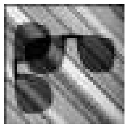
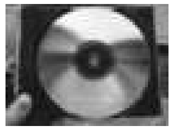
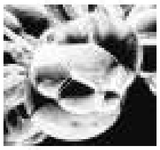
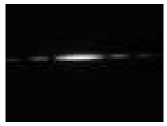
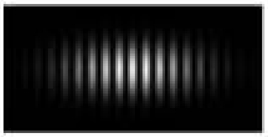
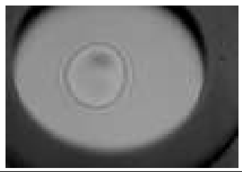
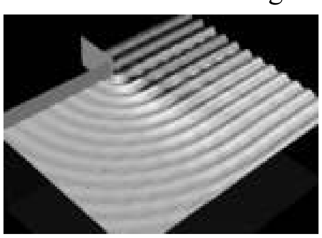
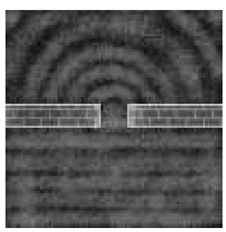





Wave Nature of Light

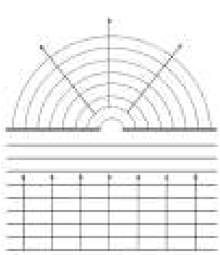




Diffraction

- Diffraction is the bending of a wave around a barrier or through an opening into the shadow region.

Diffraction



A wave is diffracted by an aperture.

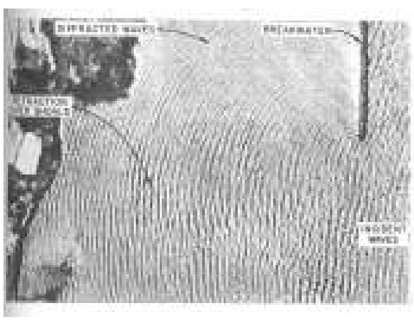
- The amount of diffraction depends on the size of the barrier or opening compared to the wavelength of the wave.
- Longer wavelengths exhibit more diffraction.
  - Owl hoots around trees
  - Water waves around small boats
  - Light waves diffract for very small openings – on the order of 1 wavelength

Diffraction Applet

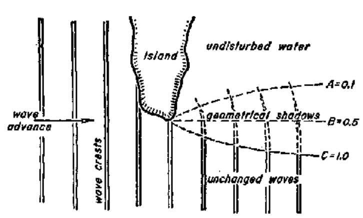
- This applet shows the diffraction of waves by a narrow opening.
- The waves bend into the shadow region.

Breakwater Diffraction

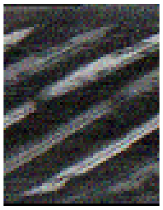
- Water waves diffract around barriers which have constructed as breakwaters.



Small Island Diffraction



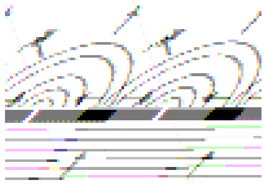
Huygens' Principle



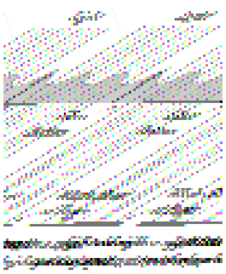
Christiaan **Huygens**

(1629-1695)

- According to Huygens' principle, each of the two slits in Young's experiment acts as a point source of light waves.

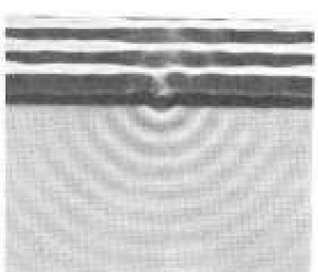


Ripple Tank Waves



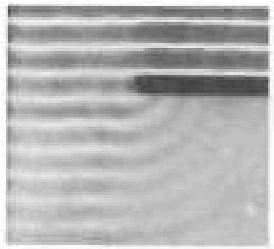
- The crests of water waves act as converging lenses for the light shining from above.
- On the screen, the crests are bright, and the troughs are dark.

Ripple Tank Waves



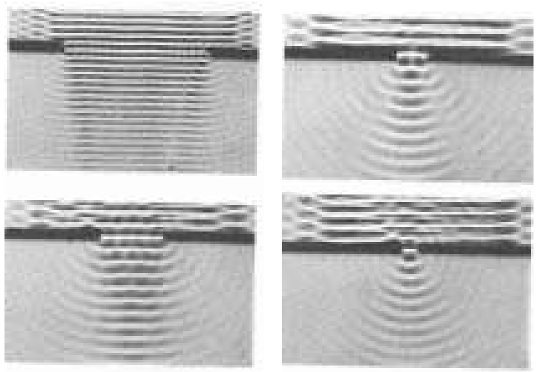
Diffraction of ripples through a narrow opening.

Ripple Tank Waves



Diffraction of ripples around the edge of a barrier.

Diffraction Slit Width Variation



Diffraction Pattern - Fingers

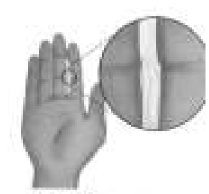
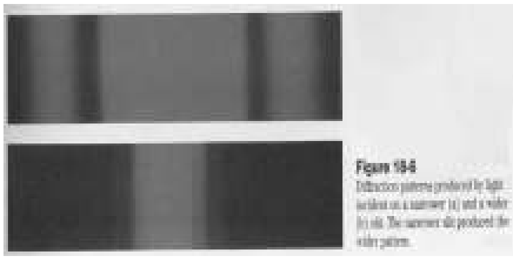


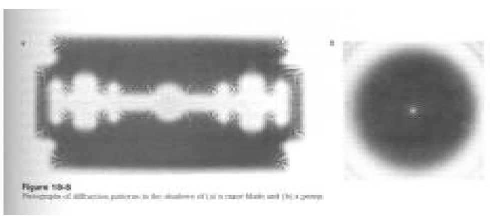
Figure 18-7

- Make a narrow opening between two fingers and look through the opening at a light. You will see thin fringes resembling hairs. These are nodes or dark fringes.

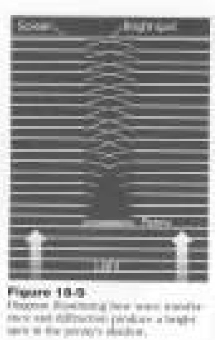
Diffraction – Slit Width



Razor Blade & Penny Diffraction



Poisson's Spot Explained



Diffraction Links

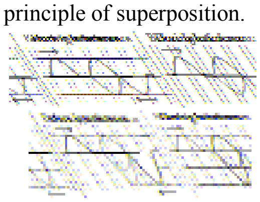
- http://www.cfd-solutions.co.uk/waves.htm
- http://www.spacesciencegroup.nsula.edu/lessons/defaultie.asp?Theme=waves&PageName=diffraction
- http://lectureonline.cl.msu.edu/~mmp/kap13/cd372.htm
- http://www.glenbrook.k12.il.us/gbssci/phys/Class/waves/u10l3b.html
- http://www.coastal.udel.edu/ngs/waves.html

Interference

- When two waves interfere, the resulting displacement of the medium at any location is the algebraic sum of the displacements of the individual waves at that same location. This is called the principle of superposition.

Constructive Interference

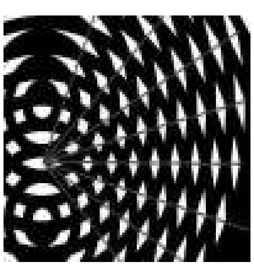
Antinode



Destructive Interference

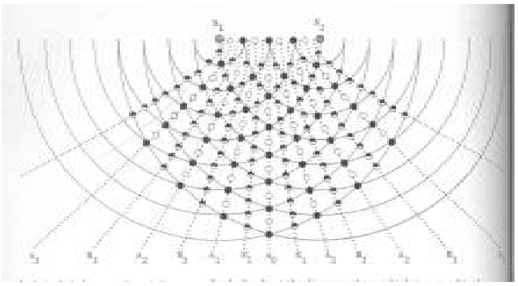
Node

Double Source Interference

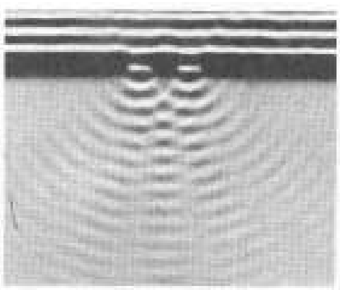


- When 2 periodic circular patterns interfere, a pattern of constructive and destructive interference emerges.
- “Lines” connecting nodes are called nodal lines
- “Lines” connecting antinodes are called antinodal lines

Double Source Nodal Lines



Ripple Tank Waves



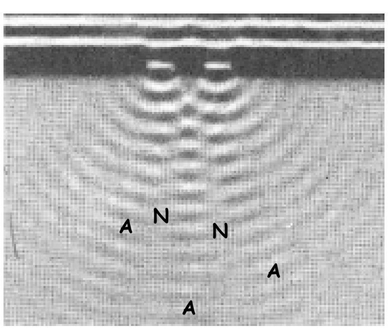
Diffraction of ripples through two narrow openings.

The diffraction due to the two narrow openings results in a pattern of nodal and antinodal lines similar to that of a double source interference pattern.

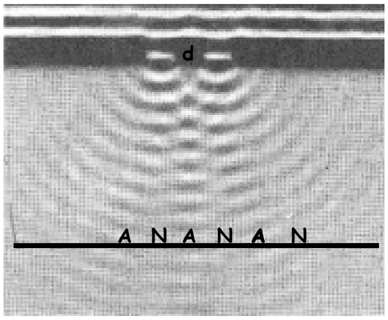
Ripple Tank Waves

Antinodal Lines

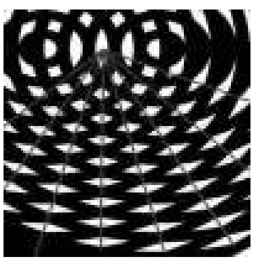
Nodal Lines



Inserting a Screen

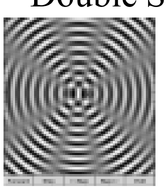


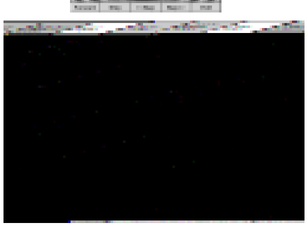
Double Source Interference

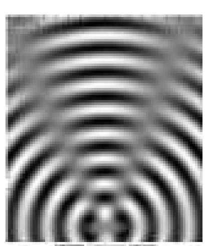


- When 2 periodic circular patterns interfere, a pattern of constructive and destructive interference emerges.
- "Lines" connecting **nodes** are called nodal lines
- "Lines" connecting **antinodes** are called antinodal lines

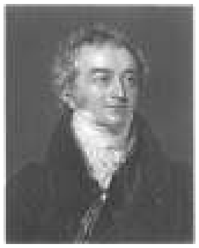
Double Source Applets







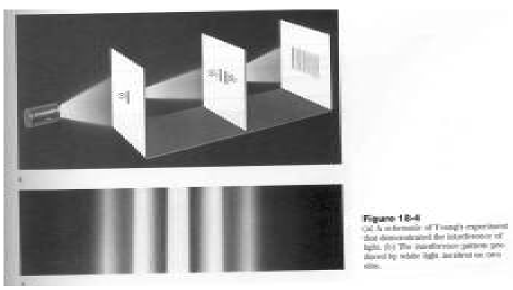
Thomas Young



1773 - 1829

- Scientist
- Physician
- Renaissance Man
- Interference
- Elastic Behavior of Solids
- Kinetic Energy
- Work and Energy Connection

Double Slit Interference



Light Interference

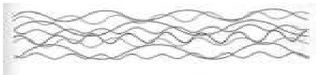
Interference is most noticeable when light is:

- *Monochromatic* -- This means light with a specific wavelength.
- *Coherent*. This means the phase difference between the light waves remains constant over time.

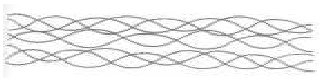
Laser light is monochromatic and coherent.

Light from incandescent lamps is *incoherent*.

Coherent & Incoherent Light



◄ Figure 31.25
Incoherent white light contains waves of many frequencies and wavelengths that are out of phase with one another.



◄ Figure 31.26
Light of a single frequency and wavelength can still be out of phase.

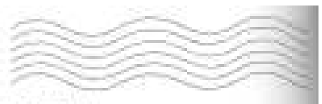
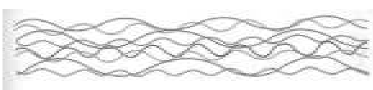


Figure 31.27

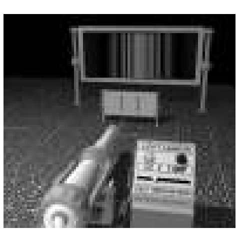
Incoherent Light

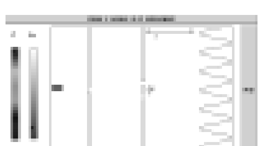


◄ Figure 31.25
Incoherent white light contains waves of many frequencies and wavelengths that are out of phase with one another.

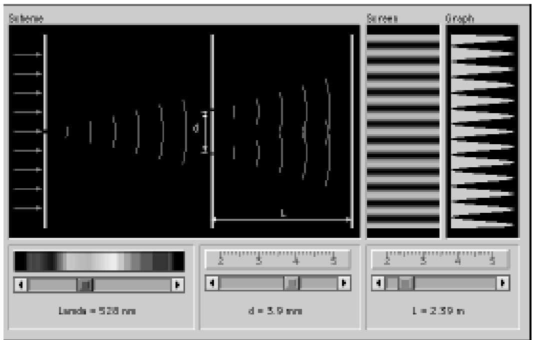
- Atoms emit radiation. For example the "excited" neon atoms in a neon sign emit light. Normally, atoms radiate their light in random directions at random times. The result is incoherent light.

Young’s Double Slit Applets

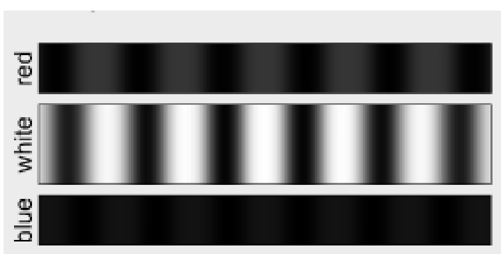




Young's Double Slit Layout



Wavelength Comparisons



Interference - Wavelength

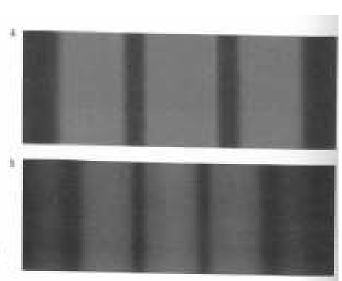
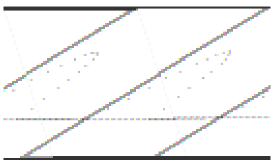
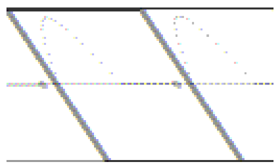
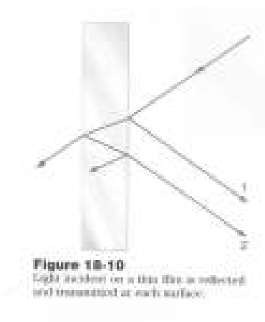


Figure 18-5

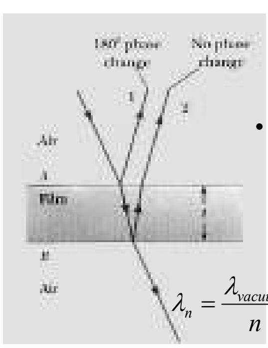
Reflections at Boundaries

Slow Medium to Fast Medium	Fast Medium to Slow Medium
	
Free End Reflection No phase change	Fixed End Reflection 180° phase change

Thin Film Interference



Thin Film Interference



$$\lambda_n = \frac{\lambda_{vacuum}}{n}$$

Phase change of ray 1

$$l_{eff\,1} = \frac{1}{2}\lambda \qquad \frac{l_{eff\,1}}{\lambda} = \frac{1}{2}$$

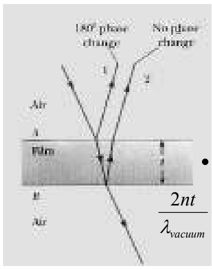
- Phase change of ray 2

$$l_{eff\,2} = 2t \qquad \frac{l_{eff\,2}}{\lambda} = \frac{2t}{\lambda}$$

- In terms of wavelength in vacuum

$$\frac{nl_{eff\,2}}{\lambda_{vacuum}} = \frac{2tn}{\lambda_{vacuum}}$$

Thin Film Interference



- difference in phase shifts of the two rays.

$$\frac{2nt}{\lambda_{vacuum}} - \frac{1}{2}$$

- Destructive Interference

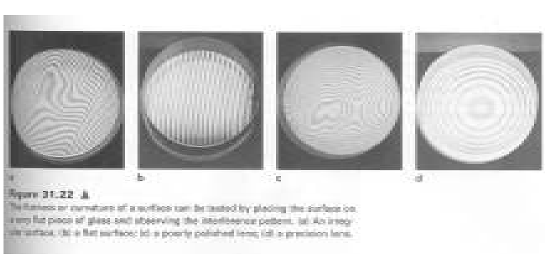
$$\frac{2nt}{\lambda_{vacuum}} - \frac{1}{2} = -\frac{1}{2}, \frac{1}{2}, \frac{3}{2}, \ldots \qquad \frac{2nt}{\lambda_{vacuum}} = m \quad m = 0,1,2,\ldots$$

- Constructive Interference

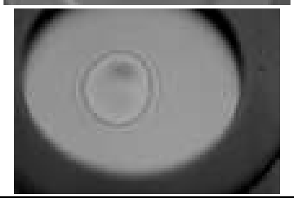
$$\frac{2nt}{\lambda_{vacuum}} - \frac{1}{2} = m \qquad m = 0,1,2,\ldots$$

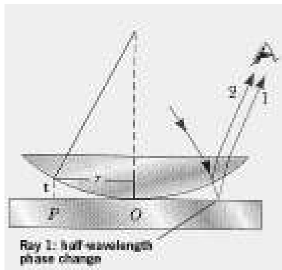
Air Wedge Interference

Air Wedge Interference

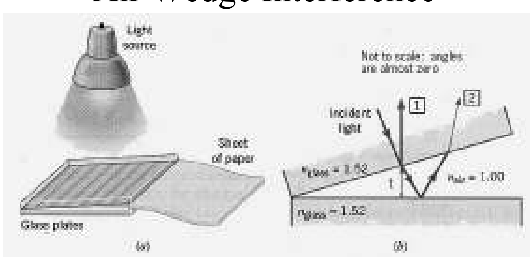


Newton's Rings





Air Wedge Interference



Constructive Interference

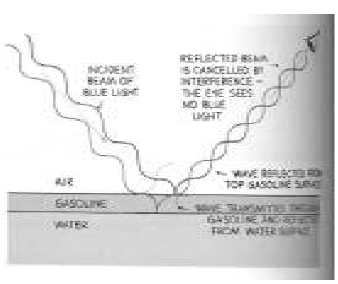
$$2t = \left(m - \frac{1}{2}\right)\lambda$$

Destructive Interference

$$2t = m\lambda$$

Fringe Spacing $\Delta t = \dfrac{\lambda}{2}$

Iridescence



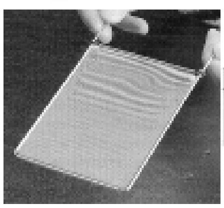
Iridescence

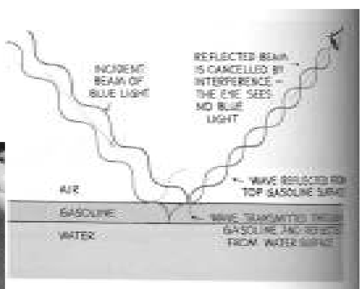
Figure 18-12
The colors on the puddle are caused by interference of light reflected from the top and bottom of the thin oil film floating on the surface.

Figure 18-13
Light transmitted through a thin film also displays interference.

Iridescence

Figure 31.24 ▶
The thin film of gasoline is just the right thickness so that monochromatic blue light reflected from the top surface of the gasoline is canceled by light of the same wavelength reflected from the water.

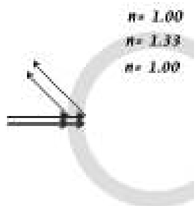




Soap Film Interference

- This soap film varies in thickness and produces a rainbow of colors.
- The top part is so thin it looks black.
- All colors destructively interfere there.

Sample 6



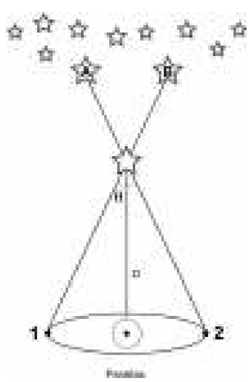
- A soap bubble is illuminated by a combination of red light ($\lambda = 692$ nm) and blue light ($\lambda = 519$ nm).
- What minimum thickness of the soap bubble film will result in blue light being not reflected?

$$t = \frac{m\lambda_{vacuum}}{2n}$$

$$t = \frac{1 \cdot 519\,\text{nm}}{2 \cdot 1.33} = 195\,\text{nm}$$

- Parallax

Apparent change in position of object due to shift in position of observer



Camera 1 – Camera 2

Binocular Vision

- Two Eyes
- Camera 1 – Camera 2
- One of the reasons that we can perceive depth.
  - Our brain uses the two images (one from each eye) to judge the distance to an object.
  - Subconscious use of parallax

3D Circle

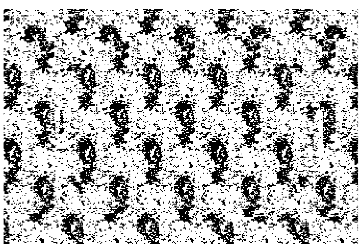
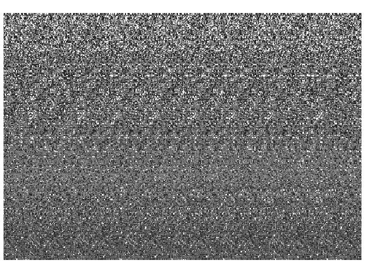


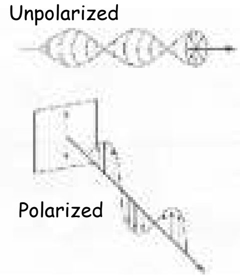
fig. 5

Cow



Unpolarized & Polarized Light

Polarization of Light



Electric fields of unpolarized light vibrate in all directions perpendicular to the direction the light travels.

A **polarizing filter** can constrain light to vibrate in only one direction

Polarizing Filters

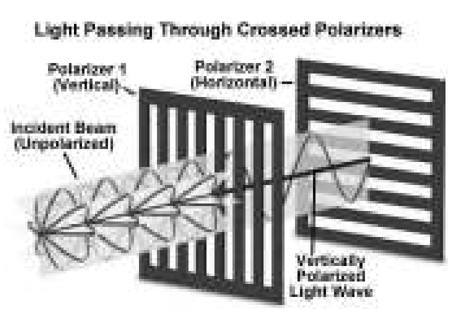
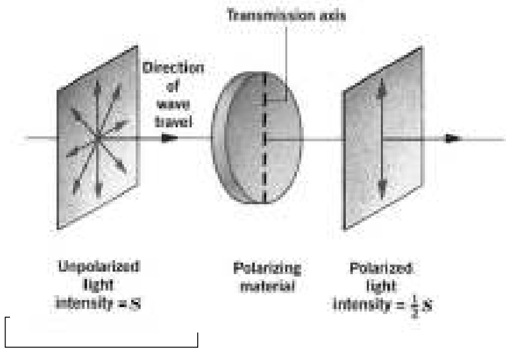
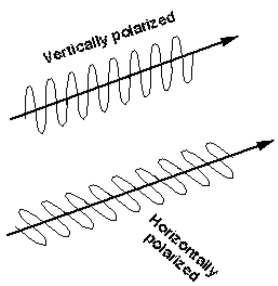


Figure 1

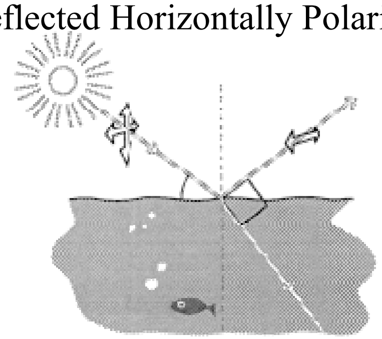
Polarization



Polarization



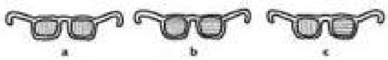
Reflected Horizontally Polarized



•**Polarization of Reflected Light**

Polarizing Glasses

Which pair of glasses is best suited for automobile drivers? (The polarization axes are shown by the straight lines.)

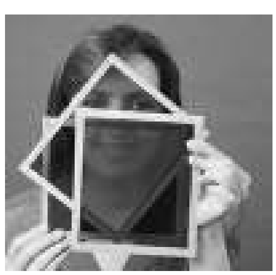


Two Polarizers

Parallel Axes

Perpendicular Axes

Insert Third Polarizer



Polarization Applets

- **Molecular View of Polarization**
- **Polarization of Reflected Light**
- **Polarizing Filters**

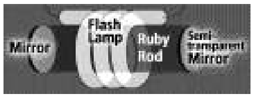
LASER

- Light
- Amplification by
- Stimulated
- Emission of
- Radiation

Stimulated Emission

- If a photon whose frequency corresponds to the energy difference between the excited and ground states strikes an excited atom, the atom is stimulated as it falls back to a lower energy state to emit a second photon of the same (or a proportional) frequency, in phase with and in the same direction as the bombarding photon.
- This process is called *stimulated emission*. The bombarding photon and the emitted photon may then each strike other excited atoms, stimulating further emission of photons, all of the same frequency and phase. This process produces a sudden burst of coherent radiation as all the atoms discharge in a rapid chain reaction.

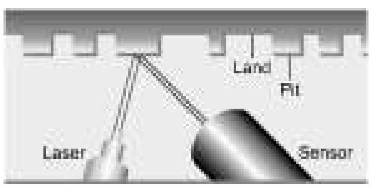
Laser



- A laser is a device that creates and amplifies a narrow, intense beam of coherent light.

•In a ruby laser, light from the flash lamp, in what is called "optical pumping", excites the molecules in the ruby rod, and they bounce back and forth between two mirrors until coherent light escapes from the cavity.

Interference in CDs

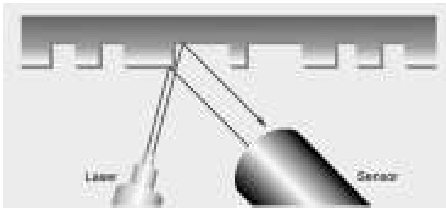


- Laser shines light onto track of CD
- Discs have "pits" in the surface
- Sensor reads signal from laser
- CD Burners

Constructive Interference

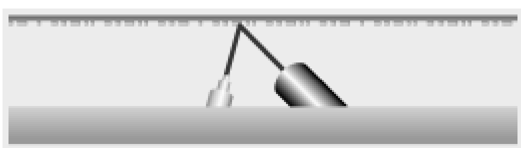
- When entire beam reflects from the "pit" or when entire beam reflects from the "land" – constructive interference results – "on"

Destructive Interference



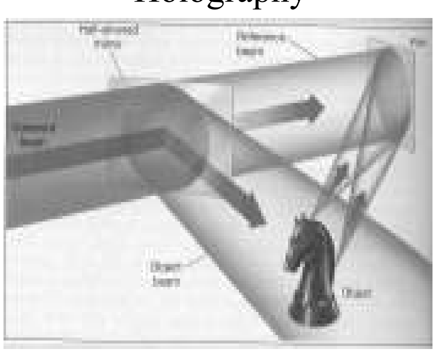
- “Pits” are ¼ λ above the “land”
- When part of beam reflects from “pit” and part from “land”
- Destructive interference – interpreted as “off”

Laser Scans Disc



- Intensity of the reflected light varies as the disc rotates.
- Intensity is measured and interpreted as a series of ones and zeros (digital information).
- Information is then relayed to other systems that interpret it.

Holography



Viewing a Hologram