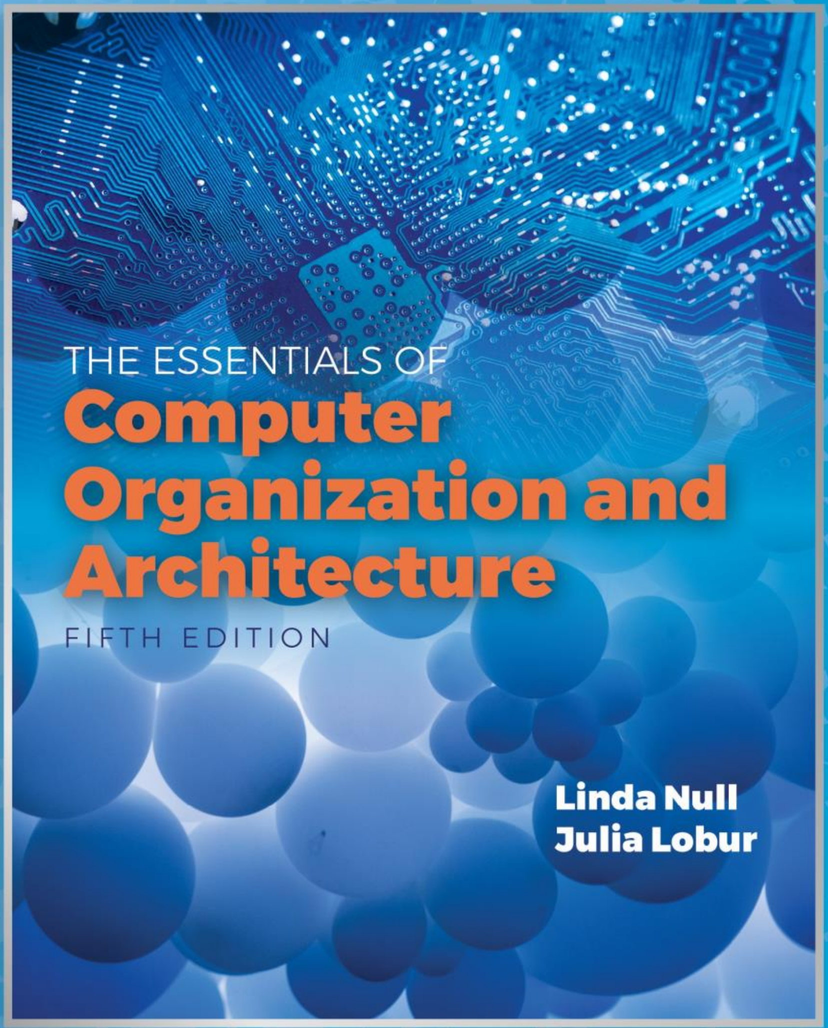
This is the fifth lecture of Chapter 7

No recording

Chapter 7

Input/Output Systems (E)



Quick review of last lecture

- Magnetic Tape
  - Digital linear tape (DLT) and Serpentine recording
  - Digital audio tape (DAT) and helical scan recording
  - Linear Tape Open (TLO)
    - a linear digital tape format
    - hold up to 1.4TB (Generation 5)
- Redundant Array of Independent Disks (RAID)
  - RAID Levels 0 – 6
  - RAID DP
  - RAID 10
  - RAID 50

7.10 The Future of Data Storage (1 of 11)

- Advances in technology have defied all efforts to define the ultimate upper limit for magnetic disk storage.
  - In the 1970s, the upper limit was thought to be around $2MB/in^2$.
  - Today's disks commonly support $20TB/in^2$.
- Improvements have occurred in several different technologies including:
  - Materials science.
  - Magneto-optical recording heads.
  - Error correcting codes.

7.10 The Future of Data Storage (2 of 11)

- As data densities increase, bit cells consist of proportionately fewer magnetic grains.
- There is a point at which there are too few grains to hold a value, and a 1 might spontaneously change to a 0, or vice versa.
- This point is called the superparamagnetic limit.
  - In 2006, the superparamagnetic limit is thought to lie between 150GB/in^2 and 200GB/in^2.
- Even if this limit is wrong by a few orders of magnitude, the greatest gains in magnetic storage have probably already been realized.

7.10 The Future of Data Storage (3 of 11)

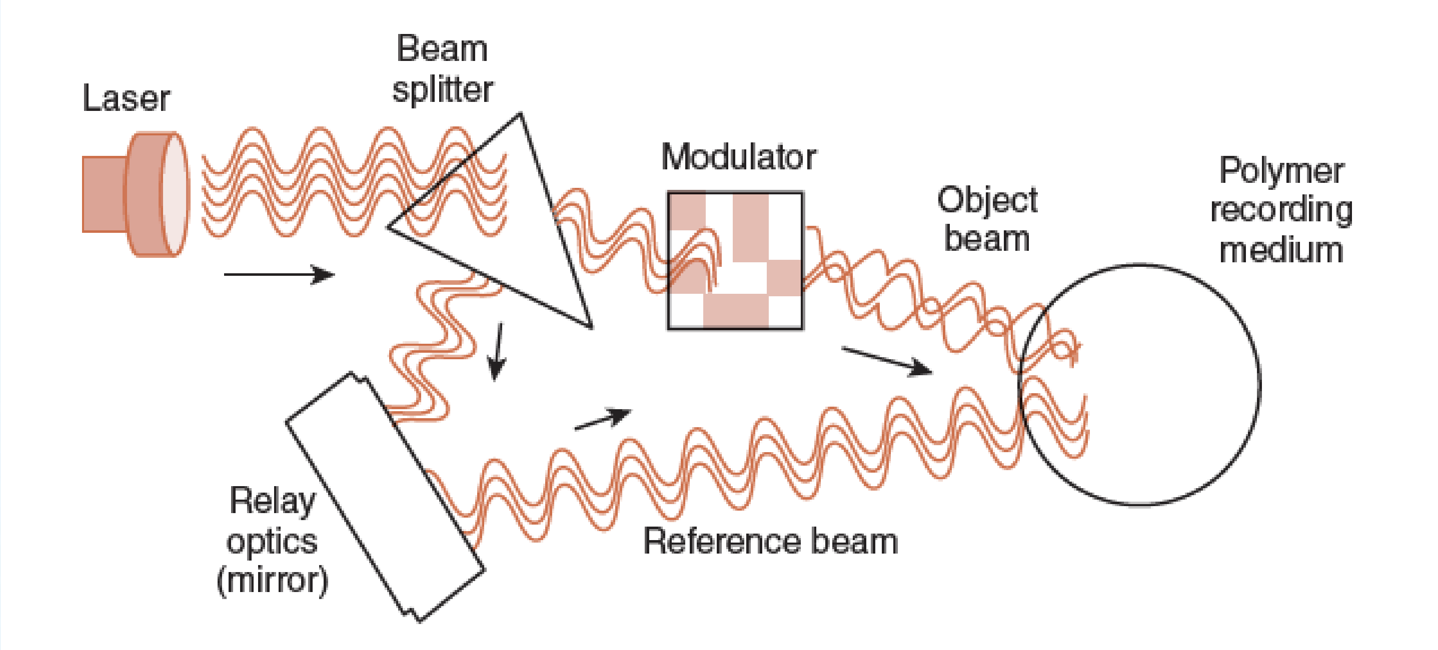
- Future exponential gains in data storage most likely will occur through the use of totally new technologies.
- Research into finding suitable replacements for magnetic disks is taking place on several fronts.
- Some of the more interesting technologies include:
  - Biological materials
  - Holographic systems
  - Micro-electro-mechanical devices
  - Carbon nanotubes
  - Memristors

7.10 The Future of Data Storage (4 of 11)

- Present day biological data storage systems combine organic compounds such as proteins or oils with inorganic (magnetizable) substances.
- Early prototypes have encouraged the expectation that densities of 1Tb/in^2 are attainable.
- Of course, the ultimate biological data storage medium is DNA.
  - Trillions of messages can be stored in a tiny strand of DNA.
- Practical DNA-based data storage is most likely decades away.

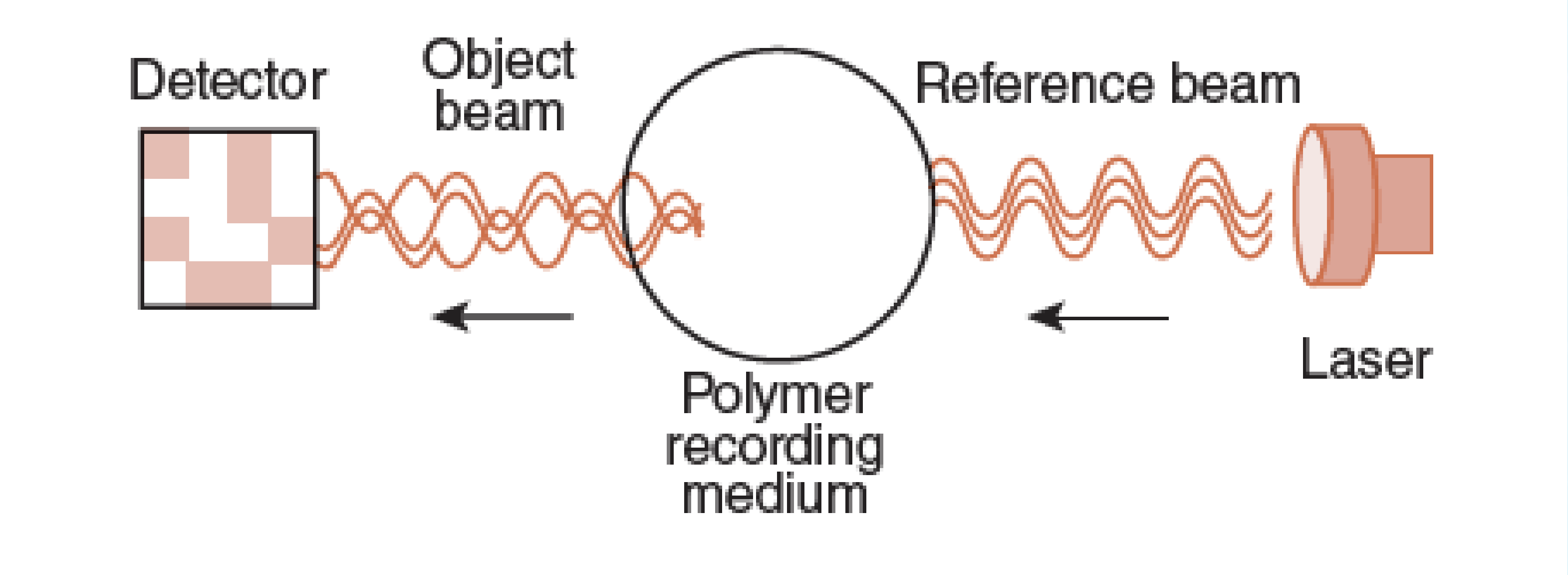
7.10 The Future of Data Storage (5 of 11)

- Holographic storage uses a pair of laser beams to etch a three-dimensional hologram onto a polymer medium.



7.10 The Future of Data Storage (6 of 11)

- Data is retrieved by passing the reference beam through the hologram, thereby reproducing the original coded object beam.



7.10 The Future of Data Storage (7 of 11)

- Because holograms are three-dimensional, tremendous data densities are possible.
- Experimental systems have achieved over $30GB/in^2$, with transfer rates of around 1GBps.
- In addition, holographic storage is content addressable.
  - This means that there is no need for a file directory on the disk. Accordingly, access time is reduced.
- The major challenge is in finding an inexpensive, stable, rewriteable holographic medium.

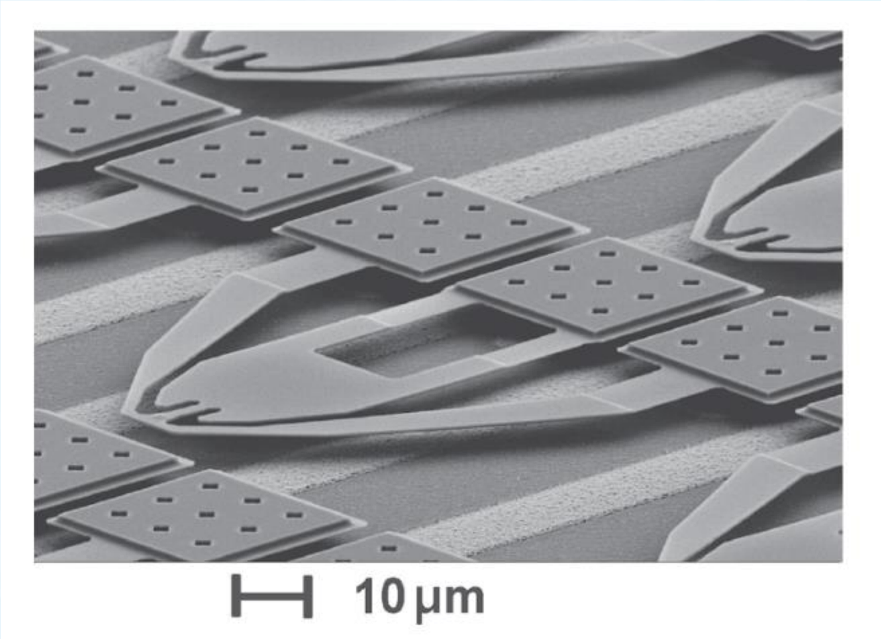
7.10 The Future of Data Storage (8 of 11)

- Micro-electro-mechanical storage (MEMS) devices offer another promising approach to mass storage.
- IBM's Millipede is one such device.
- Prototypes have achieved densities of 100GB/in^2 with 1TB/in^2 expected as the technology is refined.
- A photomicrograph of Millipede is shown on the next slide.

7.10 The Future of Data Storage (9 of 11)

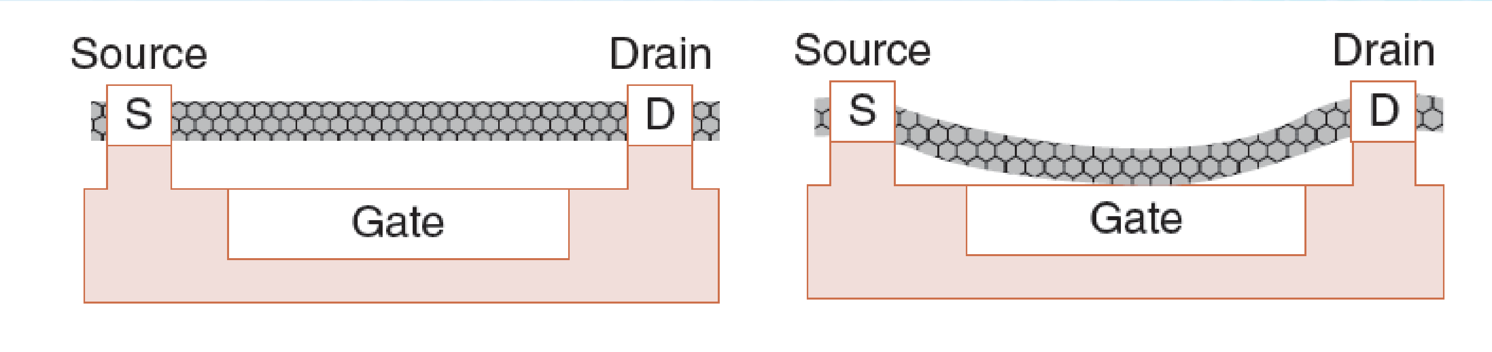
- Millipede consists of thousands of cantilevers that record a binary 1 by pressing a heated tip into a polymer substrate.

  - The tip reads a binary 1 when it dips into the imprint in the polymer.



7.10 The Future of Data Storage (10 of 11)

- CNTs are a cylindrical form of elemental carbon: The walls of the cylinders are one atom thick.
- CNTs can act like switches, opening and closing to store bits.
- Once "set" the CNT stays in place until a release voltage is applied.



7.10 The Future of Data Storage (11 of 11)

- Memristors are electronic components that combine the properties of a resistor with memory.
- Resistance to current flow can be controlled so that states of “high” and “low” store data bits.
- Like CNTs, memristor memories are non-volatile, holding their state until certain threshold voltages are applied.
- These non-volatile memories promise enormous energy savings and increased data access speeds in the very near future.

Conclusion (1 of 3)

- I/O systems are critical to the overall performance of a computer system.
- Amdahl's Law quantifies this assertion.
- I/O systems consist of memory blocks, cabling, control circuitry, interfaces, and media.
- I/O control methods include programmed I/O, interrupt-based I/O, DMA, and channel I/O.
- Buses require control lines, a clock, and data lines. Timing diagrams specify operational details.

Conclusion (2 of 3)

- Magnetic disk is the principal form of durable storage.
- Disk performance metrics include seek time, rotational delay, and reliability estimates.
- Enterprise SSDs save energy and provide improved data access for government and industry.
- Optical disks provide long-term storage for large amounts of data, although access is slow.
- Magnetic tape is also an archival medium sill widely used.

Conclusion (3 of 3)

- RAID gives disk systems improved performance and reliability. RAID 3 and RAID 5 are the most common.
- RAID 6 and RAID DP protect against dual disk failure, but RAID DP offers better performance.
- Any one of several new technologies including biological, holographic, CNT, memristor, or mechanical may someday replace magnetic disks.
- The hardest part of data storage may be in locating the data after it’s stored.