WAVE OPTICS

WAVEFRONTS AND REFRACTION

- Points of constant phase are called wavefronts. Wavefronts striking a surface reflect according to $\theta_i = \theta_r$. The velocity of a wave is given by the frequency and wavelength: $v = f\lambda$.
- When a wave enters a medium with a different index of refraction n the frequency does not change but the velocity does: $n = c/v$, where c is the speed of light in vacuum (air) and v is the velocity of light inside the medium. The wavelength also changes: $\lambda_n = \lambda/n$

COHERENT LIGHT AND INTERFERENCE

- Coherent light is light emitted with one particular phase. Conventional light is produced by emission from individual atoms with random phases and is therefore incoherent. LASERs are coherent.
- If we split a light beam of a fixed wavelength into two beams, then they will interfere constructively or destructively depending on the pathlength difference ΔL:
  Constructive Interference: $\Delta L = m\lambda$ with $m = 0, 1, 2, \ldots$
  Destructive Interference: $\Delta L = (m + 1/2)\lambda$ with $m = 0, 1, 2, \ldots$

DOUBLE-SLIT INTERFERENCE

- Monochromatic light on a mask with two thin slits which are separated by a distance d will produce an interference pattern:
  Constructive interference (bright fringes): $d\,\sin\theta = m\lambda$ $m = 0, 1, 2, \ldots$
  Destructive interference (dark fringes): $d\,\sin\theta = (m + 1/2)\lambda$ $m = 0, 1, 2, \ldots$
- If D is the distance between screen and the slits, then the location of maxima and minima on the screen with respect to the central maximum is given by $y_m = D\tan\theta_m = D\sin\theta_m = mD\lambda/d$. The approximation $\tan\theta = \sin\theta = \theta$ (in radians) is valid for small angles.
- The intensity I on the screen as a function of the angle θ is given by $I = 4I_0\cos^2(\phi/2)$, where I_0 is the intensity of a single slit and $\phi = (2\pi d/\lambda)\sin\theta$.

THIN-FILM INTERFERENCE

- Light incident on a thin film reflects partly from the front surface, and enters partly the glass which is then reflected from the back surface. Since both light beams come from the same source, they have a fixed phase relationship which depends on the difference in path lengths.
- In the medium, the wavelength changes from λ to $\lambda_2 = \lambda/n_2$. In addition, if light is reflected by a surface to a medium with a higher n, its phase changes by $180°$, and if light is reflected on a surface to a medium with lower n, the phase remains unchanged.

	$n_1 < n_2 > n_3$ or $n_1 > n_2 < n_3$	$n_1 < n_2 < n_3$ or $n_1 > n_2 > n_3$
Constructive Interference	$2L = (m + 1/2)\lambda/n_2$	$2L = m\lambda/n_2$
Destructive Interference	$2L = m\lambda/n_2$	$2L = (m + 1/2)\lambda/n_2$

SINGLE SLIT DIFFRACTION

- There is no fundamental difference between diffraction and interference.
- One talks of diffraction when there are many waves involved in the interference instead of only two.
- If one illuminate a thin slit with a beam of light one observes in addition to the central bright spot, other (much less) bright spots on the sides, separated by interference minima. This pattern is due to interference between the light-wavelets going through the slit.
- Angles for diffraction minima: $m\lambda = a \sin\theta \;\; m = 1, 2, 3, \ldots$ where a is the slit width.
- Note: $m = 0$ is missing in these formulas – The bright central maximum is located there. The intensities of the noncentral maxima are much less than that of the central maximum. The width of the central maximum is twice that of the noncentral maxima.
- The intensity I on the screen as a function of the angle θ is given by $I = I_m(\sin\alpha/\alpha)^2$, where I_m is the maximum intensity which occurs at the center and $\alpha = \phi/2 = (\pi a/\lambda)\sin\theta$.

DIFFRACTION BY A DOUBLE SLIT

- For a double slit with finite slit widths a the intensity is given by a combination of the single slit diffraction and the double slit interference: $I = I_m(\cos^2\beta)(\sin\alpha/\alpha)^2$, with $\beta = (\pi d/\lambda)\sin\theta$ and $\alpha = (\pi a/\lambda)\sin\theta$, where d is the distance between the two slits and a is the width of the slits.

DIFFRACTION GRATING

- A diffraction grating is a mask containing a very large number of parallel slits at equal distances d.
- Waves from two neighboring slits will be in phase whenever: $\sin\theta = m\lambda/d \quad m = 0, 1, 2 \ldots$
- In the two-slit interference, destructive interference would only be given at exactly the midpoint of two consecutive maxima (path difference = $\lambda/2$). For a diffraction grating, there are many more possible conditions of destructive interference. Thus there are sharp maxima at angles given by the above equation, and between them, there is destructive interference.
- The number of slits is by one larger than the number of secondary minima between primary maxima.
- The interference pattern of the slit separation and the individual slit widths add up to the total interference pattern.