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Computer Organization and Architecture
8th Edition

Chapter 6

External Memory

Types of External Memory

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

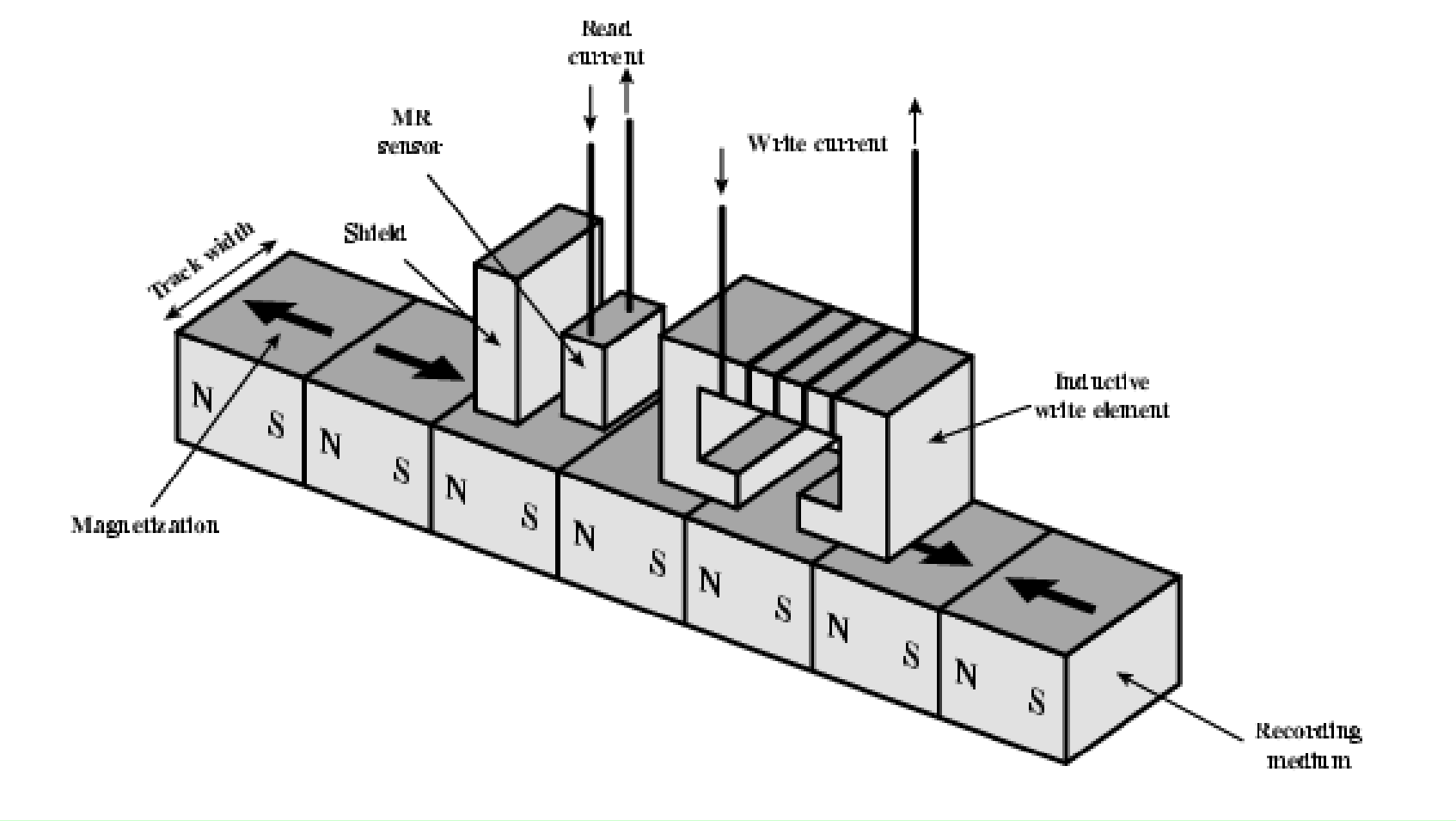
Magnetic Disk

- Disk substrate coated with magnetizable material (iron oxide…rust)
- Substrate used to be aluminium
- Now glass
  - Improved surface uniformity
    - Increases reliability
  - Reduction in surface defects
    - Reduced read/write errors
  - Lower flight heights (See later)
  - 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
  - Partially shielded magneto resistive (MR) sensor
  - Electrical resistance depends on direction of magnetic field
  - High frequency operation
    - Higher storage density and speed

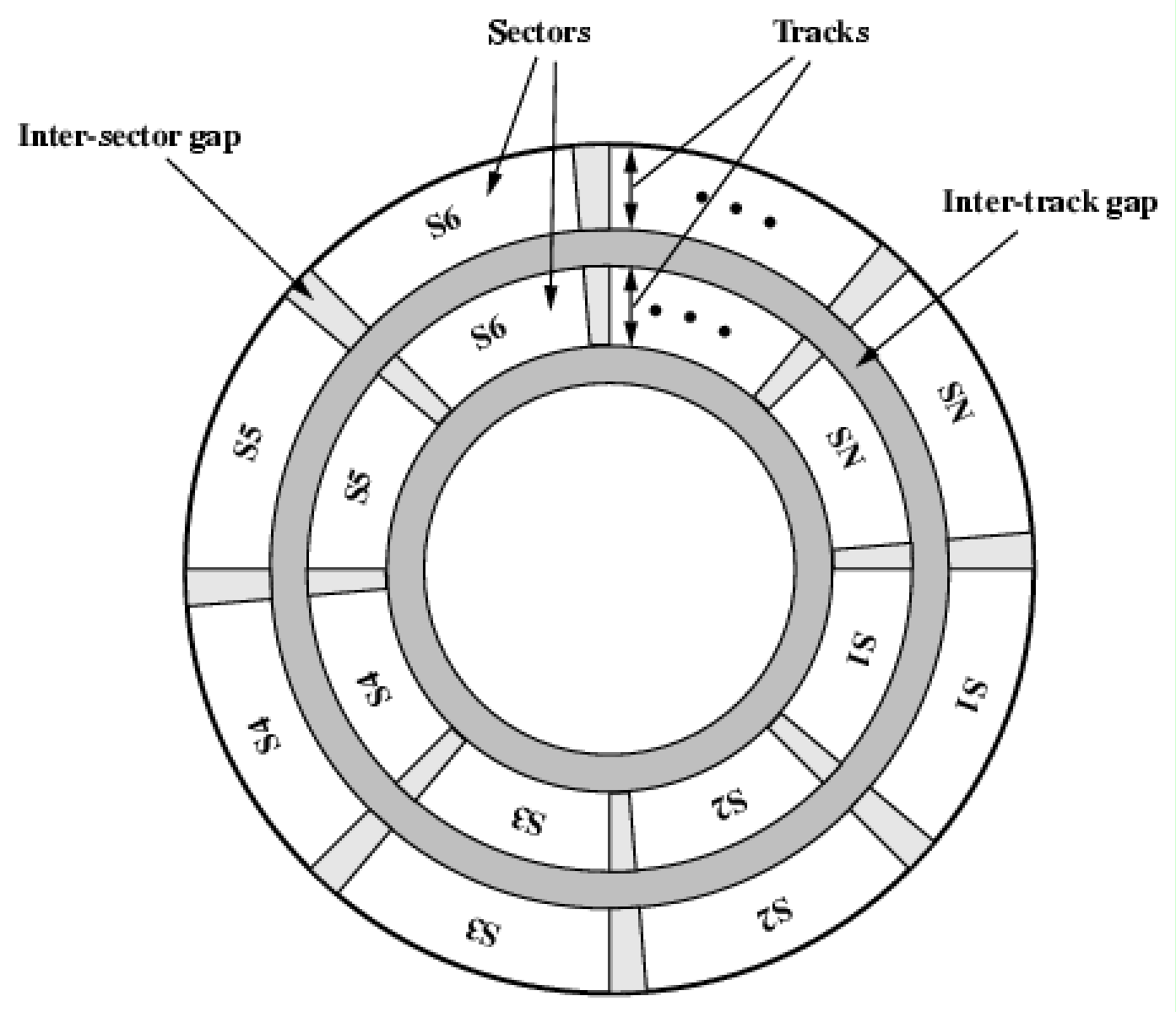
Inductive Write MR Read



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

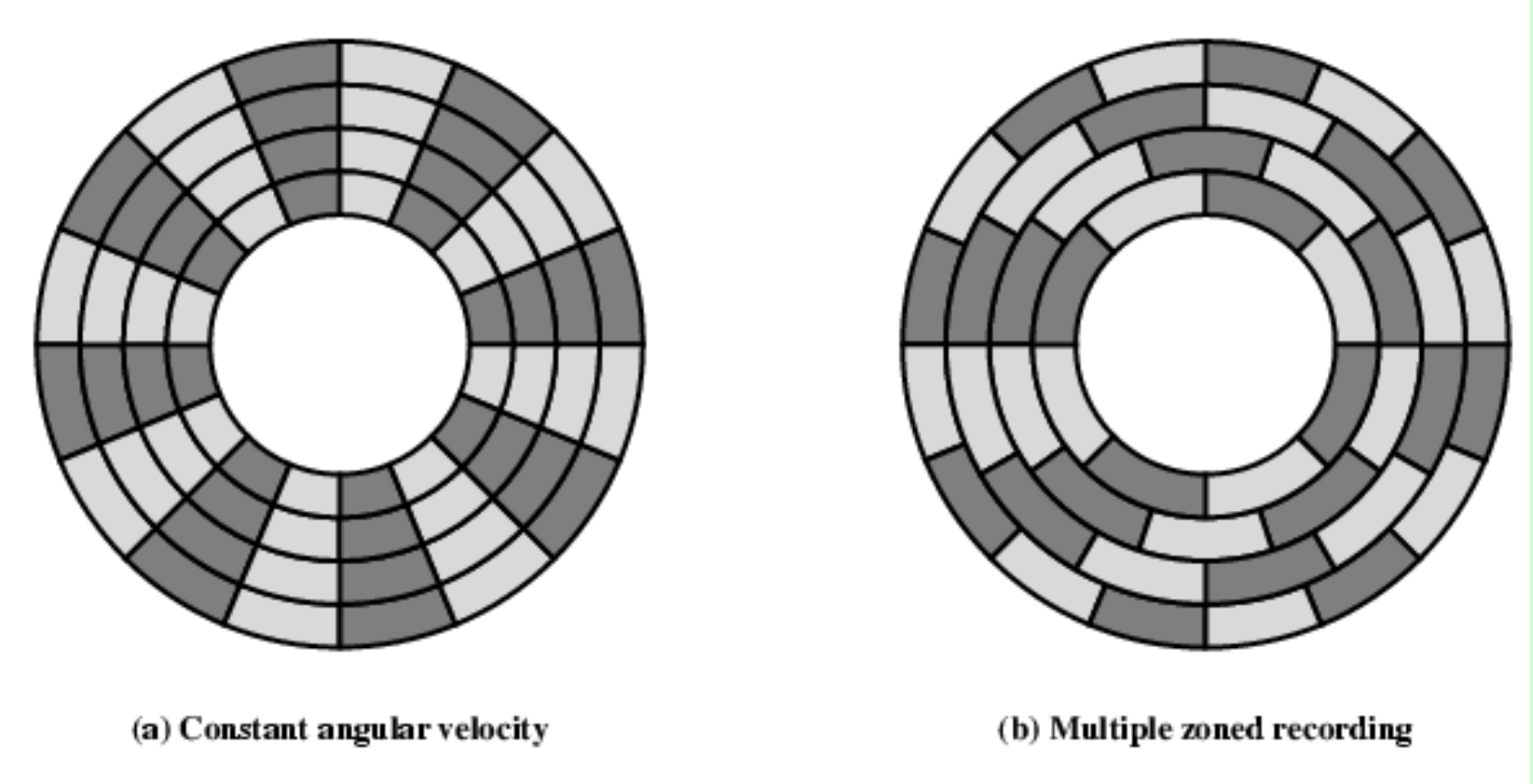
Disk Data Layout



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



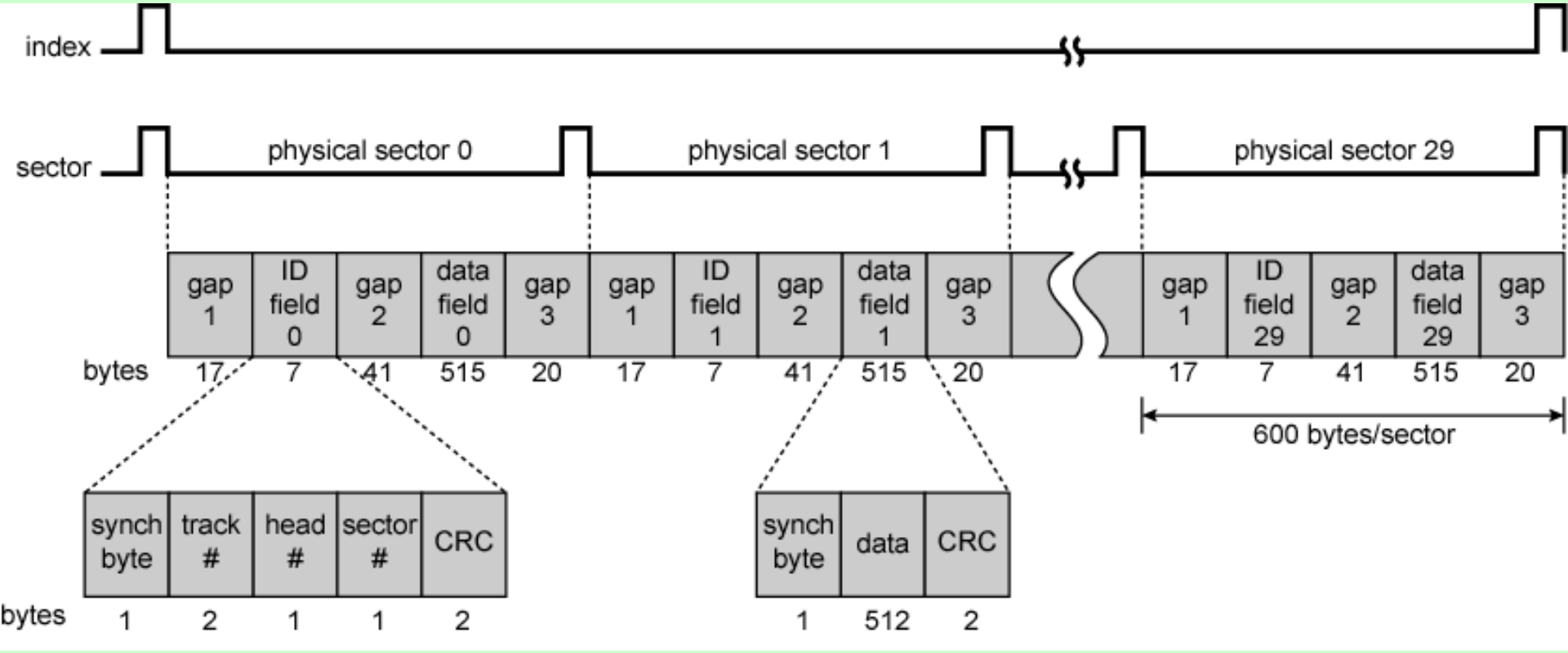
(a) Constant angular velocity

(b) Multiple zoned recording

Finding Sectors

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

Winchester Disk Format
Seagate ST506



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

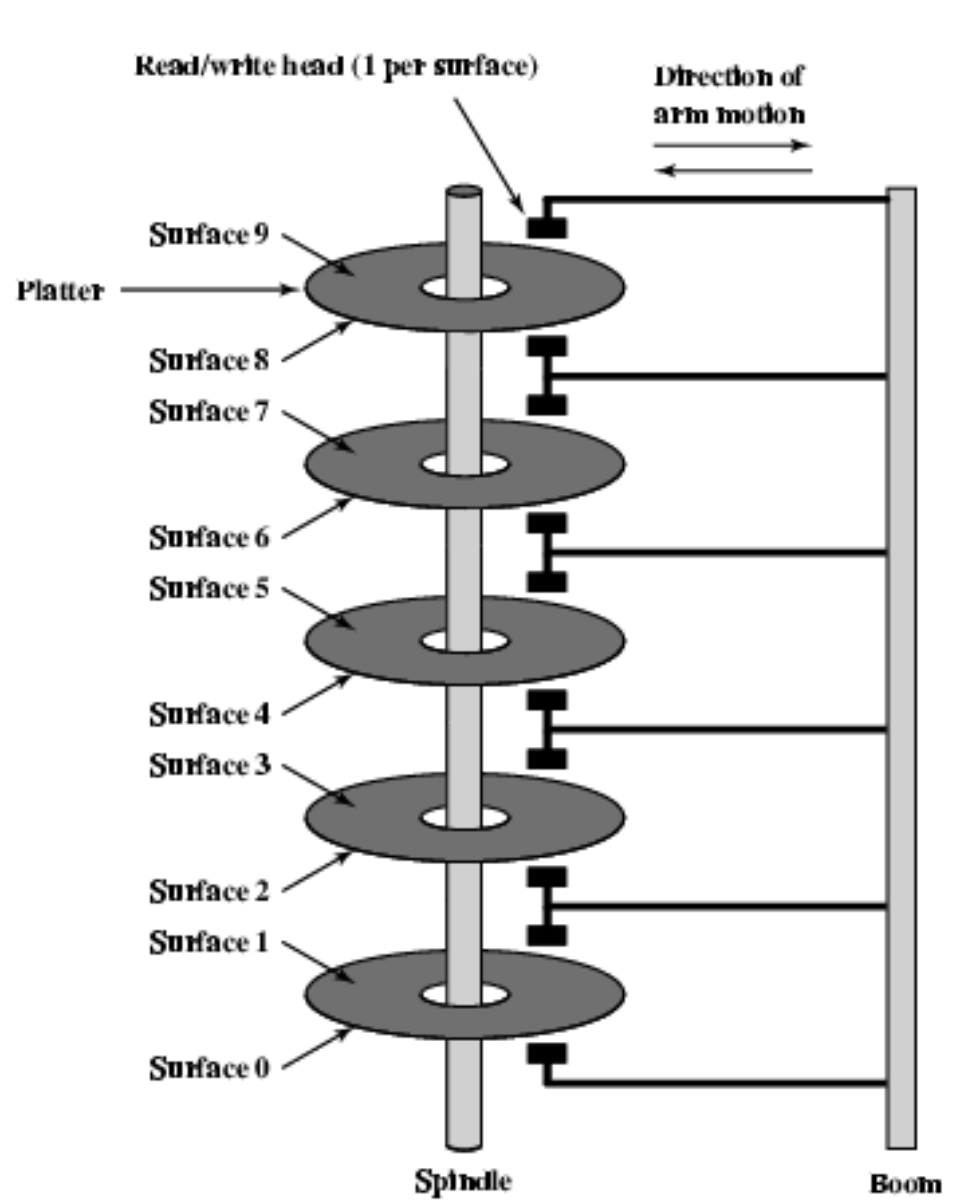
Removable or Not

- 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

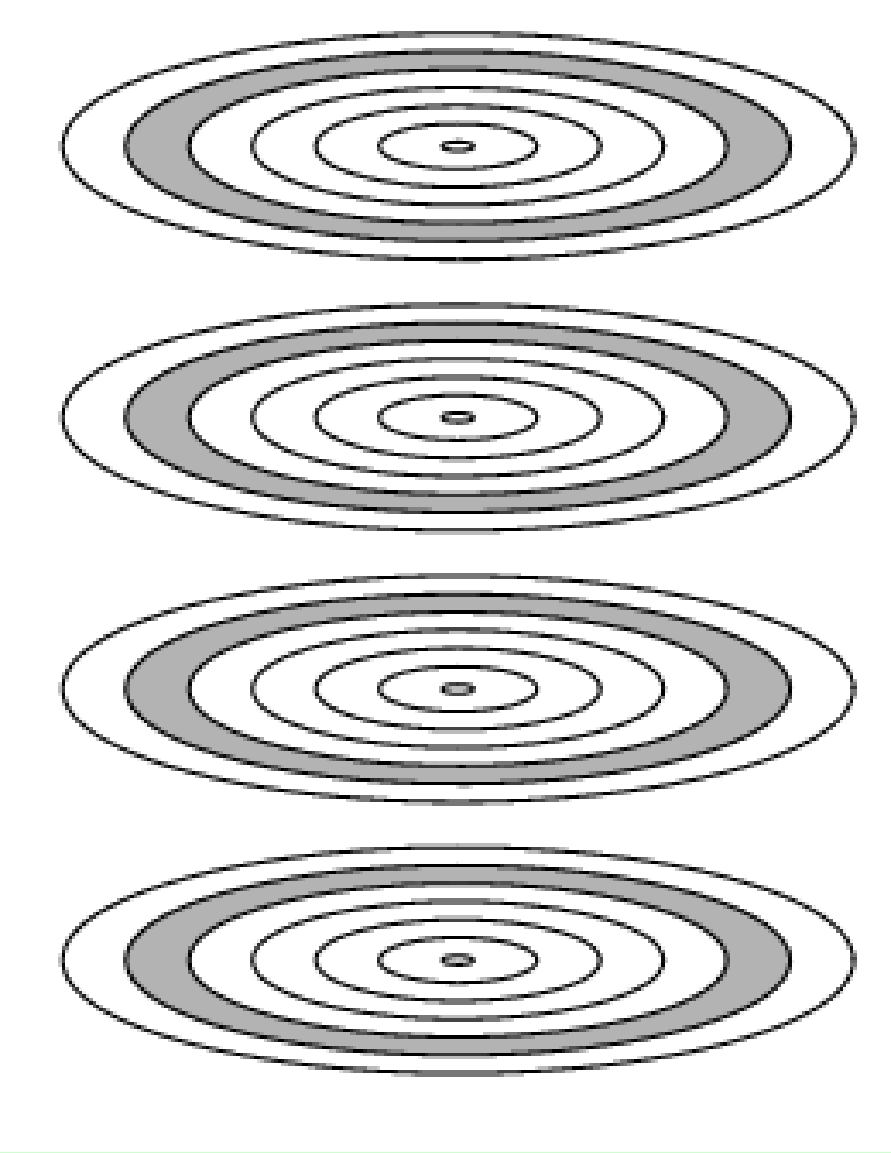
Multiple Platter

- 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)

Multiple Platters



Tracks and Cylinders



Floppy Disk

- 8″, 5.25″, 3.5″
- Small capacity
  - —Up to 1.44Mbyte (2.88M never popular)
- Slow
- Universal
- Cheap
- Obsolete?

Winchester Hard Disk (1)

- Developed by IBM in Winchester (USA)
- Sealed unit
- One or more platters (disks)
- Heads fly on boundary layer of air as disk spins
- Very small head to disk gap
- Getting more robust

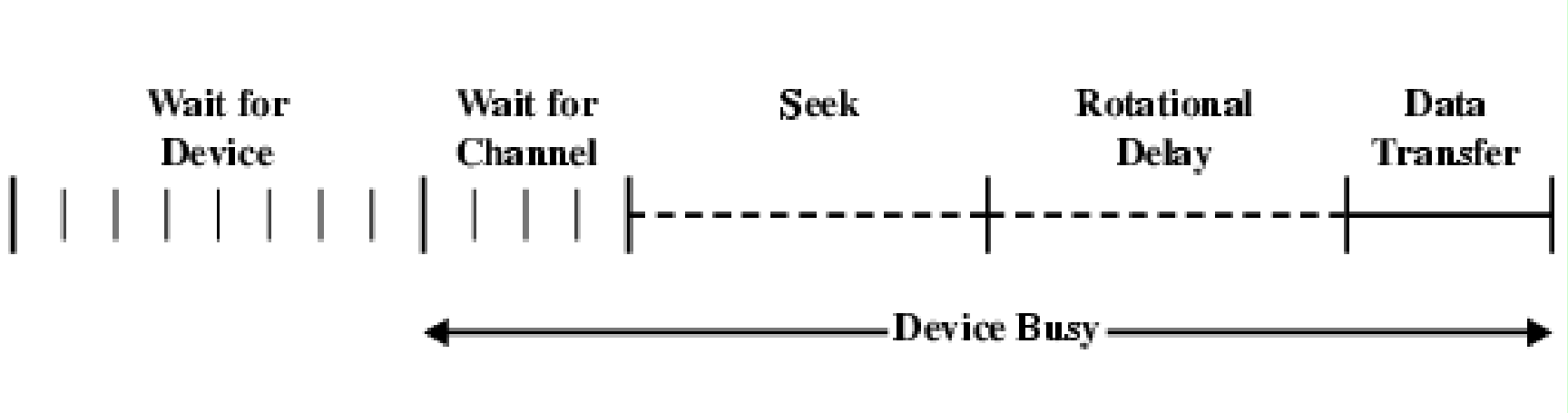
Winchester Hard Disk (2)

- Universal
- Cheap
- Fastest external storage
- Getting larger all the time
  - —250 Gigabyte now easily available

Speed

- Seek time
  - —Moving head to correct track
- (Rotational) latency
  - —Waiting for data to rotate under head
- Access time = Seek + Latency
- Transfer rate

Timing of Disk I/O Transfer



RAID

- Redundant Array of Independent Disks
- Redundant Array of Inexpensive Disks
- 6 levels in common use
- Not a hierarchy
- Set of physical disks viewed as single logical drive by O/S
- Data distributed across physical drives
- Can use redundant capacity to store parity information

RAID 0

- No redundancy
- Data striped across all disks
- Round Robin striping
- Increase speed
  - Multiple data requests probably not on same disk
  - Disks seek in parallel
  - A set of data is likely to be striped across multiple disks

RAID 1

- Mirrored Disks
- Data is striped across disks
- 2 copies of each stripe on separate disks
- Read from either
- Write to both
- Recovery is simple
  - —Swap faulty disk & re-mirror
  - —No down time
- Expensive

RAID 2

- Disks are synchronized
- Very small stripes
  - —Often single byte/word
- Error correction calculated across corresponding bits on disks
- Multiple parity disks store Hamming code error correction in corresponding positions
- Lots of redundancy
  - —Expensive
  - —Not used

RAID 3

- Similar to RAID 2
- Only one redundant disk, no matter how large the array
- Simple parity bit for each set of corresponding bits
- Data on failed drive can be reconstructed from surviving data and parity info
- Very high transfer rates

RAID 4

- Each disk operates independently
- Good for high I/O request rate
- Large stripes
- Bit by bit parity calculated across stripes on each disk
- Parity stored on parity disk

RAID 5

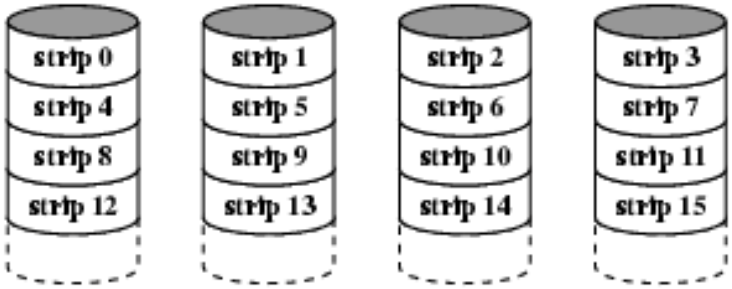
- Like RAID 4
- Parity striped across all disks
- Round robin allocation for parity stripe
- Avoids RAID 4 bottleneck at parity disk
- Commonly used in network servers

- N.B. DOES NOT MEAN 5 DISKS!!!!!

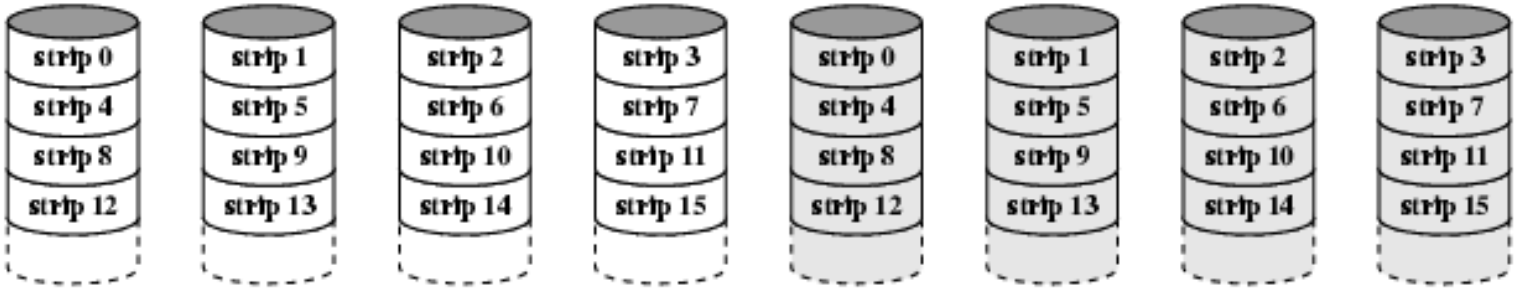
RAID 6

- Two parity calculations
- Stored in separate blocks on different disks
- User requirement of N disks needs N+2
- High data availability
  - Three disks need to fail for data loss
  - Significant write penalty

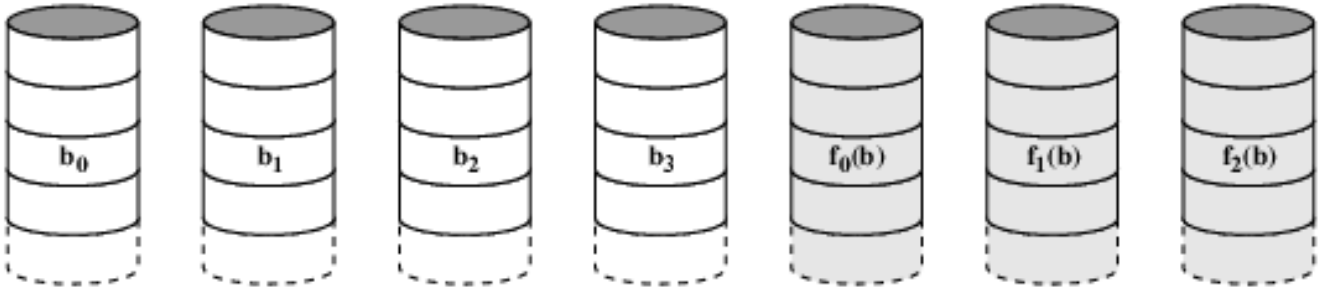
RAID 0, 1, 2



(a) RAID 0 (non-redundant)

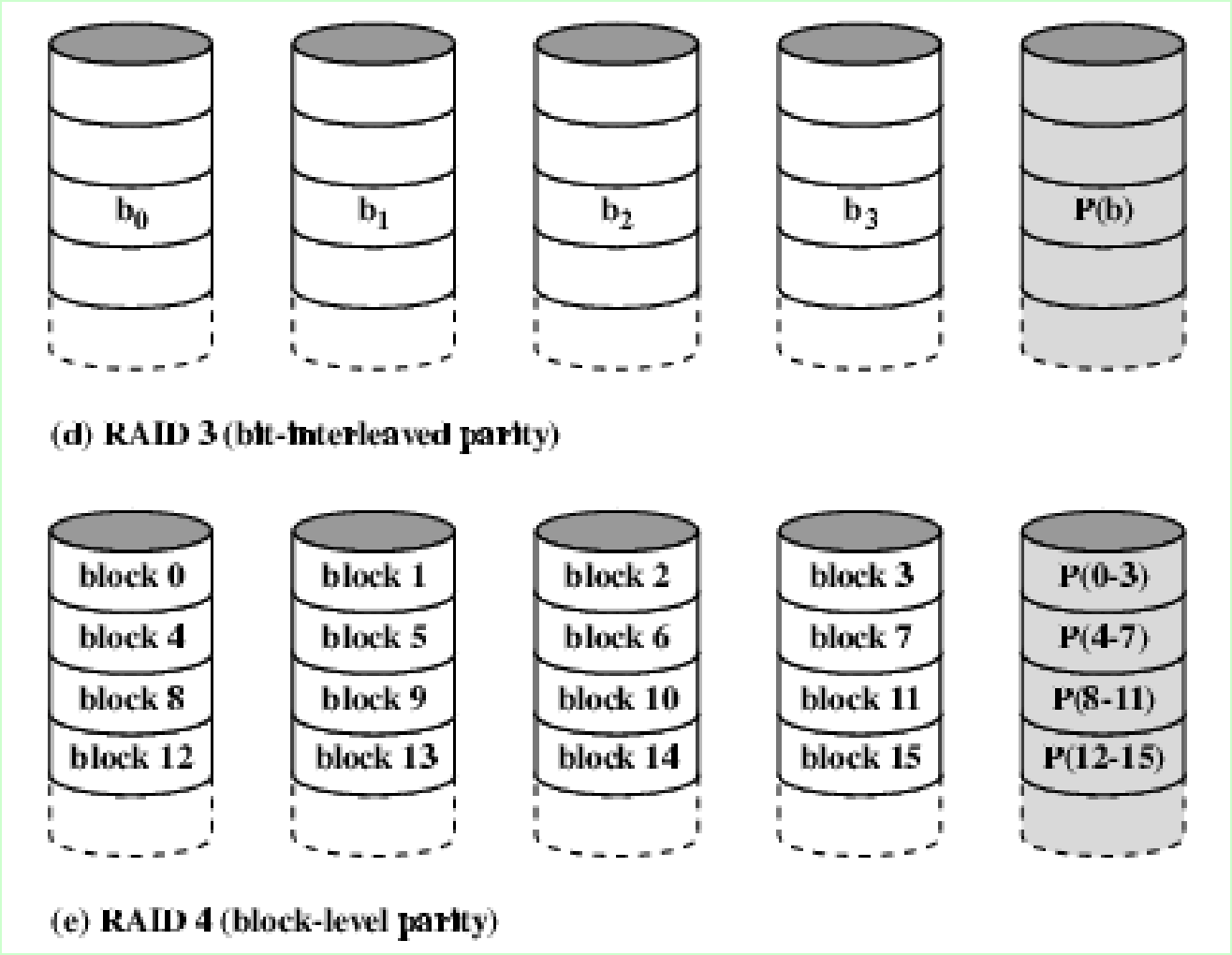


(b) RAID 1 (mirrored)



(c) RAID 2 (redundancy through Hamming code)

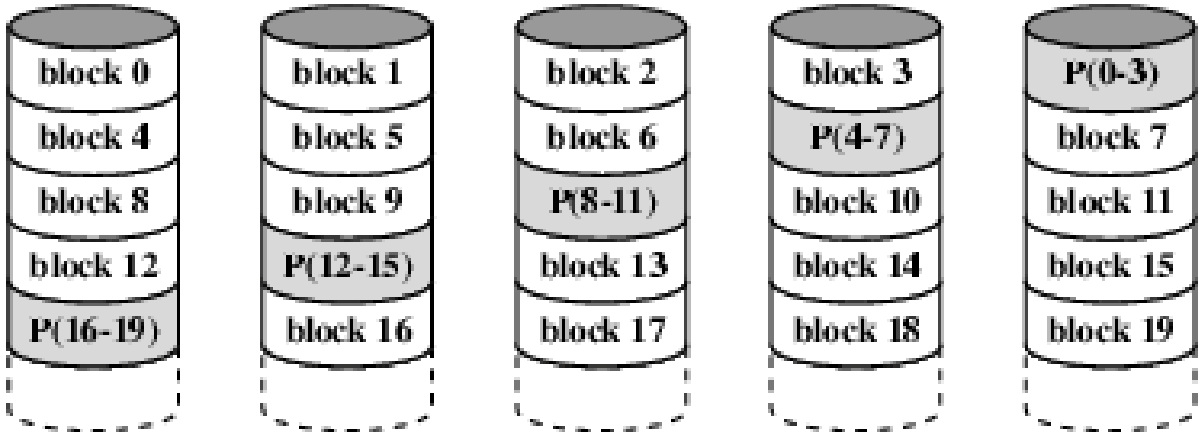
RAID 3 & 4



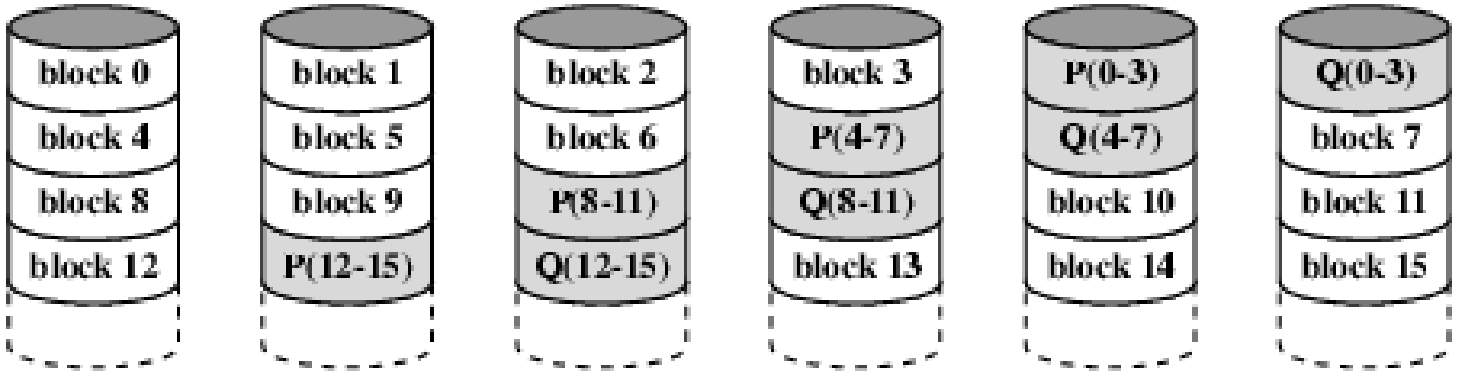
(d) RAID 3 (bit-interleaved parity)

(e) RAID 4 (block-level parity)

RAID 5 & 6

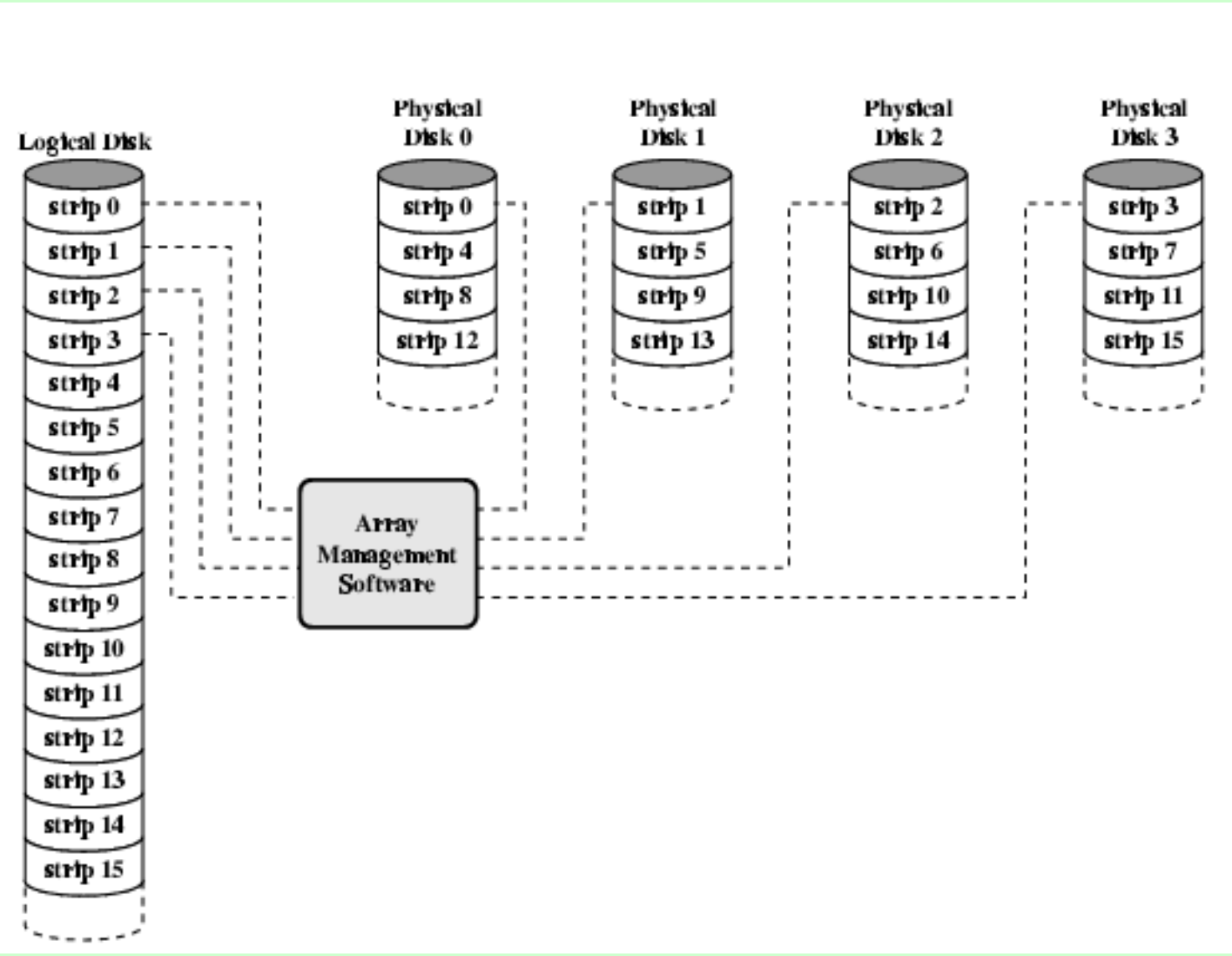


(f) RAID 5 (block-level distributed parity)



(g) RAID 6 (dual redundancy)

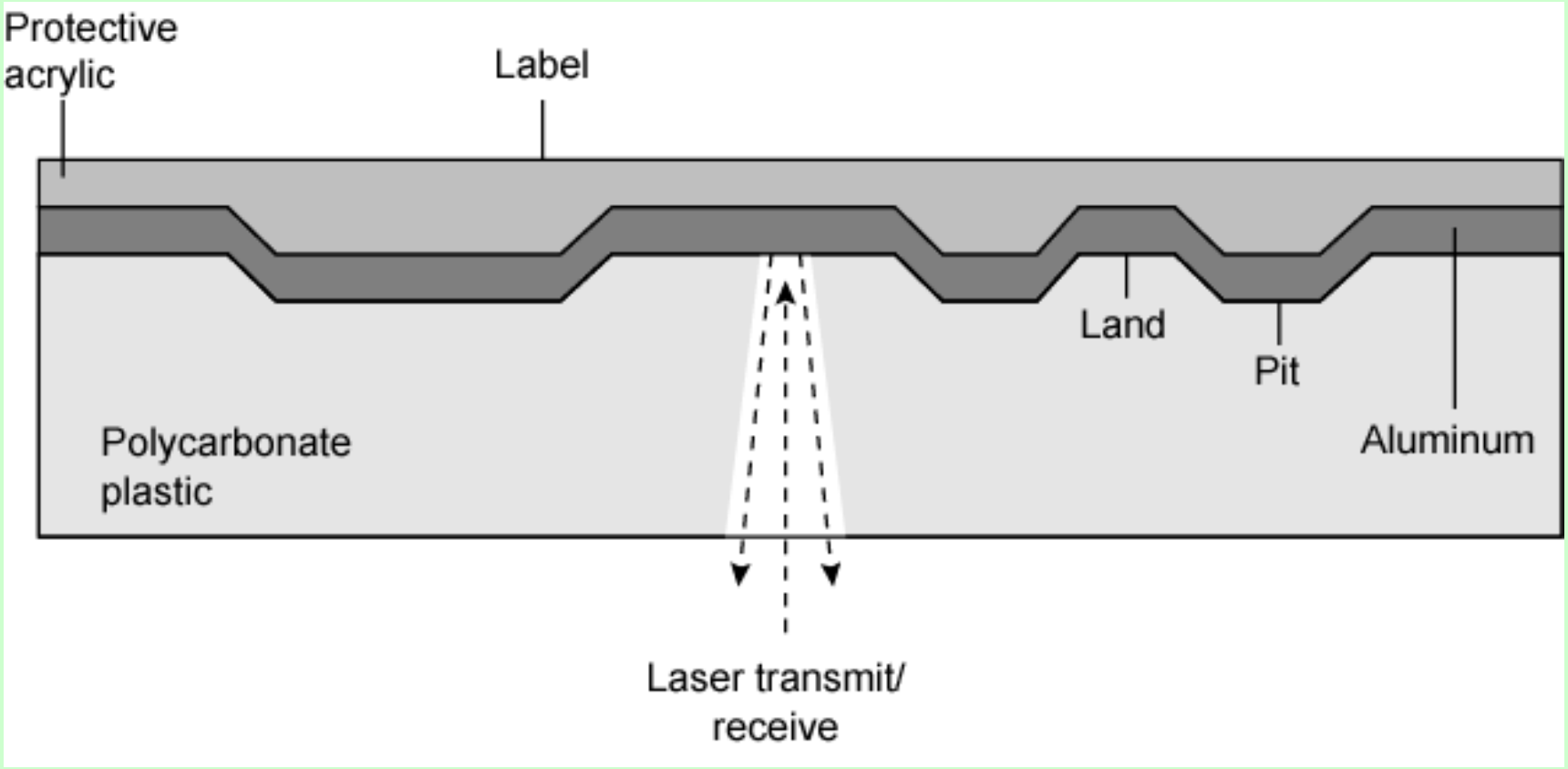
Data Mapping For RAID 0



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

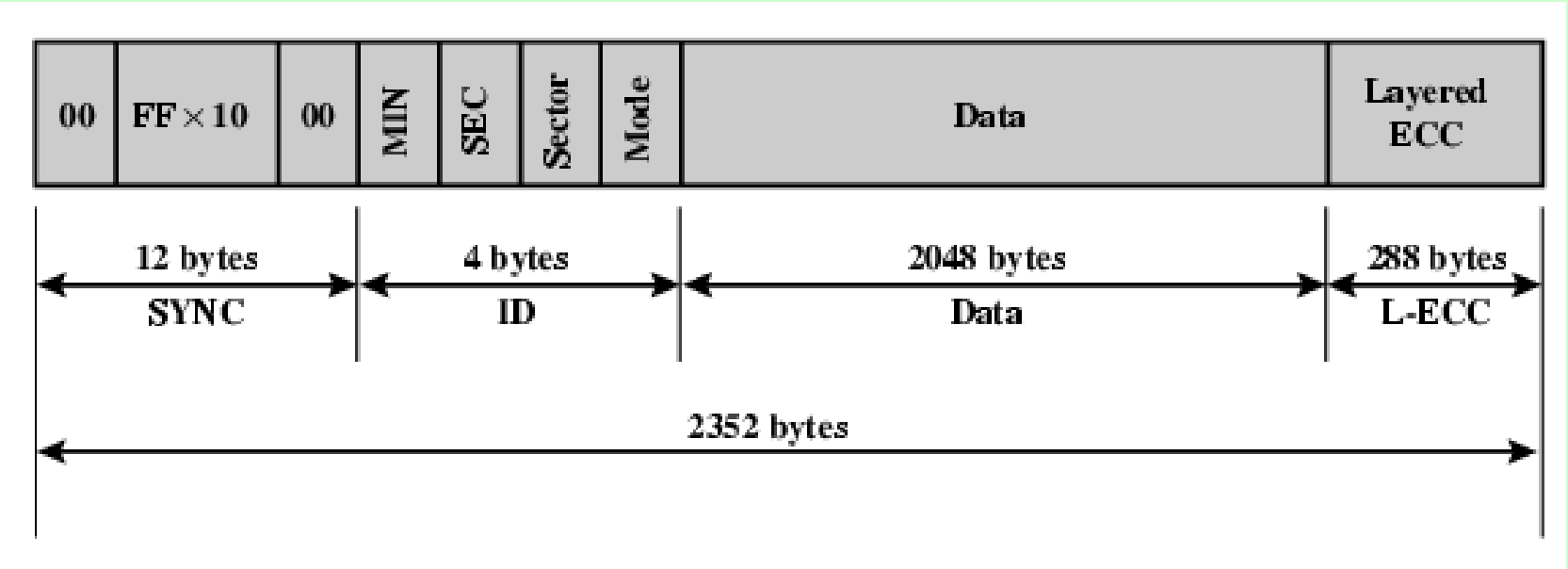
CD Operation



CD-ROM Drive Speeds

- Audio is single speed
  - —Constant linier velocity
  - —1.2 ms^{-1}
  - —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

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

- Difficult
- Move head to rough position
- Set correct speed
- Read address
- Adjust to required location
- (Yawn!)

CD-ROM for & against

- Large capacity (?)
- Easy to mass produce
- Removable
- Robust

- Expensive for small runs
- Slow
- Read only

Other Optical Storage

- CD-Recordable (CD-R)
  - WORM
  - Now affordable
  - Compatible with CD-ROM drives
- CD-RW
  - Erasable
  - Getting cheaper
  - Mostly CD-ROM drive compatible
  - Phase change
    - Material has two different reflectivities in different phase states

DVD - what's in a name?

- Digital Video Disk
  - —Used to indicate a player for movies
    - Only plays video disks
- Digital Versatile Disk
  - —Used to indicate a computer drive
    - Will read computer disks and play video disks
- Dogs Veritable Dinner
- Officially - nothing!!!

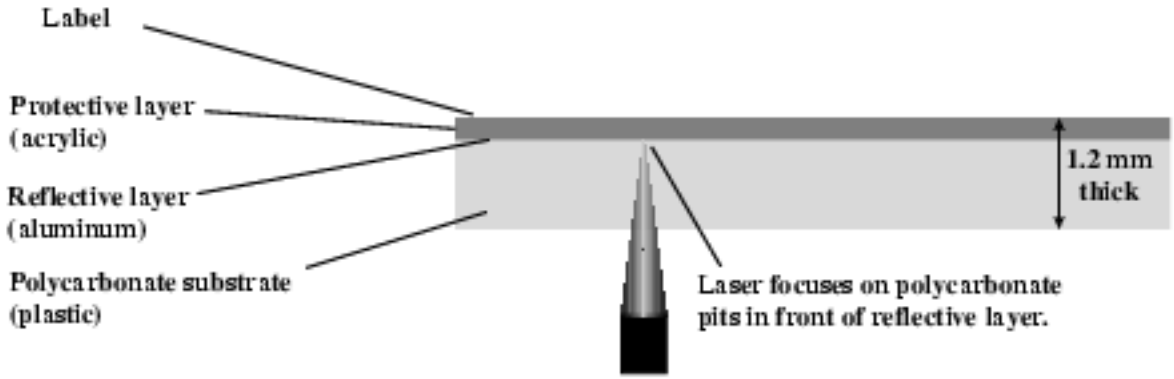
DVD - technology

- Multi-layer
- Very high capacity (4.7G per layer)
- Full length movie on single disk
  - —Using MPEG compression
- Finally standardized (honest!)
- Movies carry regional coding
- Players only play correct region films
- Can be “fixed”

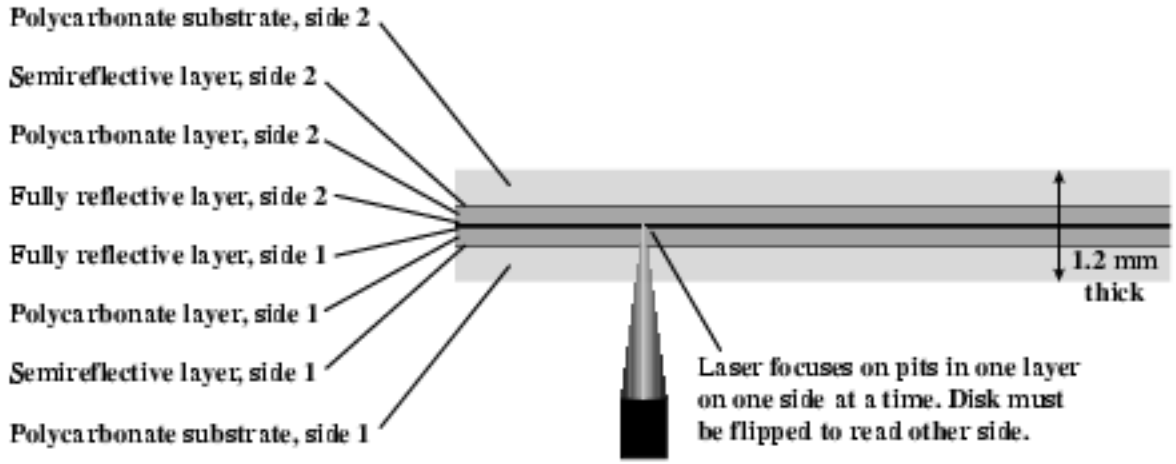
DVD – Writable

- Loads of trouble with standards
- First generation DVD drives may not read first generation DVD-W disks
- First generation DVD drives may not read CD-RW disks
- Wait for it to settle down before buying!

CD and DVD



(a) CD-ROM - Capacity 682 MB

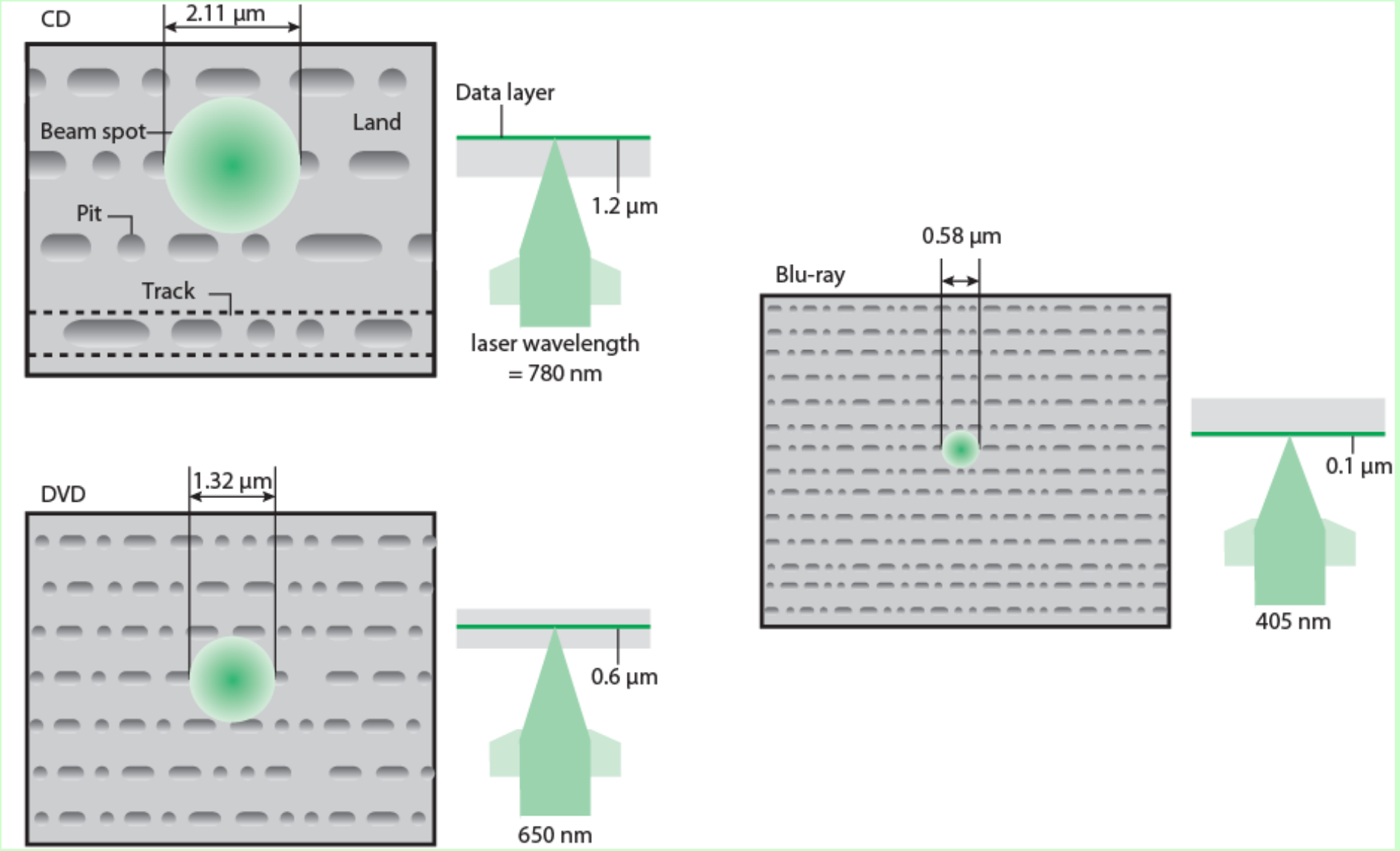


(b) DVD-ROM, double-sided, dual-layer - Capacity 17 GB

High Definition Optical Disks

- Designed for high definition videos
- Much higher capacity than DVD
  - —Shorter wavelength laser
    - Blue-violet range
  - —Smaller pits
- HD-DVD
  - —15GB single side single layer
- Blue-ray
  - —Data layer closer to laser
    - Tighter focus, less distortion, smaller pits
  - —25GB on single layer
  - —Available read only (BD-ROM), Recordable once (BR-R) and re-recordable (BR-RE)

Optical Memory Characteristics



Magnetic Tape

- Serial access
- Slow
- Very cheap
- Backup and archive
- Linear Tape-Open (LTO) Tape Drives
  - Developed late 1990s
  - Open source alternative to proprietary tape systems

Linear Tape-Open (LTO) Tape Drives

	LTO-1	LTO-2	LTO-3	LTO-4	LTO-5	LTO-6
Release date	2000	2003	2005	2007	TBA	TBA
Compressed capacity	200 GB	400 GB	800 GB	1600 GB	3.2 TB	6.4 TB
Compressed transfer rate (MB/s)	40	80	160	240	360	540
Linear density (bits/mm)	4880	7398	9638	13300		
Tape tracks	384	512	704	896		
Tape length	609 m	609 m	680 m	820 m		
Tape width (cm)	1.27	1.27	1.27	1.27		
Write elements	8	8	16	16		

Internet Resources

- Optical Storage Technology Association
  - —Good source of information about optical storage technology and vendors
  - —Extensive list of relevant links
- DLTtape
  - —Good collection of technical information and links to vendors
- Search on RAID