Optical Recording and Communications

Observations about Optical Recording and Communications

- Optical disks can store lots of audio or video
- That audio or video is of the highest quality
- Optical disks continue to play perfectly for years
- Playback of optical disks involves lasers
- Lasers and fibers are used in communication

5 Questions about Optical Recording and Communication

- How is information represented digitally?
- How is information recorded on an optical disk?
- How is information read from an optical disk?
- How can light carry information long distances?
- Why does light follow an optical fiber's bends?

Question 1

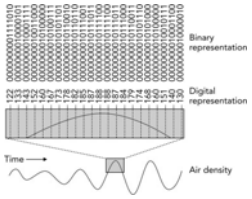
- How is information represented digitally?

Review of Digital Representation

- Audio or video info is a sequence of numbers
- Each number can be represented digitally
  - by putting specific symbols in a set of digits.
  - Digital representations often involve binary digits,
  - which can each hold only two symbols: 0 and 1.
  - Each symbol is a discrete value of a physical quantity
- Digital representations have
  - good noise-immunity
  - and permit error correction (elimination of noise).

Digital Audio

- The air pressure in sound is measured thousands of times per second
- Each measurement is represented digitally using about 16 binary digits, each a 0 or a 1.

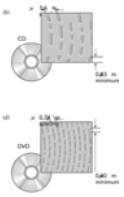


Question 2

- How is information recorded on an optical disk?

Structure of CDs and DVDs

- These disks have spiral tracks in reflective layers
- Each track contains pits and flats
- Digital symbols consist of the lengths of the pits and flats
- The track structure is made as small as can be detected by the playback system, so as to maximize the density of information.

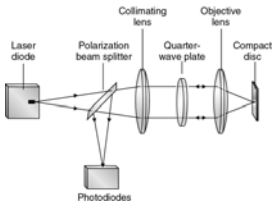


Question 3

- How is information read from an optical disk?

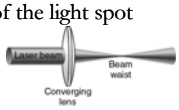
Playback Techniques

- Laser light is focused on the shiny layer
- Reflection is weaker from a pit than from a flat
- Reflected light is directed to photodiodes
- Reflected light intensity indicates pits or flats



Playback Issues

- Light must hit pits perfectly
  - Feedback optimizes the position of the light spot
- Light must hit only one pit
  - Use laser light—a single wave
  - Use a converging lens to focus that wave to a spot
- The wave forms a "waist"—its minimum width
  - Wave limits on focusing are known as diffraction
  - Waist can't be much smaller than a wavelength
  - so pit size can't be much smaller than a wavelength.



Advantages of Digital Recording

- Freedom from noise and media damage issues
  - Digital representation avoids information loss
  - Error correction ensures clean information
  - Surface contamination doesn't matter (much)
- High information density
- Data compression is possible
- Perfect, loss-less copies are possible

Question 4

- How can light carry information long distances?

Optical Communication

- Both analog and digital representations possible
- Analog representation
  - often involves AM modulation of the light
  - and is often used for remote process monitoring.
- Digital representation
  - often uses pulses with discrete amplitudes as symbols
  - and provides noise-immunity, error correction, compression, and channel-sharing.

Transmission Techniques

- Light in air: direct line-of-sight
  - Infrared remote controls
  - Infrared computer links
- Light in optical fibers: arbitrary paths
  - Optical cables and networks

The Components of Optical Communications

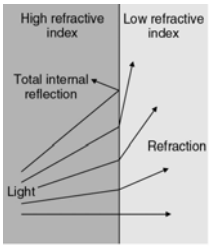
- Transmitters
  - Incandescent lamps (poor performance)
  - Light Emitting Diodes (adequate performance)
  - Laser Diodes (high performance)
- Receivers
  - Photoresistive cells (poor performance)
  - Photodiodes (high performance)
- Conduits
  - Optical Fibers (ranging from poor to high performance)

Question 5

- Why does light follow an optical fiber's bends?

Total Internal Reflection

- As light enters a material with a lower index of refraction, it bends away from the perpendicular
- If that bend exceeds 90°, the light reflects instead
- That reflection is perfect: total internal reflection



Introductory Question (revisited)

- When you submerge a digital watch in water and tilt it just right, the watch's face appears to be a perfect mirror. This mirror reflection is from

A. the outer (front) surface of the watch face
B. the inner (back) surface of the watch face

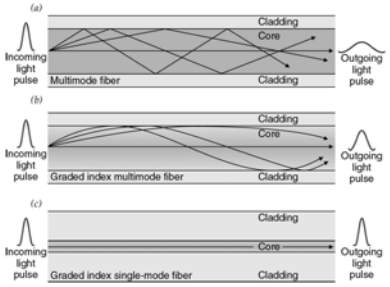
Optical Fibers

- An optical fiber consists of a high-index glass core in a low-index glass sheath
- When light tries to leave the core at a shallow angle, it experiences total internal reflection
- Light bounces endlessly through the core and emerges from the end of the fiber
- If the glass is pure and perfect enough, the light may travel for many kilometers through the fiber

Communication Issues

- Information is sent as a stream of digital symbols
  - Those symbols are usually pulses of light
  - If pulses spread out and overlap, information is lost
- To keep pulses from spreading in time
  - all the light must follow a single path through fiber
  - all frequencies of light must travel at the same speed
- The fiber's structure and materials are critical
- To limit possible paths, use a "single mode" fiber

Optical Fiber Types



Communication Issues

- To limit frequency-related spreading of pulses
  - minimize dispersion with monochromatic laser light
  - in low-dispersion glass at its optimal wavelength.
- Since light attenuates as it passes through fiber
  - use low-loss glass
  - and amplify the light periodically,
  - using fiber laser amplifiers.
- Systems using different colors can share a fiber!

Summary about Optical Recording and Communication

- Optical disks store information as pits and flats
- Focused laser light reads that information
- Digital representations allow perfect playback
- Optical fibers carry information as light