Course schedule / dates

Date / Time	Session
4/7 @ 11:30am	Discussion: Revision
4/7 @ 5pm	Mini-project submission deadline
4/11 @ 12noon	Mini-project presentations*
4/13 @ 12noon	Mini-project presentations*
4/14 @ 11:30am	Discussion: Revision*
4/18 @ 12noon	Mini-project presentations*
4/27 @ 8am – 10am	Final Exam

*Attendance expected at all sessions – there will be a quiz

Final exam info

- Date: Thursday April 27th 2023
- Time: 8am – 10am
- Location: EECS1500
- What to bring with you:
  - Calculator capable of complex math
  - Pens/pencils/ruler
- What will be provided:
  - Exam questions and paper to write on
  - Formula sheet
- You must sign to acknowledge the honor code statement.
- Questions will focus on material from lecture 12 onwards, but knowledge of earlier materials assumed.

Exam tips

- Write legibly
- Show your working, give explanations. You may have done the calculation correctly in your head, but the process is being graded too. Also, I can award points for an attempted calculation method even if the final answer is wrong.
- Check you’ve included units on final answers
- Consider how many points a question is worth to decide how much to write and how long to spend on it
- Attempt the question, write something! I try to give points wherever I can…

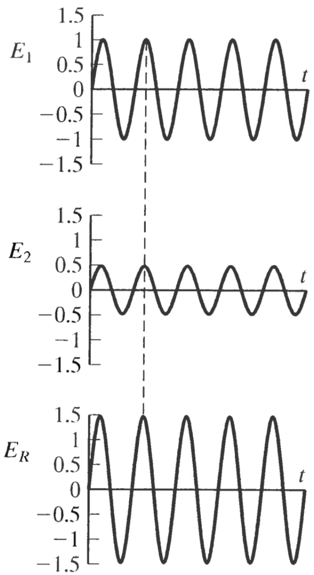
EECS 334: Principles of Optics

Revision of the course

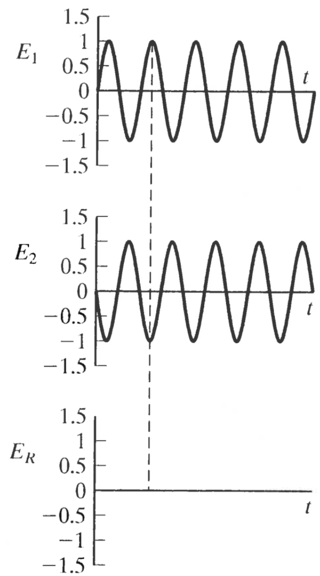
Superposition of waves

- Superposition principle: If Ψ_1 and Ψ_2 are independently solutions of the wave equation, then the linear combination $\Psi = a\Psi_1 + b\Psi_2$, where a and b are constants, is also a solution.

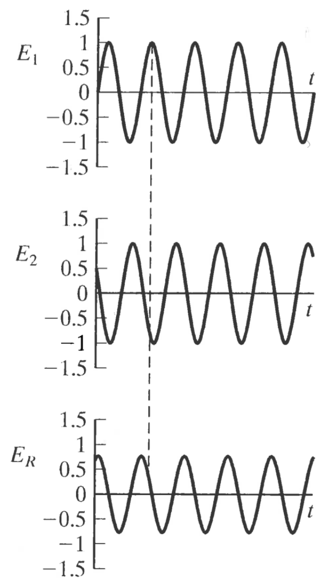
Constructive interference



Destructive interference



General superposition



Phasor diagrams

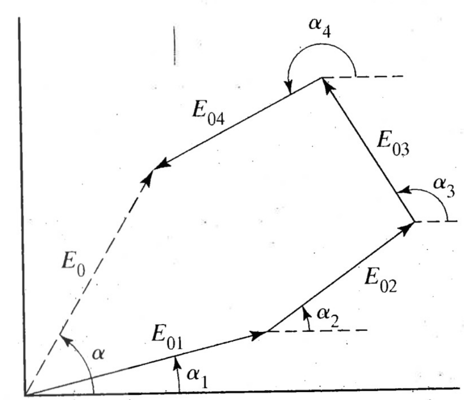


Figure 5-4 Phasor diagram for four harmonic waves of the same frequency. Superposition produces a resultant wave of the same frequency, with amplitude E_0 and phase α.

Superposition of waves

- Amplitude of resultant field, E_0, can be determined from

$$E_0^2 = \sum_{i=1}^{N} E_{0i}^2 + 2\sum_{j>i}^{N}\sum_{i=1}^{N} E_{0i}E_{0j}\cos\left(\alpha_j - \alpha_i\right)$$

- And the resultant phase can be determined from,

$$\tan\alpha = \frac{\sum_{i=1}^{N} E_{0i}\sin\alpha_1}{\sum_{i=1}^{N} E_{0i}\cos\alpha_1}$$

Random and Coherent sources

For N randomly phased sources of equal amplitude and frequency

$$E_0^2 = N E_0^2$$

If N sources are coherent and in phase so that all α_i are equal and amplitudes are equal

$$E_0^2 = N^2 E_0^2$$

Standing waves

- Forward and reverse wave exist → standing wave

$$E_R = A(x)\cos(\omega t) = 2E_0 \sin(kx)$$

- Nodes where A(x) = 0 or at $x = m\left(\frac{\lambda}{2}\right)$

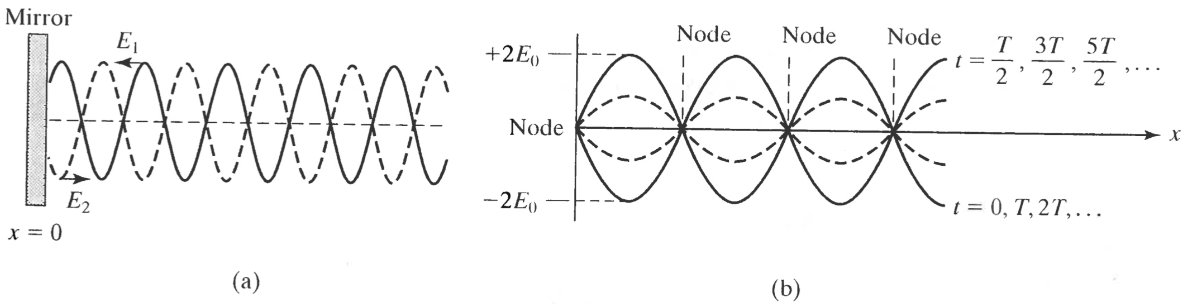


Figure 5-5 Standing waves. (a) A typical standing wave situation occurs when a wave E_1 and its reflection E_2 exist along the same medium. For the case shown, a π phase shift has occurred upon reflection so that a node (zero displacement) will exist at the mirror. (b) Resultant displacement of a standing wave, shown at various instants. The solid lines represent the maximum displacement of the wave. The displacement at the nodes is always zero.

Standing wave in a laser cavity

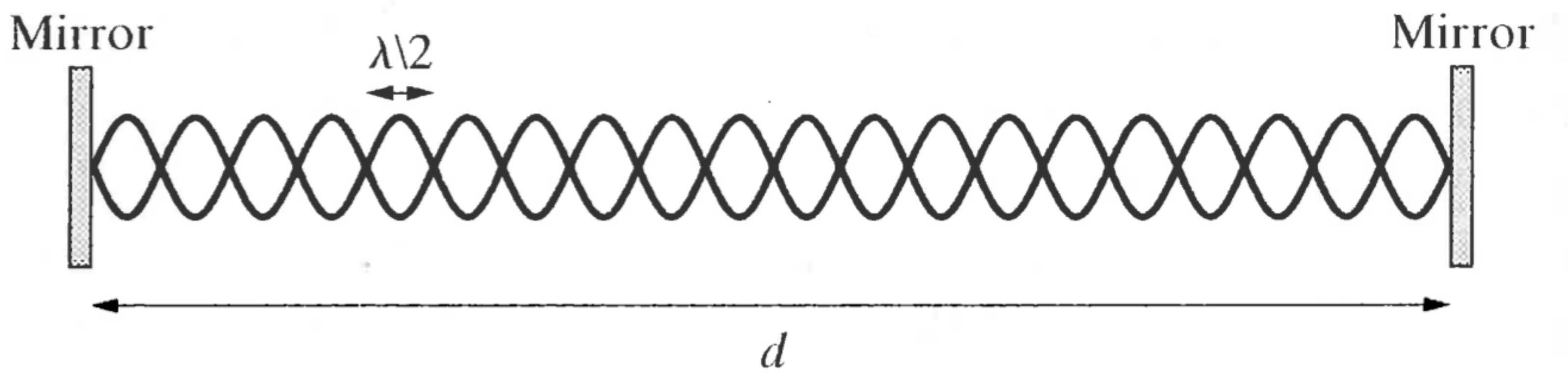


Figure 5-6 Standing wave mode of a laser cavity with mirror spacing d. Each loop of the standing wave envelope is of length $\lambda/2$. In a typical laser cavity, about 1 million half-waves fit into the length of the cavity.

The beat phenomena

- Waves with comparable amplitude but different ν

$$E_1 = E_0 \cos\left(k_1 x - \omega_1 t\right)$$
$$E_2 = E_0 \cos\left(k_2 x - \omega_2 t\right)$$

- Combine to produce

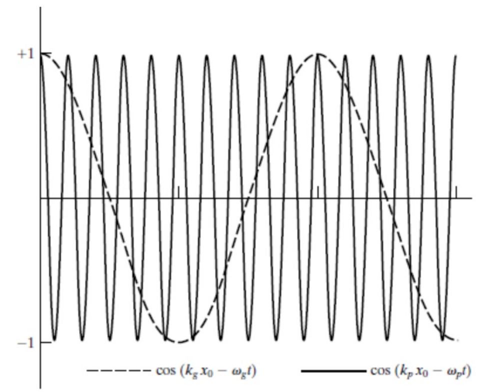
$$E_R = 2E_0 \cos\left(k_p x - \omega_p t\right)\cos\left(k_g x - \omega_g t\right)$$

$$\omega_p = \frac{\omega_1 + \omega_2}{2} \qquad k_p = \frac{k_1 + k_2}{2}$$

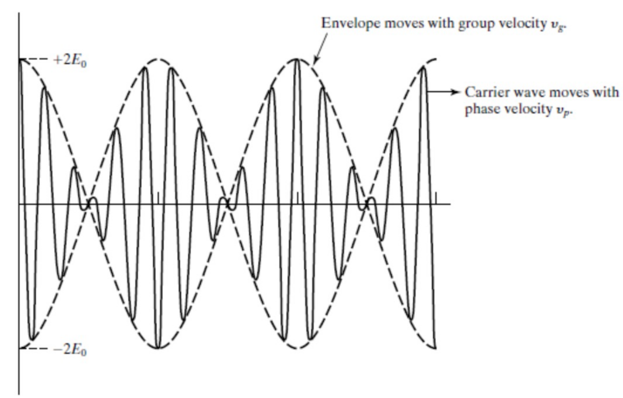
$$\omega_g = \frac{\omega_1 - \omega_2}{2} \qquad k_g = \frac{k_1 - k_2}{2}$$

- ω_g and k_g will be smaller than ω_p and k_p

(a) At $x=x_0$, where $\omega_p >> \omega_g$



(a)



(b)

(b) Modulated wave representing Equ^n 5.33

The beat phenomena

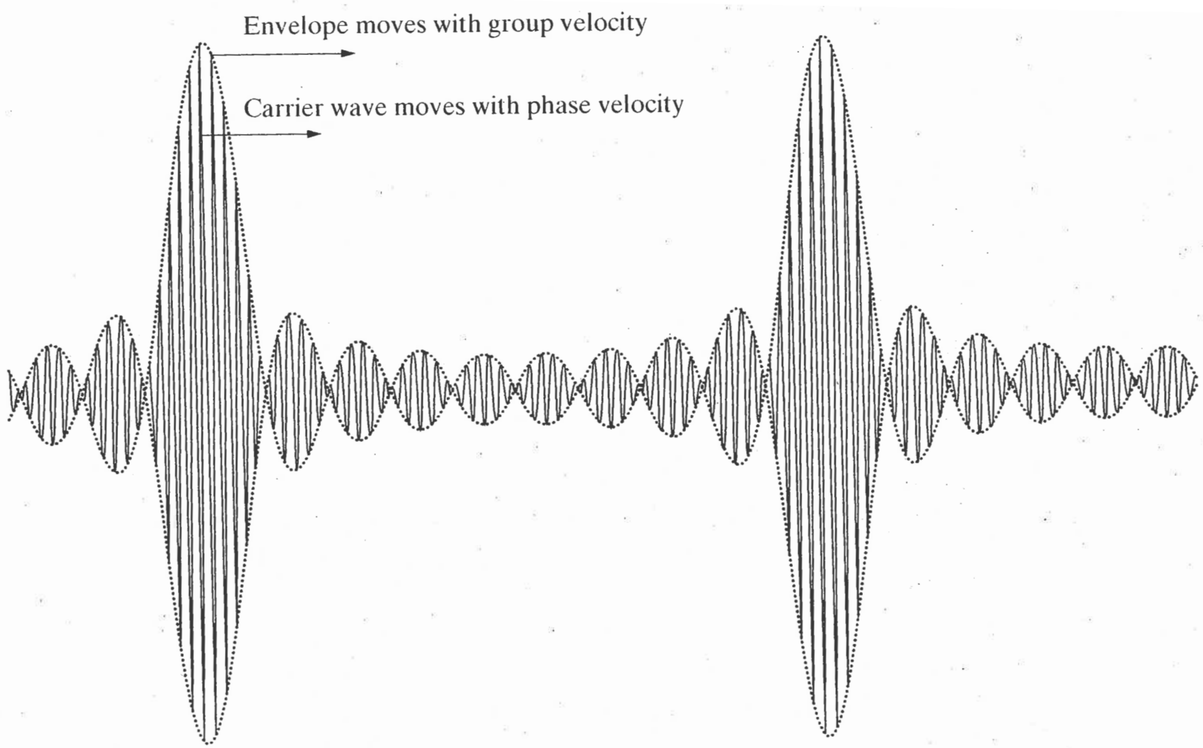


Figure 5-8 Snapshot of a waveform that is the sum of 10 equal-amplitude harmonic waves with frequency spacing about 1/50 of the average frequency of the constituent harmonic waves. The dotted-line envelope moves with the group velocity and the high-frequency carrier wave moves with the phase velocity.

Phase and Group velocities

- Dispersion → EM waves of different ω travel at different v in a medium

- Phase velocity → velocity of the harmonic wave constituting the signal
- Group velocity → velocity that the positions of the maximal constructive interference propagate at.

- High-v carrier wave
- Phase velocity $$v_p = \frac{\omega_p}{k_p} = \frac{\omega_1 + \omega_2}{k_1 + k_2} \approx \frac{\omega}{k}$$
- Where $\omega_1 \approx \omega_2 = \omega$ and $k_1 \approx k_2 = \omega$
- Envelope velocity → group velocity $$v_g = \frac{\omega_g}{k_g} = \frac{\omega_1 - \omega_2}{k_1 - k_2} \approx \frac{d\omega}{dk}$$

Phase and Group velocities

- Relationship to one another: $$v_g = v_p + k\left(\frac{dv_p}{dk}\right)$$
- In a non-dispersive medium $dv_p/dk = 0$ the phase and group velocities are equal. i.e. in vacuum, $v_p = v_g = c$
- In a dispersive medium, $v_p = c/n$ ($n = n(k)$), $\frac{dv_p}{dk} = \frac{d}{dk}\left(\frac{c}{n}\right) = \frac{-c}{n^2}\left(\frac{dn}{dk}\right)$
- And $$v_g = v_p\left[1 + \frac{\lambda}{n}\left(\frac{dn}{d\lambda}\right)\right]$$
- So for normal dispersion, $dn/d\lambda < 0$ and $v_g < v_p$

Learning outcome: To describe the processes of absorption, spontaneous emission, and stimulated emission and their rates in terms of Einstein's A and B coefficients

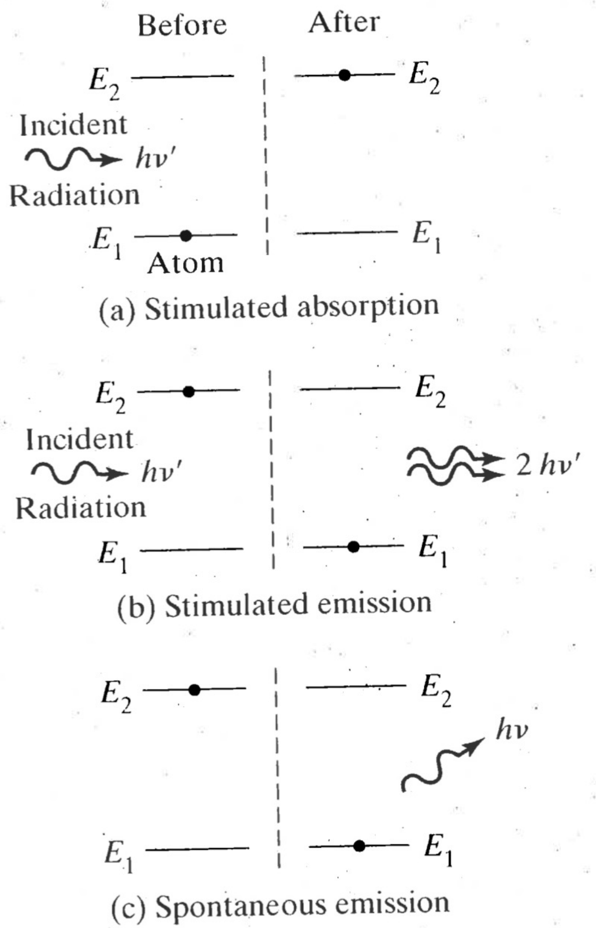


Figure 6-11 Three basic processes that affect the passage of radiation through matter.

- Stimulated absorption

$$R_{stimabs} = B_{12} g(\nu') \left(\frac{I}{c}\right) N_1$$

- Stimulated emission

$$R_{stimemi} = B_{21} g(\nu') \left(\frac{I}{c}\right) N_2$$

- Spontaneous emission

$$R_{sponemi} = A_{21} N_2$$

Learning outcome: To describe the processes of absorption, spontaneous emission, and stimulated emission and their rates in terms of Einstein's A and B coefficients

In thermal equilibrium

$$\frac{A_{21}}{B_{21}} = \frac{8\pi h\nu^3}{c^3}$$

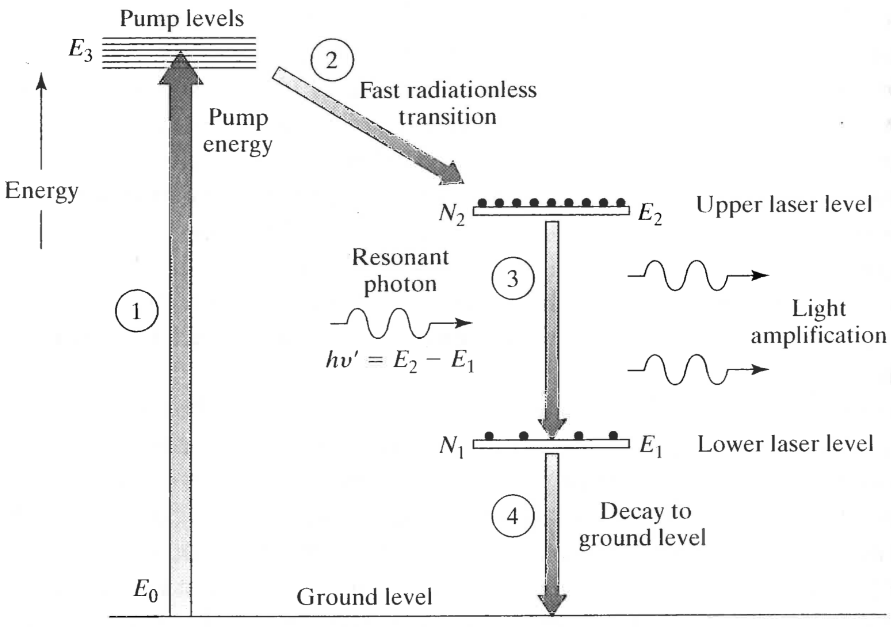
$$B_{12} = B_{21}$$

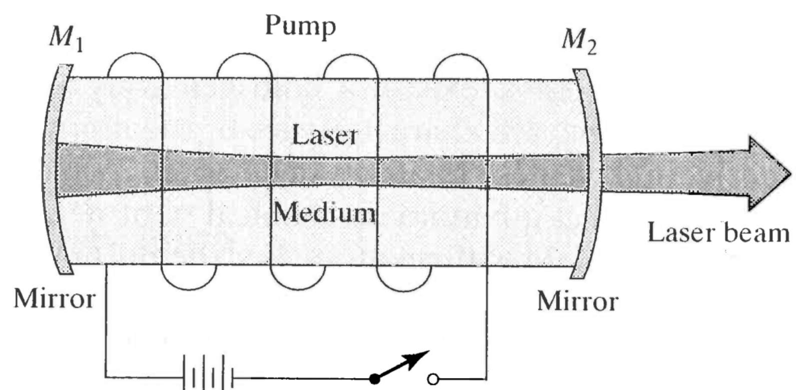
$$\frac{P_2}{P_1} = \frac{N_2}{N_1} = e^{-(E_2-E_1)/k_BT} < 1$$

i.e. in thermal equilibrium, stimulated absorption is more likely than stimulated emission.

Need population inversion $N_2 > N_1$ for amplification → achieved by pumping gain medium

Learning outcome: Explain the operation of a 3-level laser





4-level system
(note if ground and E_1 were
the same → 3-level system)

Laser light characteristics

- Monochromaticity: (almost) single wavelength
- Coherence:
  - Temporal coherence: degree of monochromaticity
  - Coherence time, t_c = average time the correct phase at a given position can be predicted
  - Spatial coherence: measure of phase front uniformity
  - Coherence length, $L_c = ct_c$, average length of light beam the phase of wave is unchanged
- Directionality: means laser beam maintains irradiance over long distances. Characterized by half-angular spread, θ, where ω_0 is the beam waist.

$$\theta = \frac{\lambda}{\pi \omega_0}$$

Learning outcome: Compute the interference patterns formed by wavefront division (Young's experiment)

- Superposition to form spatially varying constructive and destructive interference to form fringes

$$I = I_1 + I_2 + I_{12}$$

- Interference term $I_{12} = 2\epsilon_0 c \left\langle \mathbf{E_1} \cdot \mathbf{E_2} \right\rangle = \epsilon_0 c \mathbf{E_{01}} \cdot \mathbf{E_{02}} \left\langle \cos\delta \right\rangle$

- Phase difference $\delta = k(s_2 - s_1) + \phi_2 - \phi_1$

- For mutually incoherent beams, no interference $I = I_1 + I_2$

Learning outcome: Compute the interference patterns formed by wavefront division (Young's experiment)

- Mutually coherent beams produced by splitting a laser beam → recombine at detector
- Phase difference $\phi_2(t) - \phi_1(t + \delta t)$ is zero providing the difference between the paths δt is less than the coherence time $t_c = \dfrac{1}{\Delta\nu}$
- $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\delta$
- cos δ oscillates → interference fringes

m is 0 or integer

$I_{max} = I_1 + I_2 + 2\sqrt{I_1 I_2}$ when $\delta = 2m\pi$

$I_{min} = I_1 + I_2 - 2\sqrt{I_1 I_2}$ when $\delta = (2m+1)\pi$

- Fringe contrast → visibility

$$\text{visibility} = \frac{\mathrm{I_{max}} - \mathrm{I_{min}}}{\mathrm{I_{max}} + \mathrm{I_{min}}}$$

- Best contrast for $I_1 = I_2$

Learning outcome: Compute the interference patterns formed by wavefront division (Young's experiment)

- Constructive interference forms bright fringes at $y_m \approx \frac{m\lambda L}{a}$ for m = 0, $\pm$1, $\pm$2, …
- Separation between maxima $\Delta y = \frac{\lambda L}{a}$
- Intensity of the interference pattern on the screen is given by

$$I = 4I_0 \cos^2\left(\frac{\pi a y}{\lambda L}\right)$$

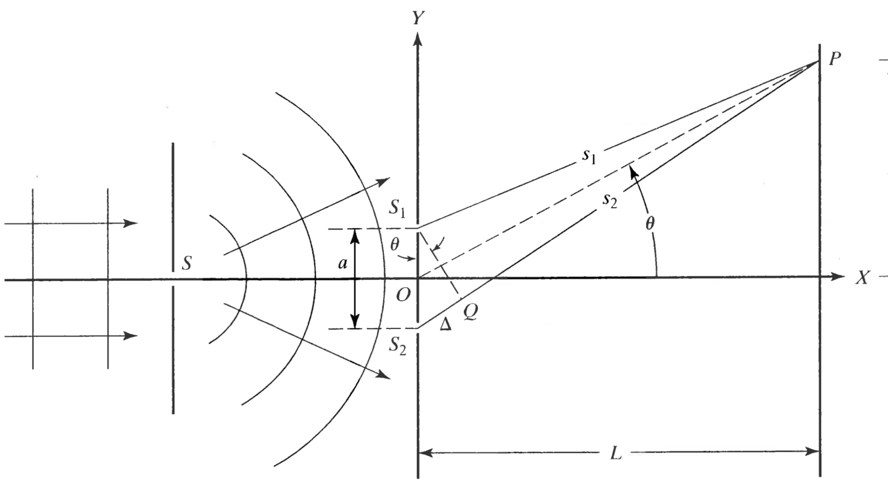


Figure 7-3 Schematic for Young's double-slit experiment. The holes S_1 and S_2 are usually slits, with the long dimensions extending into the page. The hole at S is not necessary if the source is a spatially coherent laser.

Learning outcome: Analyze the two-beam interference fringes formed by thin films and compute the interference patterns formed by amplitude division

- Lower to higher n, external reflection → π phase shift on reflection
- Higher to lower n, internal reflection → no phase shift

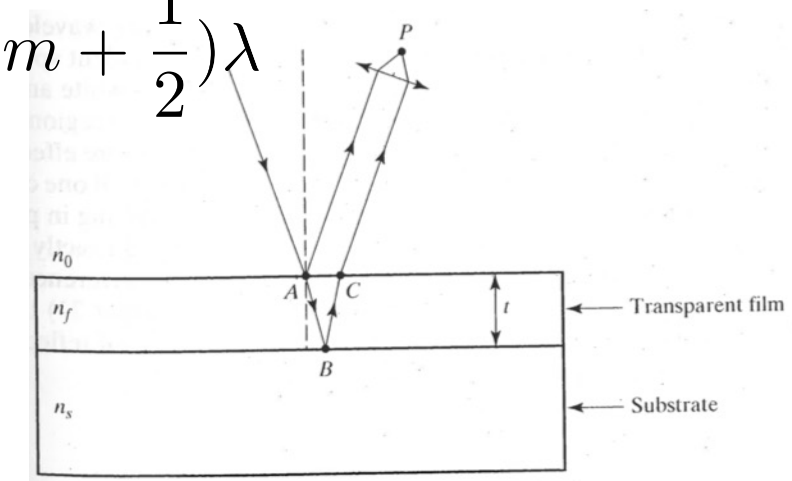
Optical path difference: $$\Delta_p = 2n_f t \cos\theta_t$$

Equivalent path difference arising from phase change on reflection:

Constructive interference: $$\Delta_p + \Delta_r = m\lambda$$

Destructive interference: $$\Delta_p + \Delta_r = (m + \frac{1}{2})\lambda$$

Where m = 0,1,2,…



Learning outcome: Design an antireflection coating

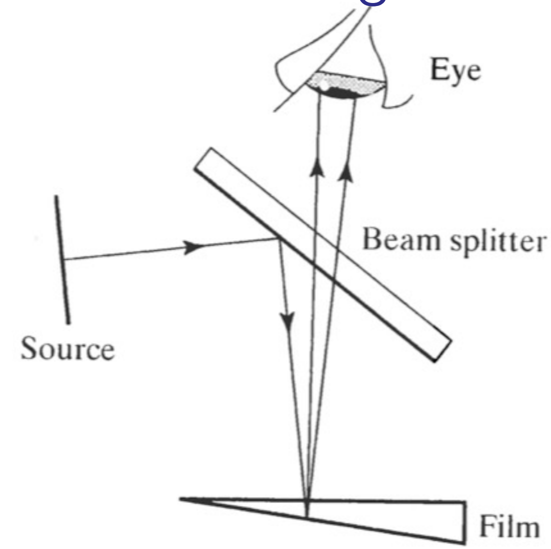
- Require destructive interference
- Need to match refractive indices of the film and substrate to get as close to equal amplitudes in the reflected beams
- Usually $n_0 = 1$ so $n_f = \sqrt{n_s}$

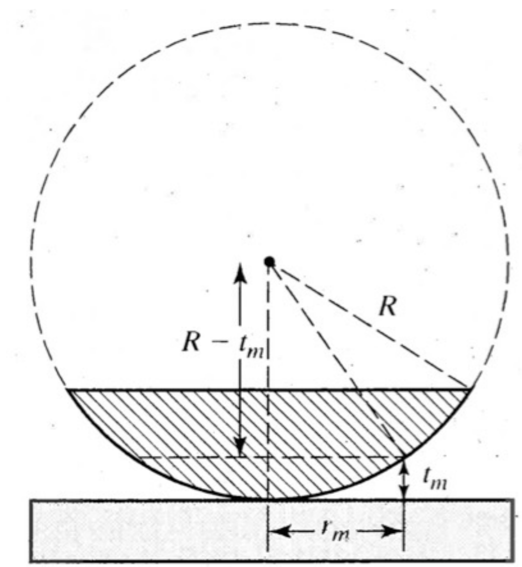
Learning outcome: Explain quantitatively Newton's rings

- Optical path difference $\Delta = 2n_f t\cos\theta_t$ varies even without variation in the angle of incidence
- Fringes form at:

$$2n_f t + \Delta_r = \begin{cases} m\lambda & \text{bright} \\ (m+\frac{1}{2})\lambda & \text{dark} \end{cases}$$

- Newton's rings $R = \dfrac{r_m^2 + t_m^2}{2t_m}$





Learning outcome: Analyze the two-beam interference fringes formed by thin films and compute the interference patterns formed by amplitude division

Thin film thickness measurement

Film of thickness, d, light at normal incidence, bright fringes when

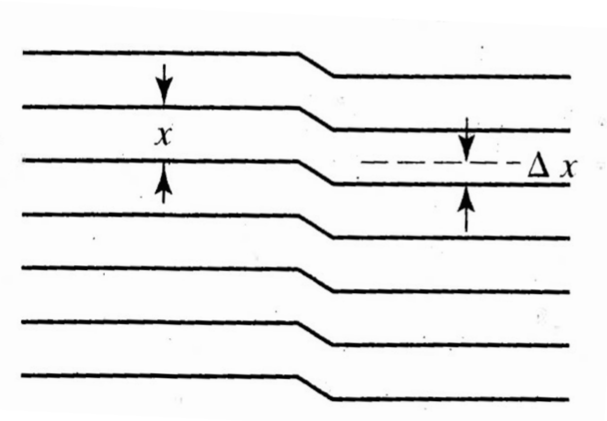
$$\Delta_p + \Delta_r = 2n_f t + \Delta_r = m\lambda$$

- Where t represents the thickness of air at some point
- Air-film thickness changes by Δt = d (n_{air} = 1)→ Δm changes accordingly

$$2\Delta t = 2d = (\Delta m)\lambda$$

- Order changes by Δm = Δx/x were x is the fringe spacing and Δx is the fringe shift.

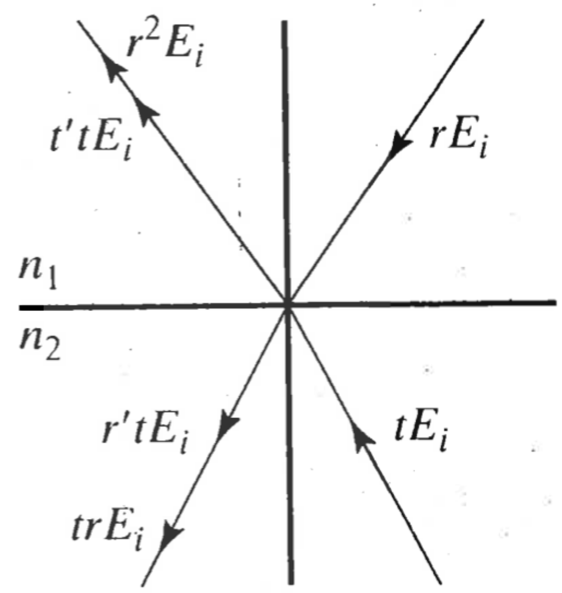
$$\boxed{d = \left(\frac{\Delta x}{x}\right)\left(\frac{\lambda}{2}\right)}$$



Learning outcome: Explain the Stokes' relations

- r and t are reflection and transmission coefficients from 1st medium
- r' and t' are reflection and transmission coefficients from 2nd medium

$$\boxed{\begin{aligned} tt' &= 1 - r^2 \\ r &= -r' \end{aligned}}$$



(c)

Learning outcome: Compute the transmitted and reflected irradiance in multiple-beam interference in a parallel plate

- Incident ray $E_0 e^{i\omega t}$

$$I_R = \left[\frac{2r^2(1-\cos\delta)}{1+r^4-2r^2\cos\delta}\right] I_i$$

$$I_T = \left[\frac{(1-r^2)^2}{1+r^4-2r^2\cos\delta}\right] I_i$$

- Reflected minima (transmitted maxima) when cos δ = 1 or $\delta = 2\pi m$

$$\Delta = 2n_f t\cos\theta_t = m\lambda$$

- Reflected maxima (transmitted minima) when cos δ = -1 or $\delta = (m + \frac{1}{2})2\pi$

$$\Delta = 2n_f t\cos\theta_t = (m + \frac{1}{2})\lambda$$

Learning outcome: Explain quantitatively the use of the Michelson Interferometer

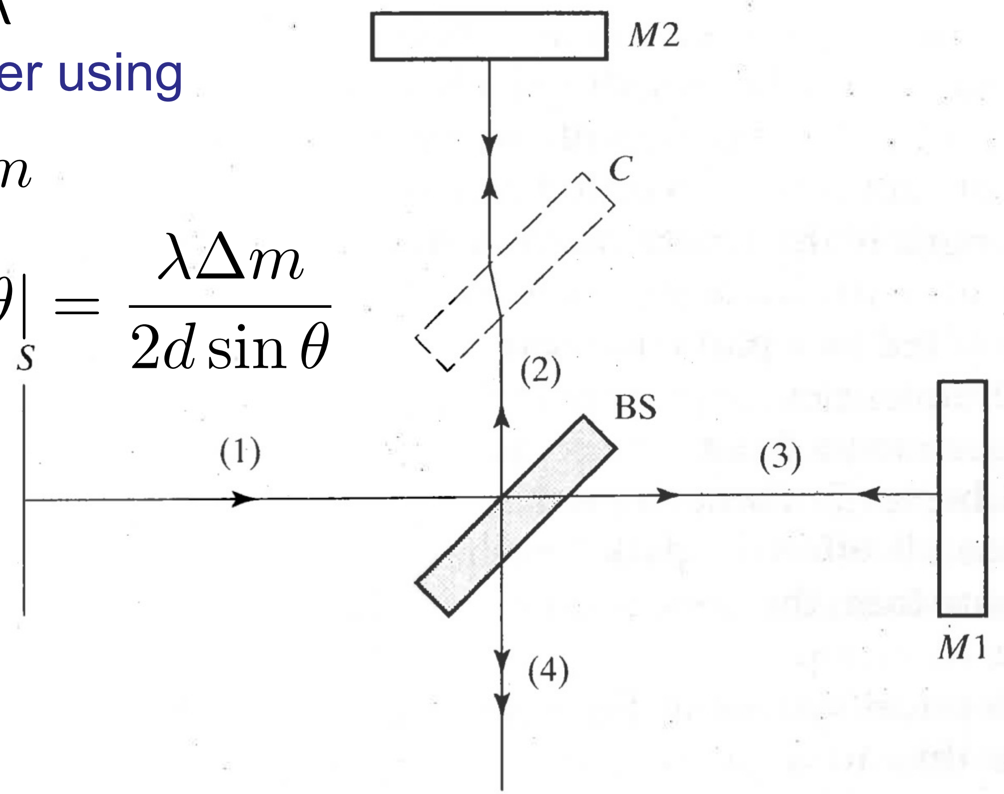
- Two-beam interference set-up
- Concentric ring interference pattern (usually)
- Dark fringes: $2d\cos\theta = m\lambda$
- For convenience, redefine order using

$$p = m_{\max} - m = \frac{2d}{\lambda} - m$$

- Angular fringe separation: $|\Delta\theta| = \dfrac{\lambda\Delta m}{2d\sin\theta}$

- Mirror translation of Δd corresponds to

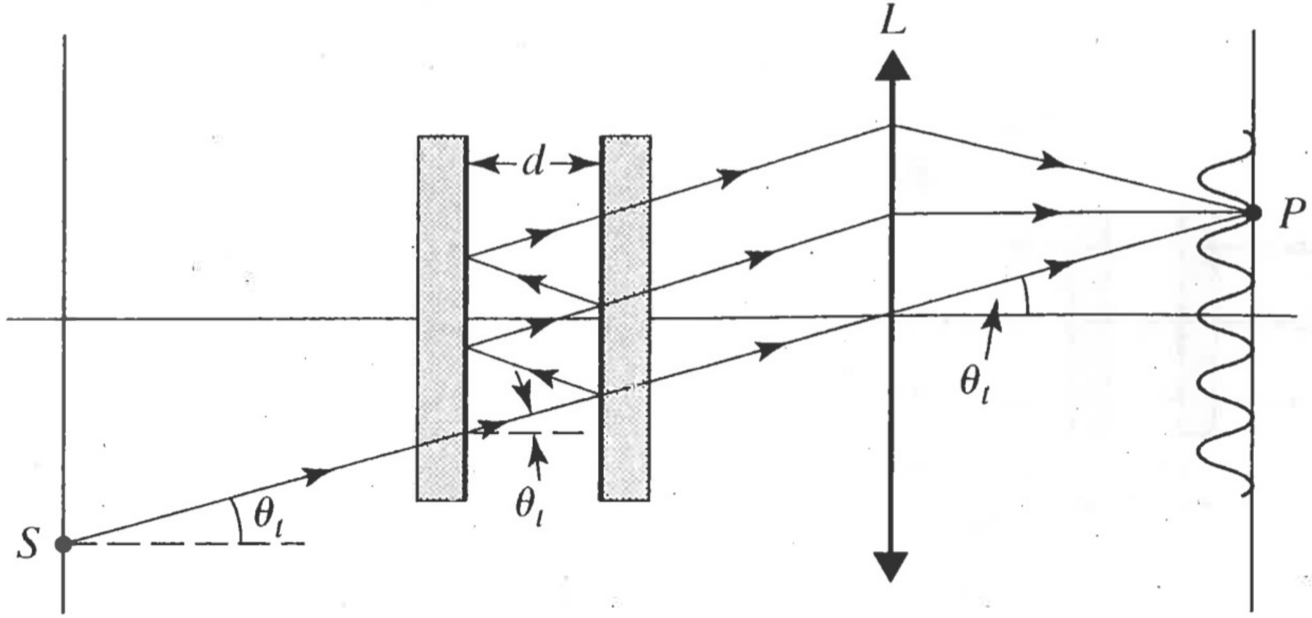
$$\Delta m = \frac{2\Delta d}{\lambda}$$



Learning outcome: Explain quantitatively the use of the Fabry-Perot Interferometer

- Multiple beam interference set-up using a cavity
- In air, bright fringes when: $2d\cos\theta_t = m\lambda$
- Derived the transmission through cavity to be an Airy pattern:

$$T = \frac{1}{1 + [4r^2/(1-r^2)^2]\sin^2(\delta/2)}$$



Learning outcome: Determine the finesse, the free-spectral range, and the Q of a Fabry-Perot

- Transmission is in the form of an Airy function:

$$\boxed{T = \frac{1}{1 + [4r^2/(1-r^2)^2]\sin^2(\delta/2)}}$$

- Round trip phase shift: $\delta = 2kd$
- Reflection coefficient, r
- Coefficient of Finesse $\boxed{F = \frac{4r^2}{(1-r^2)^2}}$
  - A measure of the fringe contrast
  - As F increases transmission peaks narrow

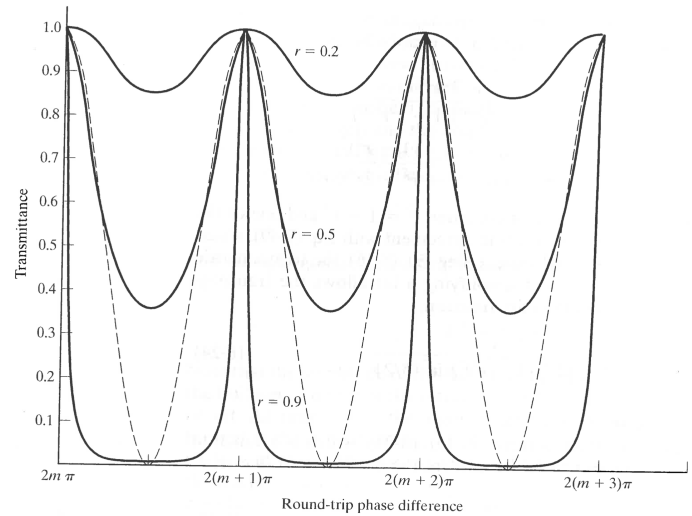


Figure 8-9 Fabry-Perot fringe profile. A plot of transmittance T versus round-trip phase difference δ for selected values of reflection coefficient r. Dashed lines represent comparable fringes from a Michelson interferometer.

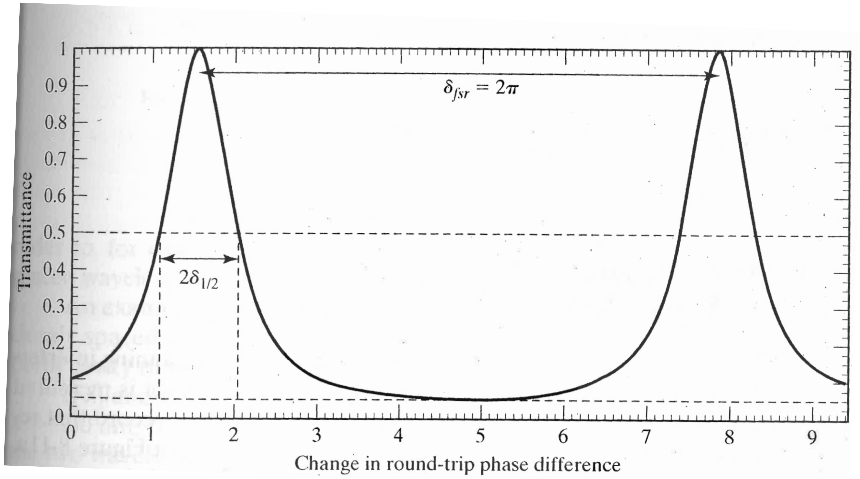
Learning outcome: Determine the finesse, the free-spectral range, and the Q of a Fabry-Perot

- Finesse: the ratio of the separation between transmission peaks to the full-width at half-maximum (FWHM) of the peaks

$$\boxed{\mathcal{F} = \frac{\pi\sqrt{F}}{2} = \frac{\pi r}{1-r^2}}$$

- The free spectral range (FSR) of the cavity is the phase separation between adjacent transmission peaks

$$\boxed{\mathcal{F} = \frac{2\pi}{2\delta_{1/2}} = \frac{\delta_{fsr}}{\mathrm{FWHM}}}$$



Learning outcome: Determine the resolving power of an interferometer

- Scanning Fabry-Perot Interferometer: change cavity length, d
  - FSR $d_{fsr} = d_{m+1} - d_m = \lambda/2$
  - Resolution criterion $\Delta d \geq 2\Delta d_{1/2} = \Delta d_{min}$
  - Resolving power
$$\boxed{\mathcal{R} = \frac{\lambda}{\Delta\lambda} = \frac{2d\mathcal{F}}{\lambda} = m\mathcal{F}}$$
- Variable-Input-Frequency Fabry-Perot Interferometer: change input frequency
  - Resonant frequencies $\nu_m = \frac{mc}{2d}$
  - FSR
$$\nu_{fsr} = \nu_{m+1} - \nu_m = \frac{c}{2d}$$
- quality factor, Q: the ratio of a nominal resonant frequency to the FWHM of the transmittance peaks $Q = \frac{\nu}{2\nu_{1/2}} = \mathcal{F}\frac{\nu}{\nu_{fsr}}$

Learning outcome: Compute the coherence time, coherence length and coherence area of a source

- Fringe visibility $V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$, is reduced with increasing time (length) until coherence is lost when the time separating the two beams is the coherence time,

$$\boxed{\tau_0 \approx \frac{1}{\Delta\nu}}$$

- Or coherence length $$\boxed{l_t = c\tau_0 = \frac{c}{\Delta\nu} \approx \frac{\lambda^2}{\Delta\lambda}}$$

Learning outcome: Compute the coherence time, coherence length and coherence area of a source

- Point source – perfect transverse coherence
- Increasing the spatial extent of the source reduces the transverse coherence
- Spatial coherence width

$$\boxed{l_s < \frac{r\lambda}{s} \cong \frac{\lambda}{\theta}}$$

Learning outcome: Compute Fraunhofer diffraction patterns formed by single and multiple slits, and by rectangular and circular apertures

- Irradiance:

$$\boxed{I = I_0\left(\frac{\sin^2\beta}{\beta^2}\right) = I_0 \text{sinc}^2\beta}$$

- Where $\beta = \frac{1}{2}kb\sin\theta$

- Width of central maximum increases with increasing distance, L, and decreases with increasing slit width, b:

$$\boxed{W = L\Delta\theta = \frac{2L\lambda}{b}}$$

- In "far-field" when $L \gg \frac{b^2}{\lambda} = \frac{\text{area of aperture}}{\lambda}$

Learning outcome: Compute Fraunhofer diffraction patterns formed by single and multiple slits, and by rectangular and circular apertures

- Rectangular aperture, width a, height b:

$$\boxed{I = I_0(\mathrm{sinc}^2\beta)(\mathrm{sinc}^2\alpha)}$$

- Where $\beta = \frac{1}{2}kb\sin\theta$ and $\alpha = \frac{1}{2}ka\sin\theta$

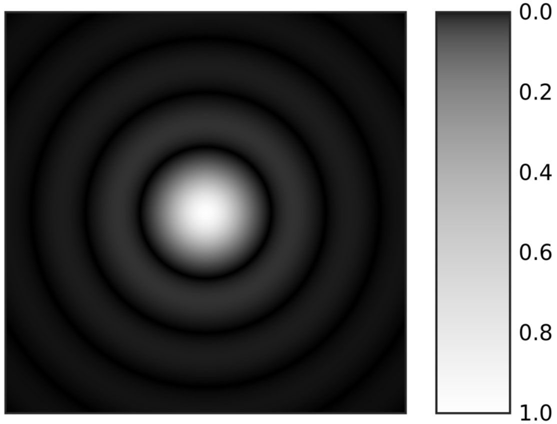
- Number of slits, N

$$\boxed{I = I_0\left(\frac{\sin\beta}{\beta}\right)^2\left(\frac{\sin N\alpha}{\sin\alpha}\right)^2}$$

Learning outcome: Compute Fraunhofer diffraction patterns formed by single and multiple slits, and by rectangular and circular apertures

- Circular aperture, diameter D: Airy disc

$$\boxed{I = I_0 \left(\frac{2 J_1(\gamma)}{\gamma} \right)^2}$$

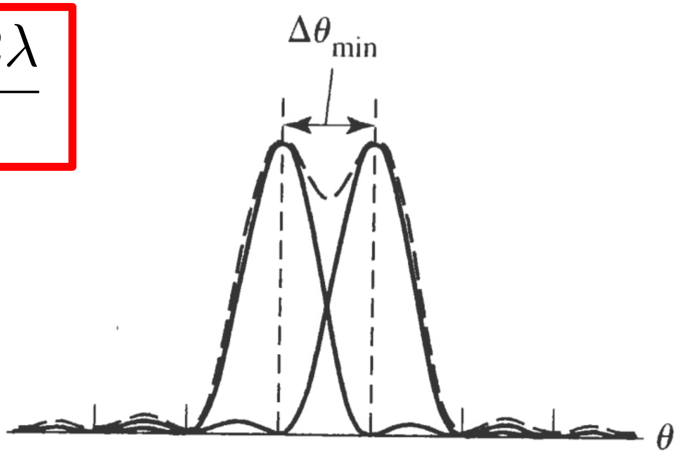


- Where $\gamma = \frac{1}{2} k D \sin\theta$
- and $J_1(\gamma)$ is the first-order Bessel function of the first kind

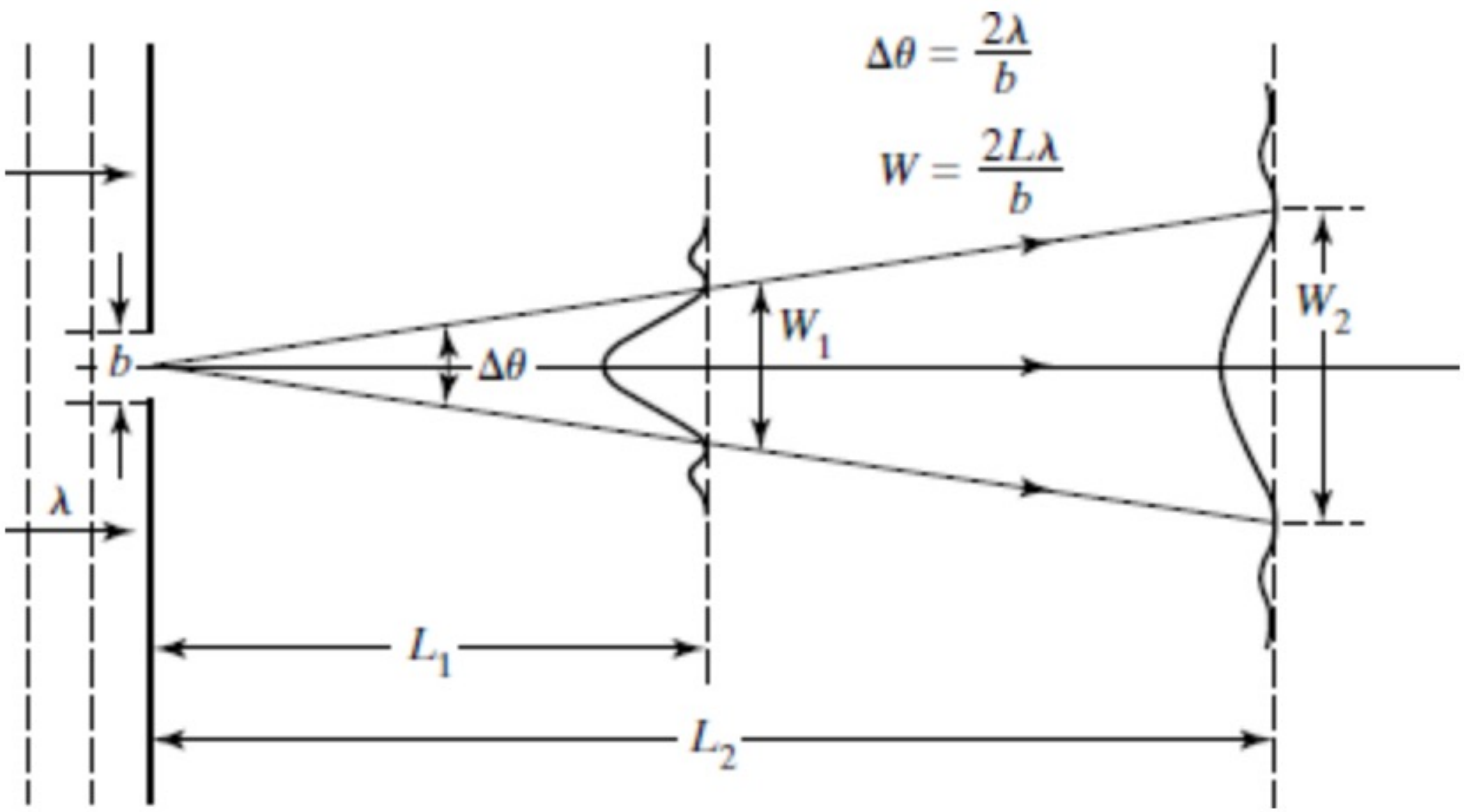
Learning outcome: Determine the resolution of imaging devices by means of Rayleigh's criterion

- Airy disc first zero gives: $$D \sin\theta = 1.22\lambda$$
- Far-field angular radius: $$\Delta\theta_{1/2} = \frac{1.22\lambda}{D}$$
- Rayleigh's criterion for just resolvable images:

$$\boxed{(\Delta\theta)_{min} = \frac{1.22\lambda}{D}}$$



Learning outcome: Determine the rate of beam spreading due to diffraction



Learning outcome: Use the diffraction equation to determine the direction of principal diffraction maxima. Determine the free spectral range, the dispersion, and the resolution of a grating.

- The diffraction equation for positions of principal maxima

$$\boxed{a(\sin\theta_i + \sin\theta_m) = m\lambda}$$

For m = 0, ±1, ±2, …

- Free spectral range for a specific order where λ_1 is shortest wavelength

$$\boxed{\lambda_{fsr} = \frac{\lambda_1}{m}}$$

- Angular dispersion $\mathfrak{D} = \dfrac{d\theta_m}{d\lambda} = \dfrac{m}{a\cos\theta_m}$

- Linear dispersion $\dfrac{dy}{d\lambda} = f\mathfrak{D}$

- Resolving power $\mathcal{R} = \dfrac{\lambda}{d\lambda} = mN$

Learning outcome: Design gratings blazed for a particular order in Littrow or normal mount

Types of grating

- Transmission grating: clear glass with grooves serving as scattering centers
- Reflection grating: periodic reflecting grooves

Blazed grating: shifts diffraction envelope peak away from zeroth order using prismatic grooves/inclined mirror faces

- Littrow mount: incident light angle close to groove face normal

$$\theta_b = \sin^{-1}\left(\frac{m\lambda}{2a}\right)$$

- Incident light along normal N to grating itself

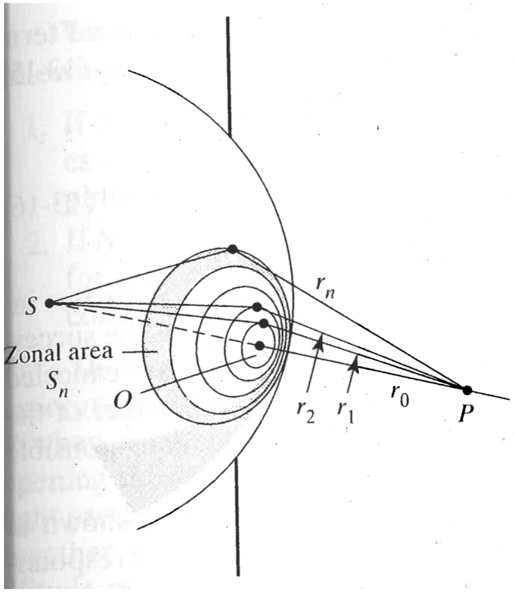
$$\theta_b = \frac{1}{2}\sin^{-1}\left(\frac{m\lambda}{a}\right)$$

Learning outcome: Determine whether one is in the Fresnel limit or the Fraunhofer (far-field) limit

- Fresnel diffraction for curved wavefront → source and/or observation point close to aperture
- Fresnel (near-field) diffraction when: $\boxed{d < \frac{A}{\lambda}}$
- Fraunhofer (far-field) diffraction when: $\boxed{d \gg \frac{A}{\lambda}}$

Learning outcome: Determine the Fresnel zones included by an aperture

- Divide circular aperture into circular zones with spacing λ/2 further from point P
- Each successive zone is exactly out of phase with preceding zone
- At point P
  $$A_n = a_1 - a_2 + a_3 - a_4 + \ldots a_n$$
- For N zones:
  - Even N $A_N \approx \frac{a_1}{2} - \frac{a_N}{2}$
  - Odd N $A_N \approx \frac{a_1}{2} + \frac{a_N}{2}$



- Small N, $a_1 \approx a_N$:
  - For odd N $A_N \approx a_1$
  - For even N $A_N \approx 0$
- Large N, $a_N \approx 0$: $A_N \approx \frac{a_1}{2}$

Learning outcomes: Compute the focal length and on-axis irradiance for a Fresnel zone plate.
Use Babinet's principle to determine the diffraction pattern of an aperture, given the pattern for its complement.

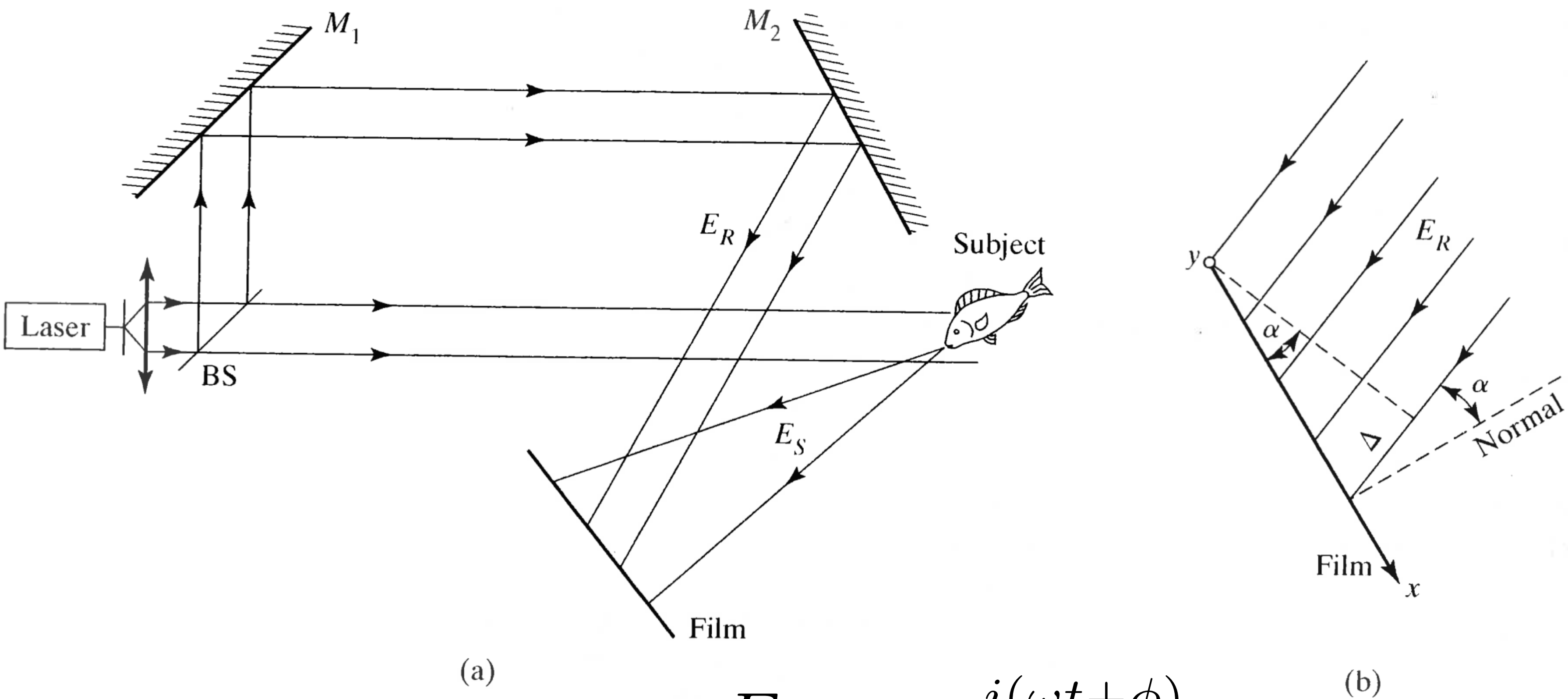
- Blocks every other zone in wavefront
- Zone plate radii $\boxed{R_N \approx \sqrt{n r_0 \lambda}}$
- First focal length (n = 1) $$r_0 = f_1 = \frac{R_1^2}{\lambda}$$
- Other maximum intensity points along axis at (for odd n): $$r_0 = f_n = \frac{R_1^2}{n\lambda}$$
- Babinet's Principle: The sum of amplitudes from complimentary apertures must equal the unobstructed amplitude

$$\boxed{E_A + E_B = E_u}$$

Learning outcome: Explain quantitatively the principles of off-axis holography

- Hologram reconstructs wavefront to provide depth perception and parallax
- Convert phase info into amplitude info by creating an interference pattern

Learning outcome: Explain quantitatively the principles of off-axis holography

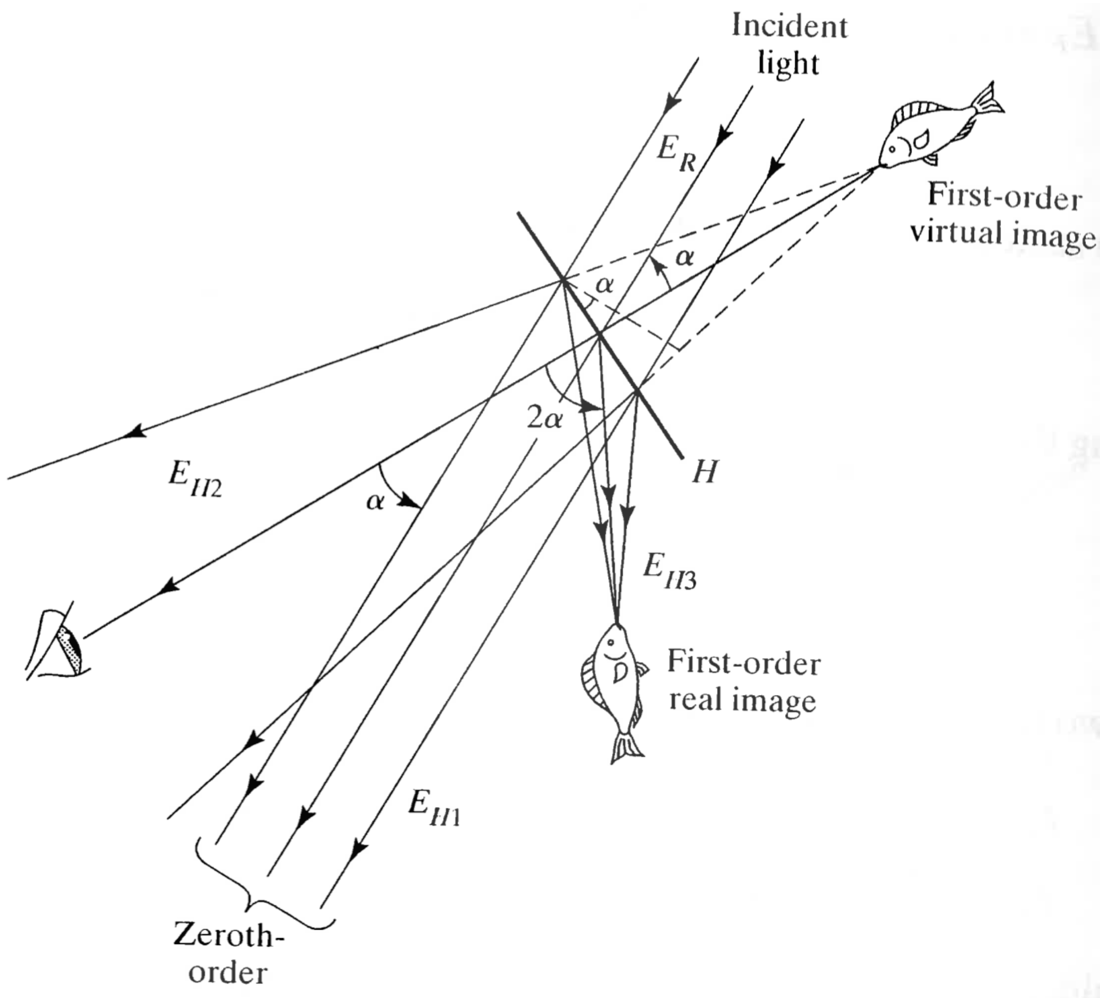


$$E_R = re^{i(\omega t+\phi)}$$

$$E_S = se^{i(\omega t+\theta)}$$

Learning outcome: Explain quantitatively the principles of off-axis holography

$$E_H \propto I_F E_R = (r^2 + s^2) E_R + r^2 s e^{i(\omega t + \theta)} + r^2 e^{i2\phi} s e^{i(\omega t - \theta)}$$



$$E_R = r e^{i(\omega t + \phi)}$$

$$E_S = s e^{i(\omega t + \theta)}$$

Learning outcome: Apply the Bragg equation to determine properties of a volume hologram

- Interference surfaces formed → 3D grating
- White light reconstruction leads to specific λ being reinforced by multiple reflections
- At a given angle θ, only a single λ satisfies the Bragg equation locally

$$\boxed{m\lambda = 2d\sin\theta}$$

Course schedule / dates

Date / Time	Session
~~4/7 @ 11:30am~~	~~Discussion: Revision~~
4/7 @ 5pm	Mini-project submission deadline
4/11 @ 12noon	Mini-project presentations*
4/13 @ 12noon	Mini-project presentations*
4/14 @ 11:30am	Discussion: Revision*
4/18 @ 12noon	Mini-project presentations*
4/27 @ 8am – 10am	Final Exam

*Attendance expected at all sessions – there will be a quiz

Homework 10 due 4/18 @ 5pm

Office hours: (Tu) 4/11 @ 2pm, (Tu) 4/18 @ 2pm,
(Wed) 4/26 @ 11am and 2pm

Final exam info

- Date: Thursday April 27th 2023
- Time: 8am – 10am
- Location: EECS1500
- What to bring with you:
  - Calculator capable of complex math
  - Pens/pencils/ruler
- What will be provided:
  - Exam questions and paper to write on
  - Formula sheet
- You must sign to acknowledge the honor code statement.
- Questions will focus on material from lecture 12 onwards, but knowledge of earlier materials assumed.