Types of External Memory

- Magnetic Disk
  - RAID
  - Removable
- Optical
  - CD-ROM
  - CD-Recordable (CD-R)
  - CD-R/W
  - DVD
- Magnetic Tape

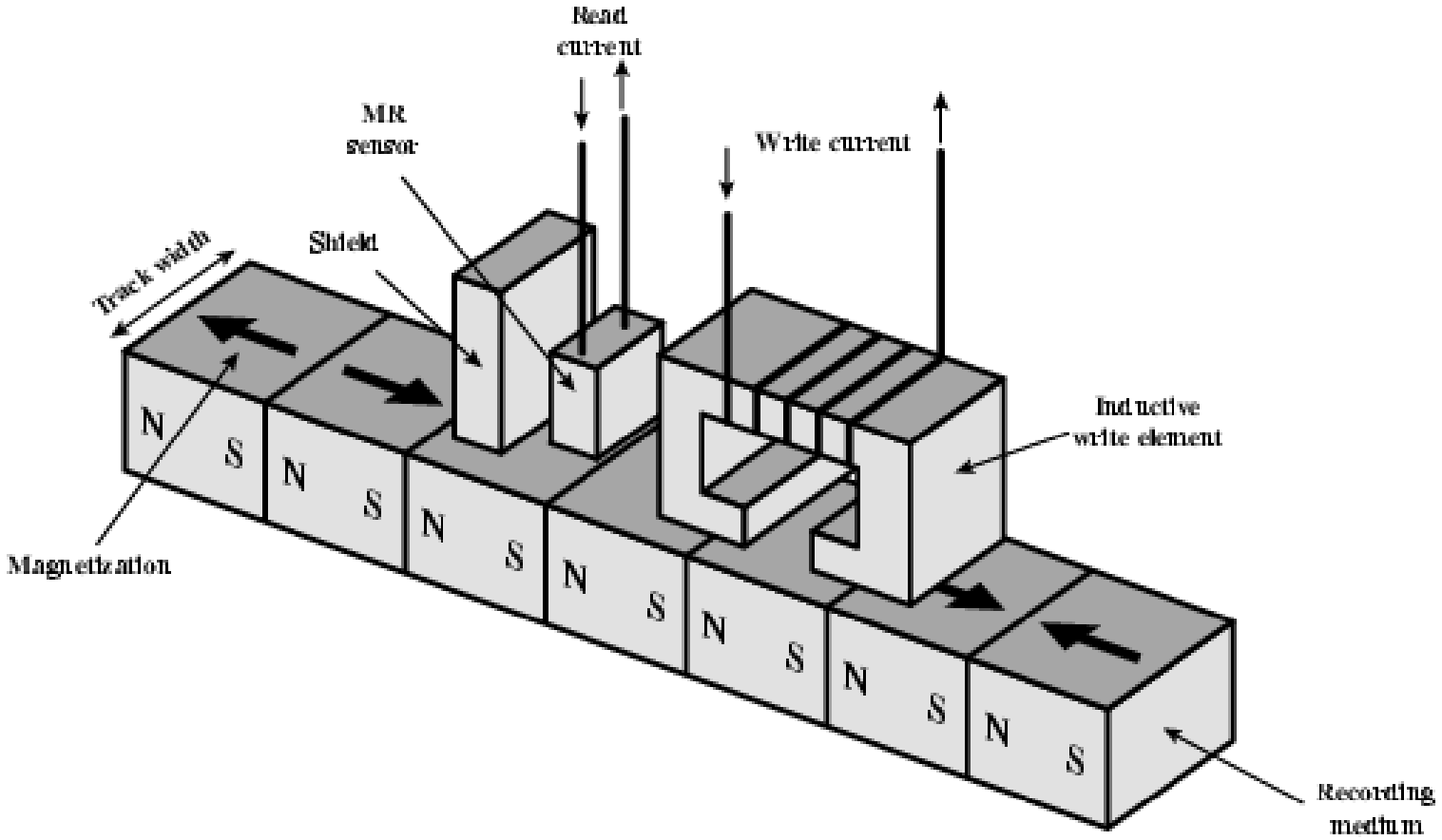
Magnetic Disk

- A disk is a circular platter constructed of non magnetic material→ substrate
- Disk substrate coated with magnetisable material (iron oxide…rust)
- Substrate used to be aluminium or aluminium alloy material.
- Now glass is used as substrate
- Benefits of using glass as substrate
  - Improved surface uniformity
    - Increases reliability
  - Reduction in surface defects
    - Reduced read/write errors
  - Better stiffness
  - Better shock/damage resistance

Read and Write Mechanisms

- Recording & retrieval via conductive coil called a head
- May be single read/write head or separate ones
- During read/write, head is stationary, platter rotates
- Write
  - Current through coil produces magnetic field
  - Pulses sent to head
  - Magnetic pattern recorded on surface below
- Read (traditional)
  - Magnetic field moving relative to coil produces current
  - Coil is the same for read and write
- Read (contemporary)
  - Separate read head, close to write head
  - The head consists of partially shielded magneto resistive (MR) sensor
  - The MR material has an electrical resistance depends on direction of magnetization medium moving under it
  - MR design allows high frequency operation which equates to greater storage density and speed

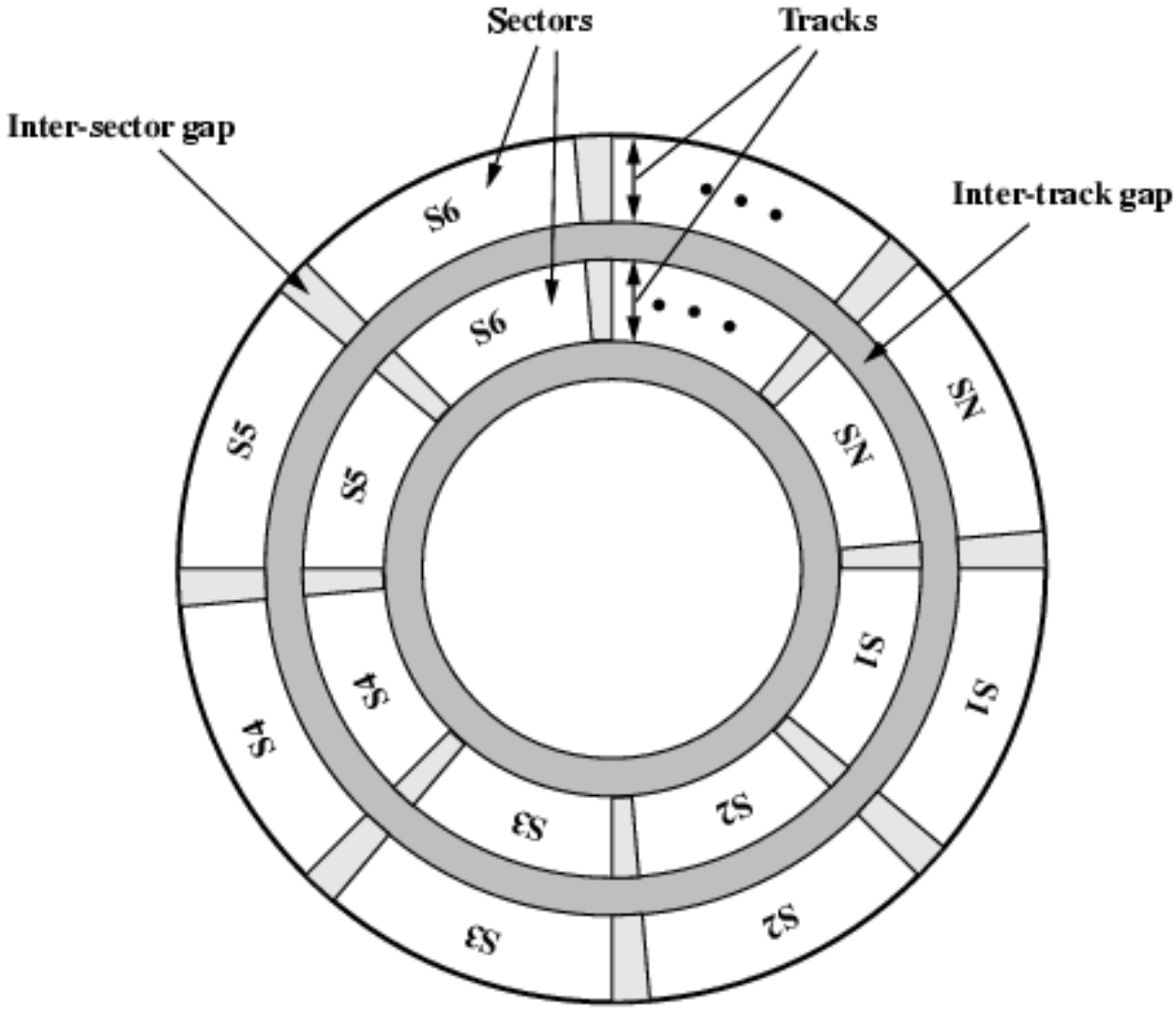
Inductive Write MR Read



Data Organization and Formatting

- Concentric rings or tracks
  - Gaps between tracks
  - Reduce gap to increase capacity
  - Same number of bits per track (variable packing density)
  - Constant angular velocity
- Tracks divided into sectors
- Minimum block size is one sector
- May have more than one sector per block

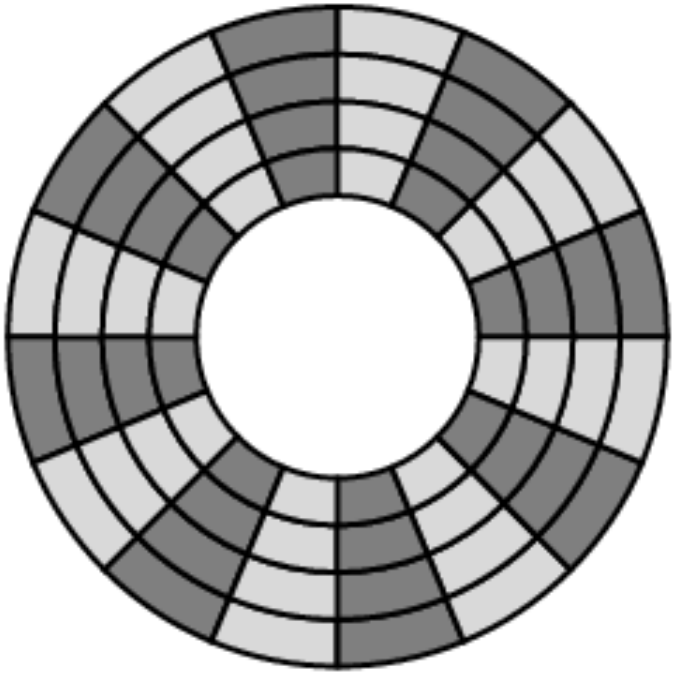
Disk Data Layout



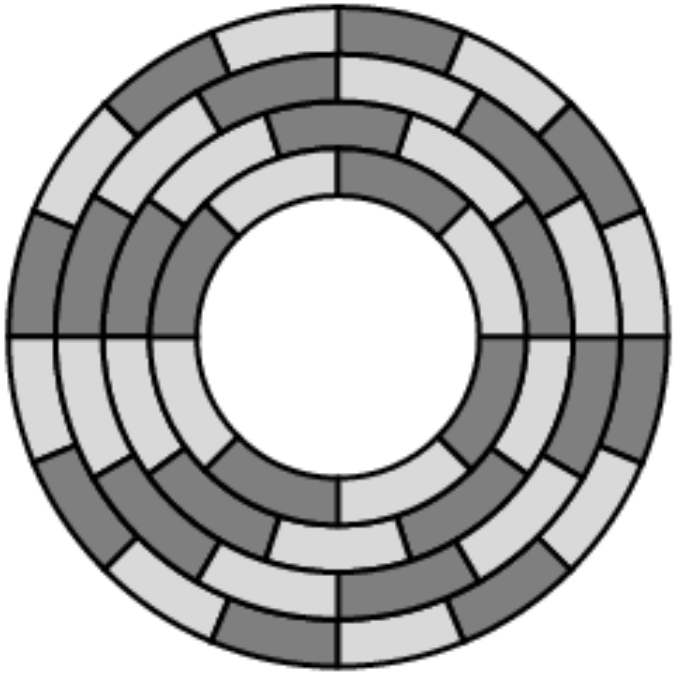
Disk Velocity

- Bit near centre of rotating disk passes fixed point slower than bit on outside of disk
- Increase spacing between bits in different tracks
- Rotate disk at constant angular velocity (CAV)
  - Gives pie shaped sectors and concentric tracks
  - Individual tracks and sectors addressable
  - Move head to given track and wait for given sector
  - Waste of space on outer tracks
    - Lower data density
- Can use zones to increase capacity
  - Each zone has fixed bits per track
  - More complex circuitry

Disk Layout Methods Diagram



(a) Constant angular velocity



(b) Multiple zoned recording

Multiple Zone Recording

- To increase density, modern hard disk systems use a technique→ Multiple Zone Recording
- The surface is divided into number of concentric zone .
- Within a zone a number, the number of bit /track is constant.
- Zones farther from the centre contain more sectors than zones closer to the centre.
- Greater overall storage capacity at the expense of somewhat more complex circuitry.

Finding Sectors

- Must be able to identify start of track and sector
- Format disk
  - Additional information not available to user
  - Marks tracks and sectors

Characteristics

- Fixed (rare) or movable head
- Removable or fixed
- Single or double (usually) sided
- Single or multiple platter
- Head mechanism
  - Contact (Floppy)
  - Fixed gap
  - Flying (Winchester)

Fixed/Movable Head Disk

- Fixed head
  - One read write head per track
  - Heads mounted on fixed ridged arm
- Movable head
  - One read write head per side
  - Mounted on a movable arm

Removable or Not

- Removable disk
  - Can be removed from drive and replaced with another disk
  - Provides unlimited storage capacity
  - Easy data transfer between systems
- Nonremovable disk
  - Permanently mounted in the drive

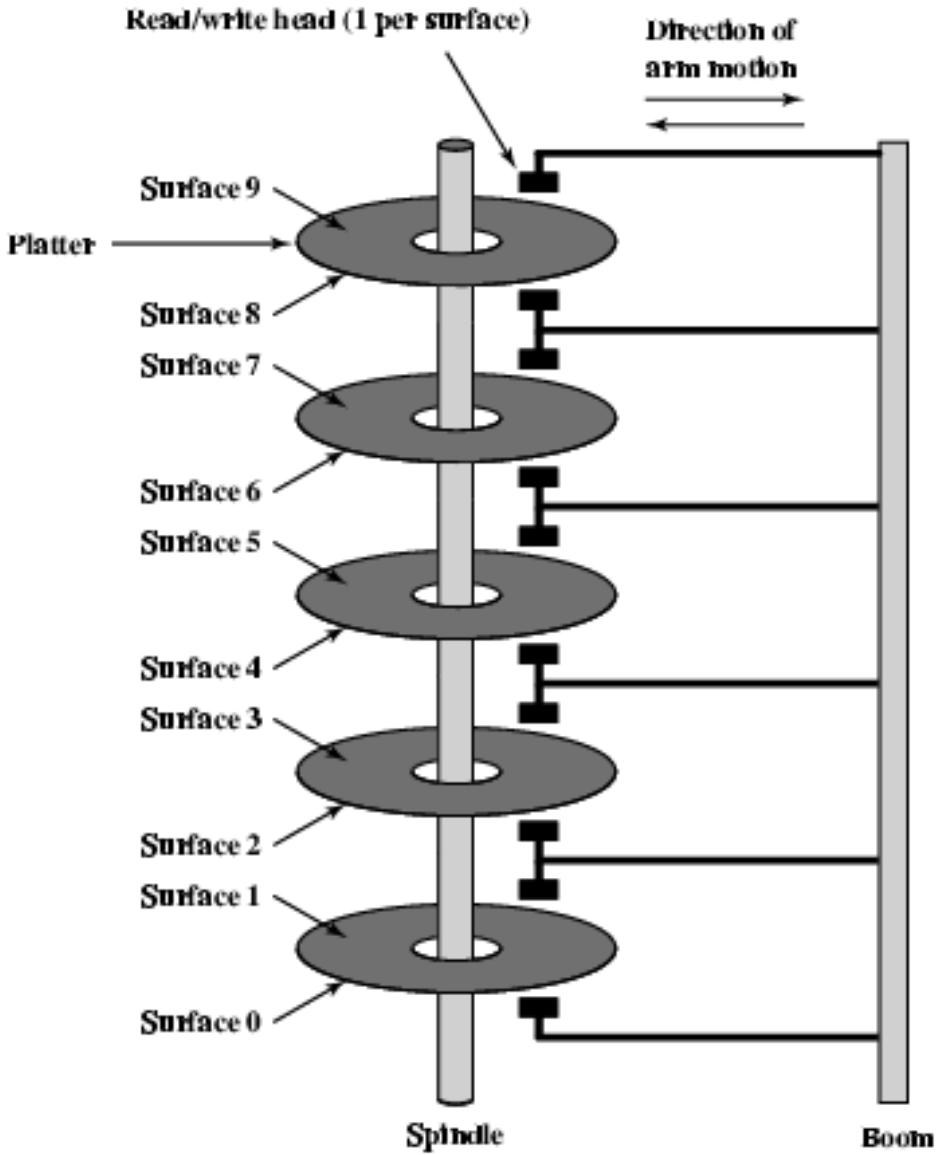
Multiple Platter

- One head per side
- Heads are joined and aligned
- Aligned tracks on each platter form cylinders
- Data is striped by cylinder
  - reduces head movement
  - Increases speed (transfer rate)

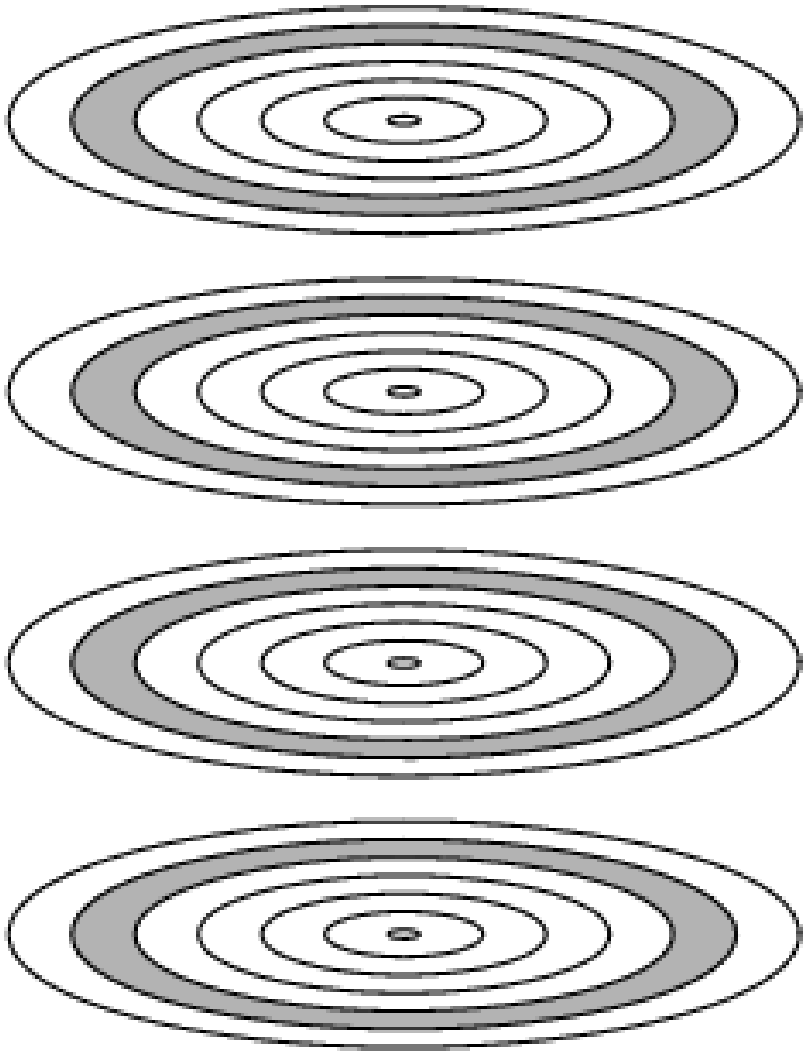
Physical Characteristics of Disk Systems

Head Motion	**Platters**
Fixed head (one per track)	Single platter
Movable head (one per surface)	Multiple platter
Disk Portability	**Head Mechanism**
Nonremovable disk	Contact (floppy)
Removable disk	Fixed gap
	Aerodynamic gap (Winchester)
Sides	
Single sided	
Double sided	

Multiple Platters



Tracks and Cylinders



Speed Parameters

- Seek time
  - Time to position head at track
- Latency (Rotational)
  - Time for head to rotate to beginning of sector
- Access time
  - Seek time + Latency time
- Transfer rate
  - The rate at which data can be transferred **after access**

    T = b / N * 1/r

    Transfer time = bytes transferred / bytes/track * sec/revolution (track)

Note: How does organization on disk (e.g. random vs sequential) effect total time?

Optical Products

CD

Compact Disk. A nonerasable disk that stores digitized audio information. The standard system uses 12-cm disks and can record more than 60 minutes of uninterrupted playing time.

CD-ROM

Compact Disk Read-Only Memory. A nonerasable disk used for storing computer data. The standard system uses 12-cm disks and can hold more than 650 Mbytes.

CD-R

CD Recordable. Similar to a CD-ROM. The user can write to the disk only once.

CD-RW

CD Rewritable. Similar to a CD-ROM. The user can erase and rewrite to the disk multiple times.

DVD

Digital Versatile Disk. A technology for producing digitized, compressed representation of video information, as well as large volumes of other digital data. Both 8 and 12 cm diameters are used, with a double-sided capacity of up to 17 Gbytes. The basic DVD is read-only (DVD-ROM).

DVD-R

DVD Recordable. Similar to a DVD-ROM. The user can write to the disk only once. Only one-sided disks can be used.

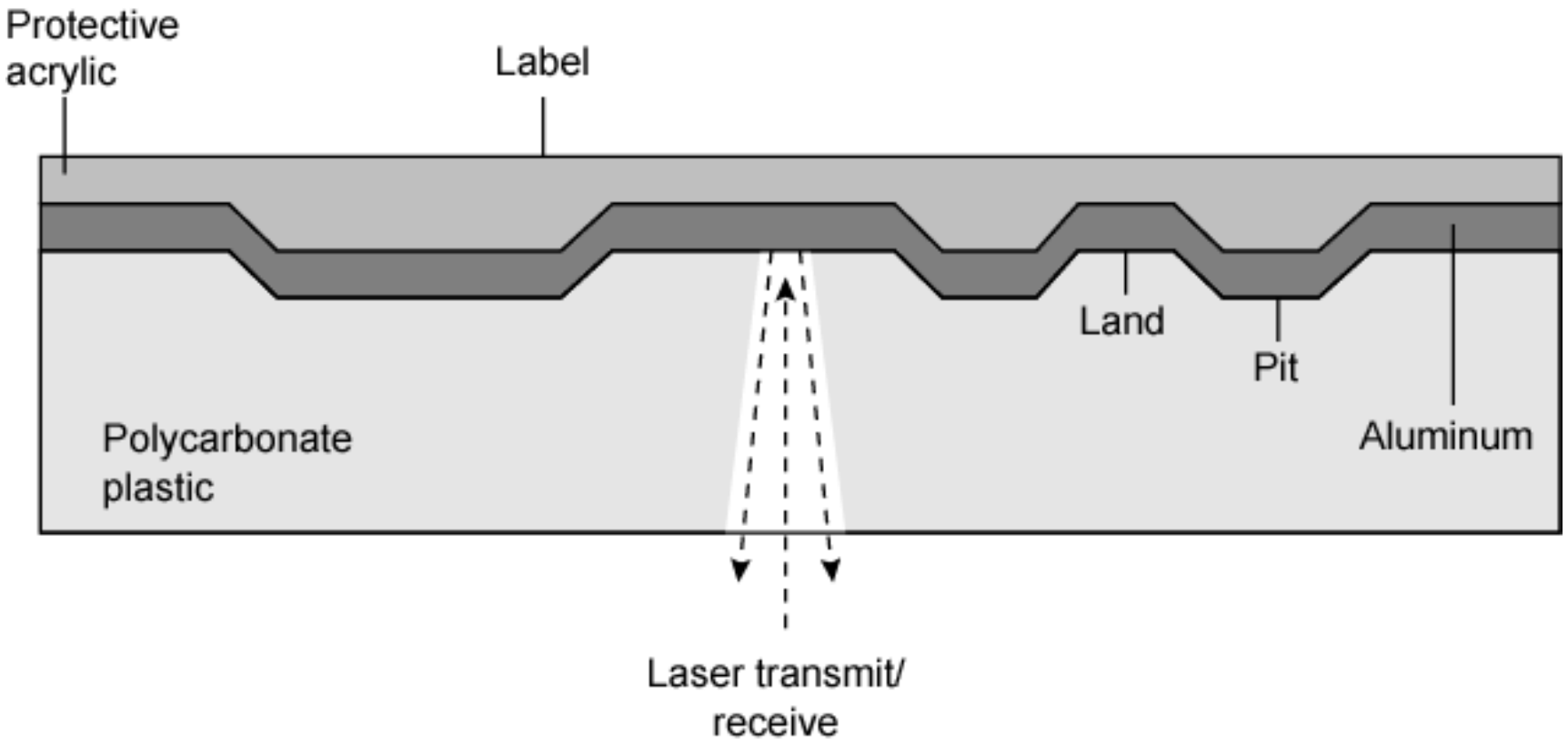
DVD-RW

DVD Rewritable. Similar to a DVD-ROM. The user can erase and rewrite to the disk multiple times. Only one-sided disks can be used.

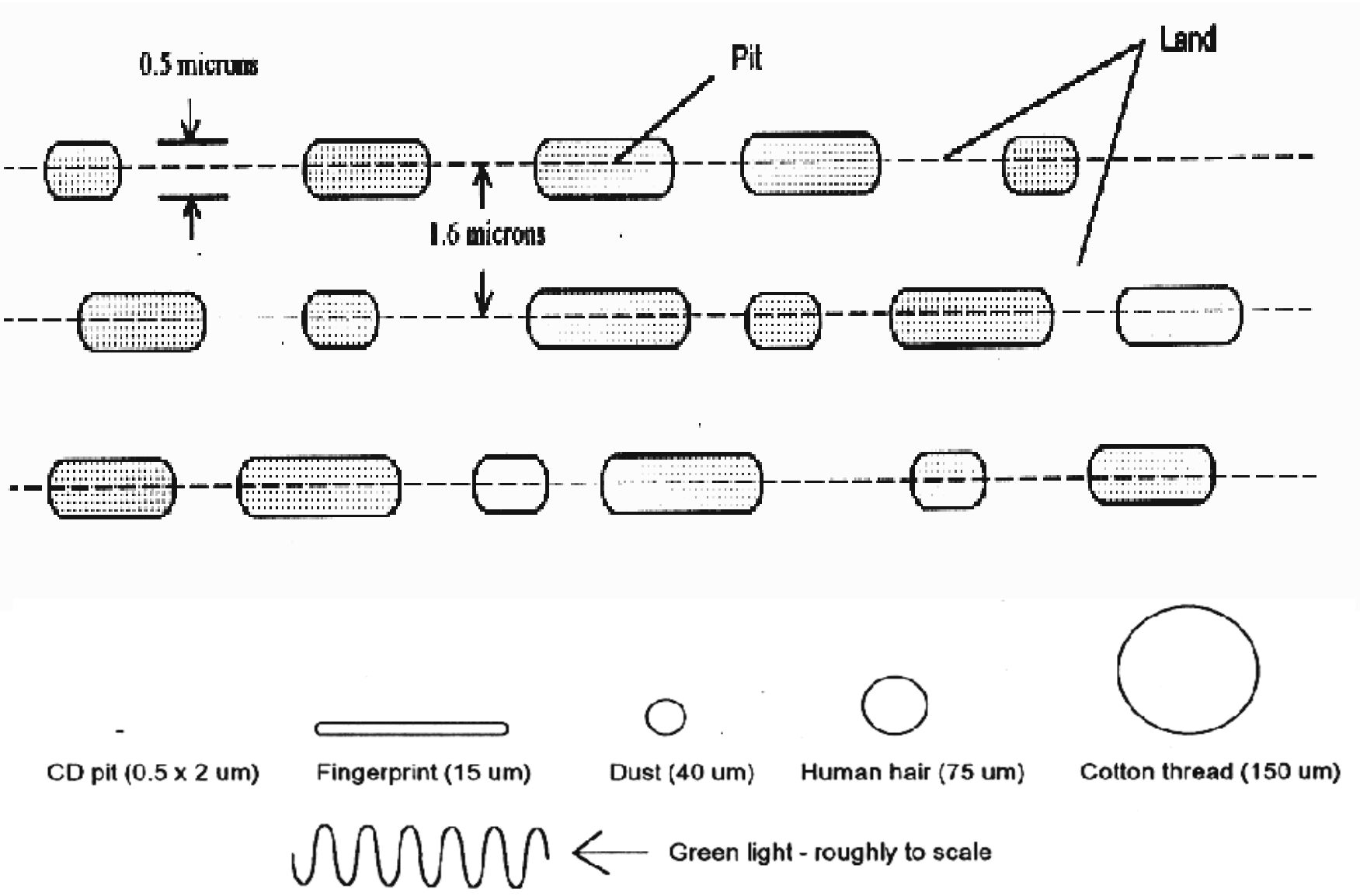
Optical Storage CD-ROM

- Originally for audio
- 650Mbytes giving over 70 minutes audio
- Polycarbonate coated with highly reflective coat, usually aluminium
- Data stored as pits
- Read by reflecting laser
- Constant packing density
- Constant linear velocity

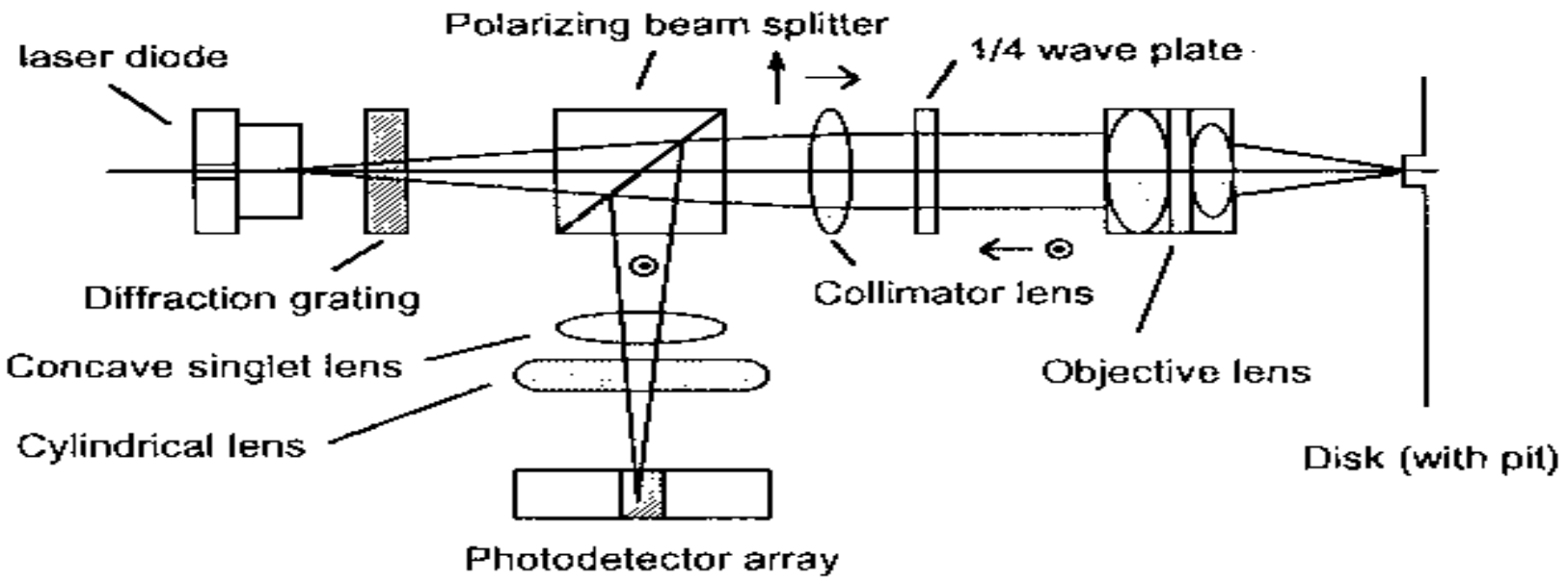
CD Construction



CD Layout


0.5 microns
Pit
Land
1.6 microns
CD pit (0.5 x 2 um)
Fingerprint (15 um)
Dust (40 um)
Human hair (75 um)
Cotton thread (150 um)
Green light - roughly to scale

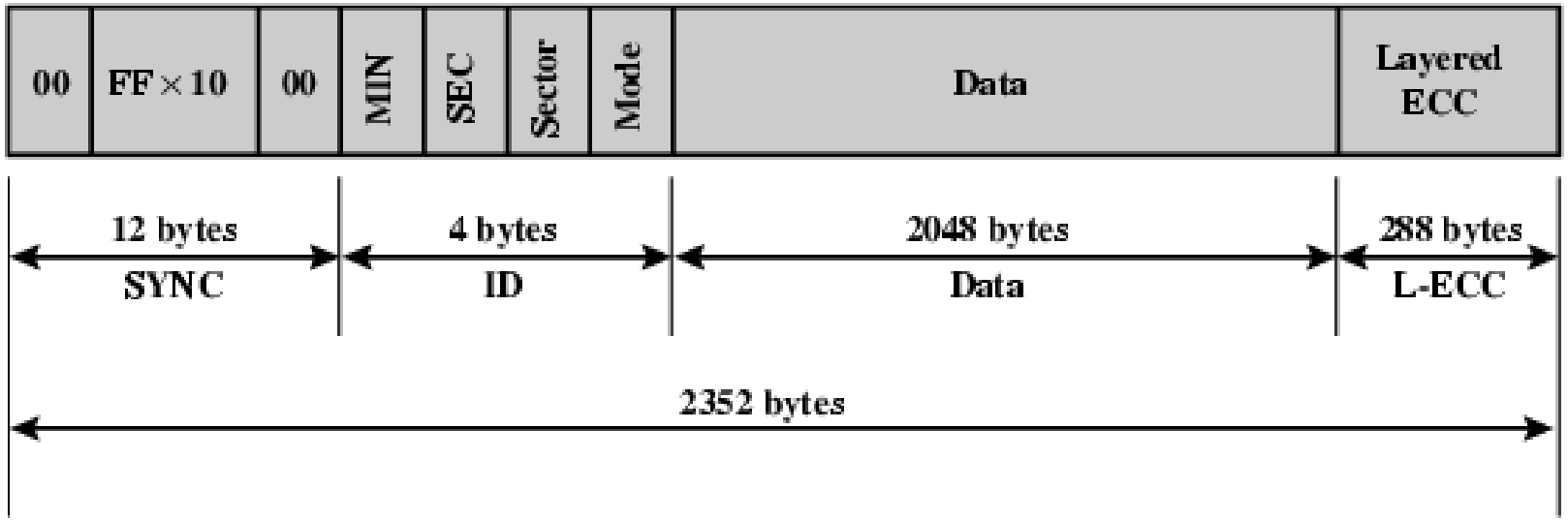
CD reader


laser diode
Polarizing beam splitter
1/4 wave plate
Diffraction grating
Collimator lens
Concave singlet lens
Objective lens
Cylindrical lens
Disk (with pit)
Photodetector array

CD-ROM Drive Speeds

- Audio is single speed
  - Constant linear velocity
  - 1.2 m/sec
  - Track (spiral) is 5.27km long
  - Gives 4391 seconds = 73.2 minutes
- Other speeds are quoted as multiples
  - e.g. 24x
  - Quoted figure is maximum drive can achieve
- Note: CD-ROM has option of error correction (not on CD)

CD-ROM Format



- Mode 0 = blank data field
- Mode 1 = 2048 byte data + error correction
- Mode 2 = 2336 byte data

Random Access on CD-ROM & CD-R

- Difficult
- Process:
  - Move head to rough position
  - Set correct speed
  - Read address
  - Adjust to required location

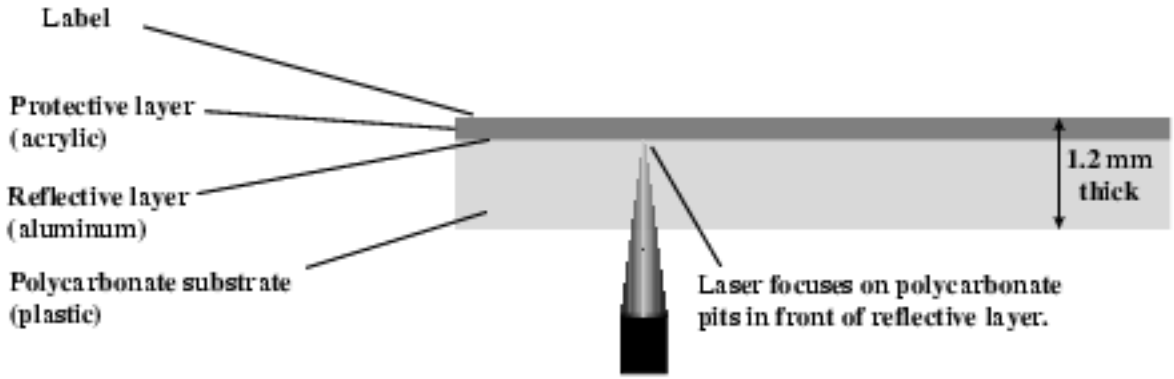
CD-RW

- Erasable
- Getting cheaper
- Mostly CD-ROM drive compatible
- Phase change
  - Material has two different reflectivities in different phase states

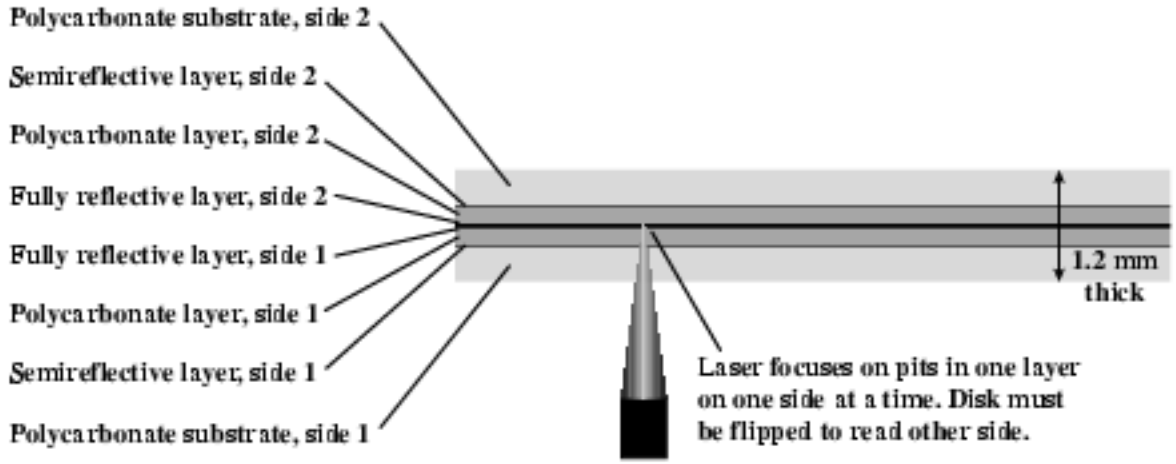
DVD - technology

- Multi-layer
- Very high capacity (4.7G per layer)
- Full length movie on single disk
  - Using MPEG compression

CD vs DVD



(a) CD-ROM - Capacity 682 MB



(b) DVD-ROM, double-sided, dual-layer - Capacity 17 GB

DVD’s

Two objectives had to be resolved to make the DVDs viable.

- The linear velocity of a DVD must be held constant and be able to reproduce a vertical frame rate of 29.97 frames/second

- Every DVD player had to have absolute tracking accuracy to insure the extremely narrow laser beam would scan exactly in the middle of the track where the data was recorded.

The solution:

- The disk is pressed with the track grooves accurately pre-cut and encoded with a constant bit rate frequency. Thus a blank DVD disk isn't really blank at all.

Magnetic Tape

- Serial access
- Slow
- Very cheap

- Used for backup and archive

References

- William Stallings “Computer Organization and architecture”, Prentice Hall, 7th edition, 2006.