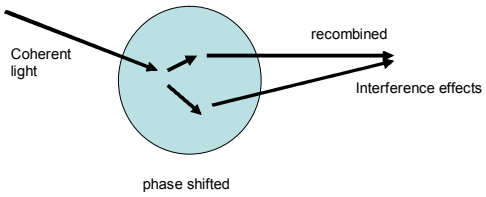
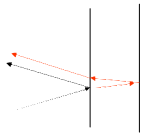
6.1 Interference and Diffraction II.

Thin film interference
Michelson Interferometer
X-ray Diffraction

Interference effects

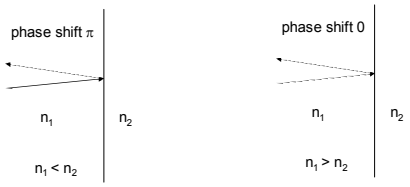


Thin film interference



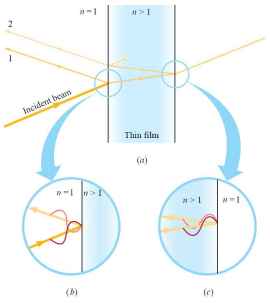
- In thin film interference the phase difference is due to reflection at either side of a thin film of transparent material.
- The phase difference is due to two factors:
  - Path difference through the film (corrected for the change in speed of light in the material)
  - Phase shift at the interface

Phase shift due to reflection



- When a wave is reflected in going from a medium with a lower refractive index to a higher refractive index the phase is shifted by π.
- When a wave is reflected in going from a medium with a higher refractive index to a lower refractive index, the phase is not shifted.

Interference due to thin film reflection (e.g. film in air)



Beams 1 and 2 reflected off the front and back surfaces of a thin film combine to show interference effects.

- A net phase shift difference of π due to reflection
- Beam 2 has a phase shift due to path difference

Conditions for constructive and destructive interference (film in air)

Constructive interference

$$2d = (m + \frac{1}{2})\frac{\lambda}{n}$$

λ/n is the speed of light in the media with refractive index n.

The condition involves the half-integer wavelength because of the phase shift due to reflection

Destructive interference

$$2d = m\frac{\lambda}{n}$$

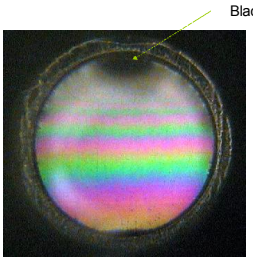
The condition involves integer wavelengths because of the phase shift of π

As d-> 0, there is destructive interference due to the phase shift

Soap film Example 37.4

A rectangular loop of wire 20 cm square is dipped into a soap solution an then held vertically, producing a soap film whose thickness varies linearly from essentially zero at the top to 1.0μm at the bottom. If the film is illuminated with 650 nm light how many bright bands will appear?

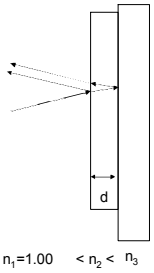
Soap film interference pattern



Anti-reflective Coating

Anti-reflective coatings are used to reduce reflections at the air-glass interface.

Anti-reflective Coating



Anti-reflective coatings consists of a thin-layer of material with a refractive index in between that of air and glass. Destructive interference between light reflected at the two surfaces reduces the intensity of reflected light.

The phase shift is π at both surfaces. Therefore no phase shift difference

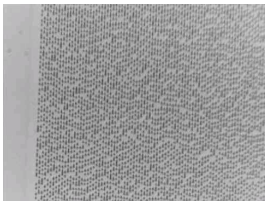
Condition for destructive interference.

$$2d = (m + \frac{1}{2})\frac{\lambda}{n_2}$$

Question

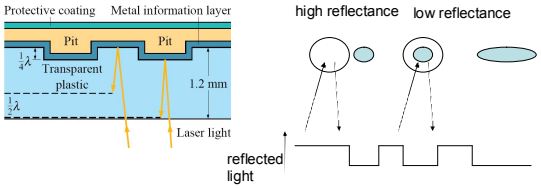
An anti-reflective coating of MgF_2 (n=1.38) is used on a glass surface to reduce reflections. Find the minimum thickness of the coating that can be used for green light (λ=550 nm).

Compact discs



Digital information stored on pits in tracks.
Spacing between tracks 1.6μm

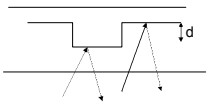
optical compact discs CD



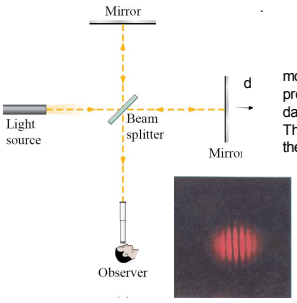
Coding of information read out by a laser beam.
Reflection from tracks is modulated by destructive interference.

Question

A cd is made out of a plastic with a refractive index of 1.55. If the cd is scanned with a laser with a wavelength of 780 nm how high should the pits on the surface be for destructive interference.



Michelson Interferometer



moving the mirror by a distance d produces fringe shifts, from bright to dark to bright.
The no. of fringe shifts, m is related to the change in the path length.

$2d = m\lambda$

Interference pattern

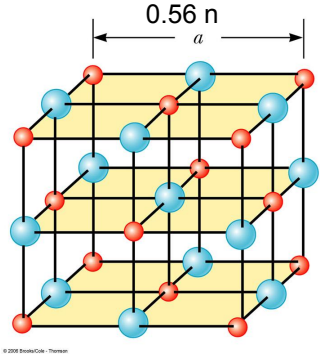
Question

A Michelson interferometer uses a hydrogen emission line at 486.1 nm. As you move one mirror, 530 bright fringes pass a fixed point in the viewer. How far did the mirror move?

X-ray diffraction

- X-ray diffraction uses x-rays to scatter from atoms in a crystal.
- The crystal acts as a 3-dimensional grating.
- The pattern of spots in the diffracted beam contains information about the 3-dimensional structure of atoms in the crystal.

NaCl Crystal – an ordered array of atoms



Diffraction of x-rays from a crystal.
Each atom acts as a wave source.

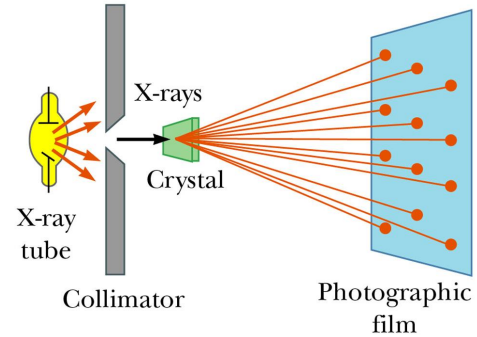
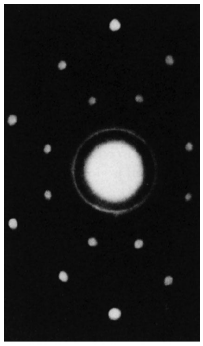
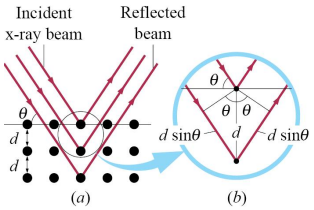


Fig. 27-11, p.883

X-ray diffraction pattern of NaCl



Bragg condition



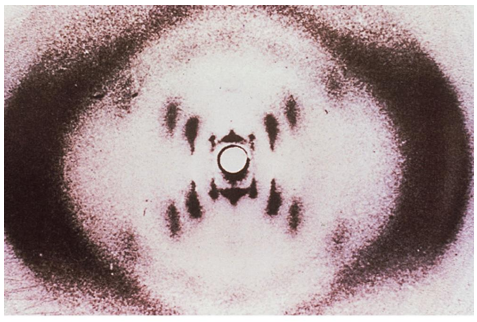
X-rays are scattered from planes of atoms in a crystal lattice spaced a distance d apart.
The condition for reflection is the condition for constructive interference of x-rays scattered from different planes (pathlength diffference =mλ.)

$$2d \sin\theta = m\lambda$$

Note the difference in the definition of θ

Question

An x-ray source with a wavelength of 0.154 nm passes through a NaCl crystal and is shows a first order diffraction peak at an angle of 15° away from the central maximum. What is the spacing of the crystal plane responsible for the diffraction?



X-ray diffraction pattern from a crystalline fiber of DNA. Watson And Crick used this data to deduce the structure of the DNA molecule

DNA structure determined by x-ray diffraction