PHYS 3038 Optics
L22 Fourier Optics
Reading Material: Ch11

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11.3.3 Fourier Methods in Diffraction Theory

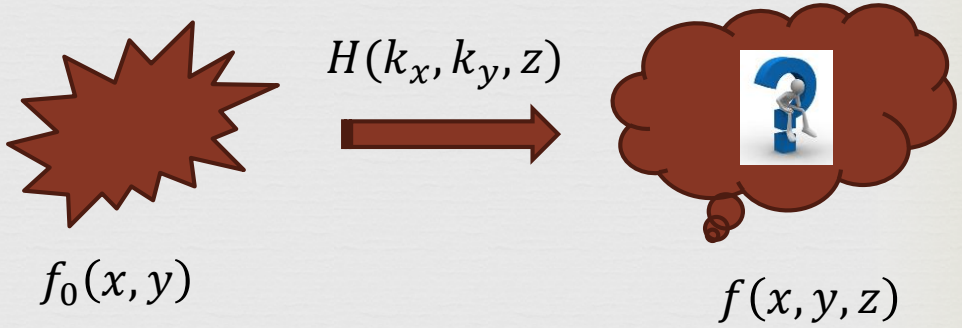
$$H(k_x, k_y, z) = e^{ik_z z} = e^{i\sqrt{k^2 - k_x^2 - k_y^2}z}$$

$$f(x, y, z) = \iint F(k_x, k_y)\, H(k_x, k_y, z) e^{i[k_x x + k_y y]} dk_x dk_y$$

$$f_0(x, y) = f(x, y, z = 0) = \iint F(k_x, k_y)\, e^{i[k_x x + k_y y]} dk_x dk_y$$

$$F(k_x, k_y) = \mathcal{F}\{f_0(x, y)\}$$

$$F(k_x, k_y) H(k_x, k_y, z) = \mathcal{F}\{f(x, y, z)\}$$



$$\mathcal{F}^{-1}\{\mathcal{F}\{f_0(x, y)\} H(k_x, k_y, z)\}$$

Fraunhofer Diffraction

10.2.4 2D Aperture

$$E = \iint \frac{\mathcal{E}_A}{r} e^{i(kr-\omega t)} dS \cong \frac{\mathcal{E}_A}{R} e^{i(kR-\omega t)} \iint e^{-ik(Xx+Yy)/R} dS$$

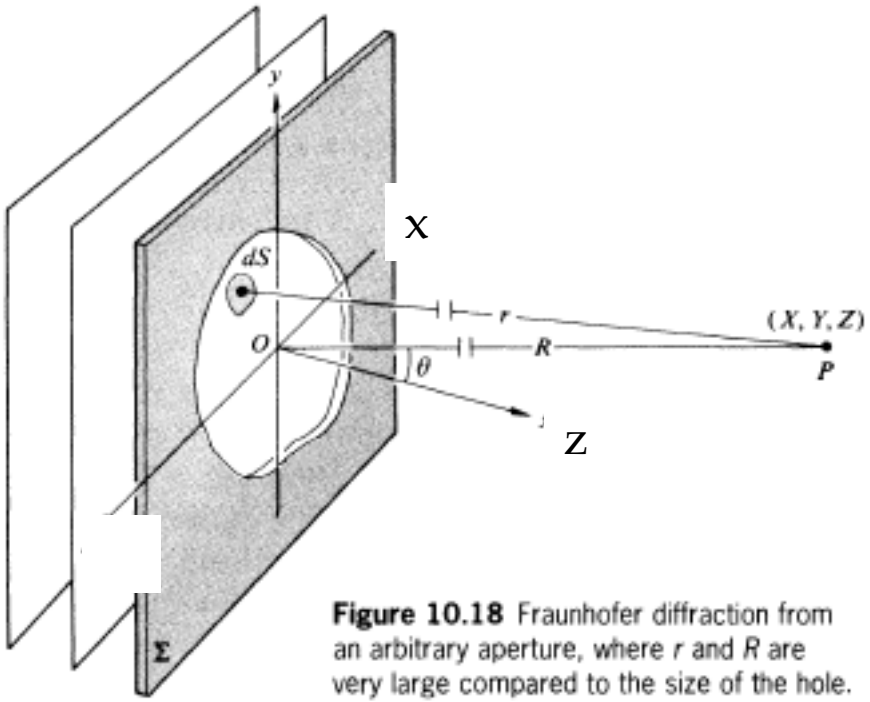


Figure 10.18 Fraunhofer diffraction from an arbitrary aperture, where r and R are very large compared to the size of the hole.

$$\cong \frac{\mathcal{E}_A}{R} e^{i(kR-\omega t)} \iint e^{-i(\frac{kX}{R}x+\frac{kY}{R}y)} dS$$

$$\cong \frac{\mathcal{E}_A}{R} e^{i(kR-\omega t)} \iint e^{-i(k_X x+k_Y y)} dS$$

$$\cong \frac{\mathcal{E}_A}{R} e^{i(kR-\omega t)} \mathcal{F}\{A(x,y)\}$$

$$k_X = \frac{kX}{R} = k\cos\beta \qquad k_Y = \frac{kY}{R} = k\cos\gamma$$

The Single Slit

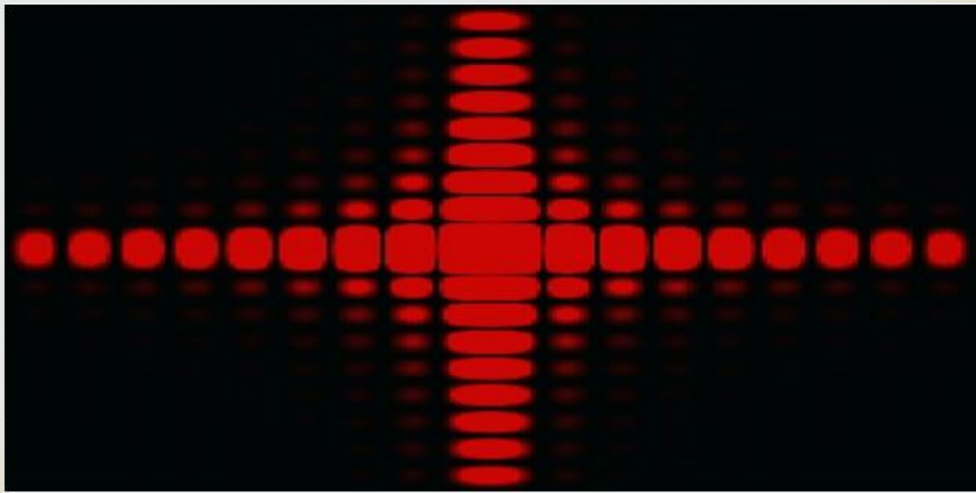
$$A(x) = \begin{cases} A_0 & |x| \le a/2 \\ 0 & |x| > a/2 \end{cases}$$

$$k_X = \frac{kX}{R} = k\cos\beta$$

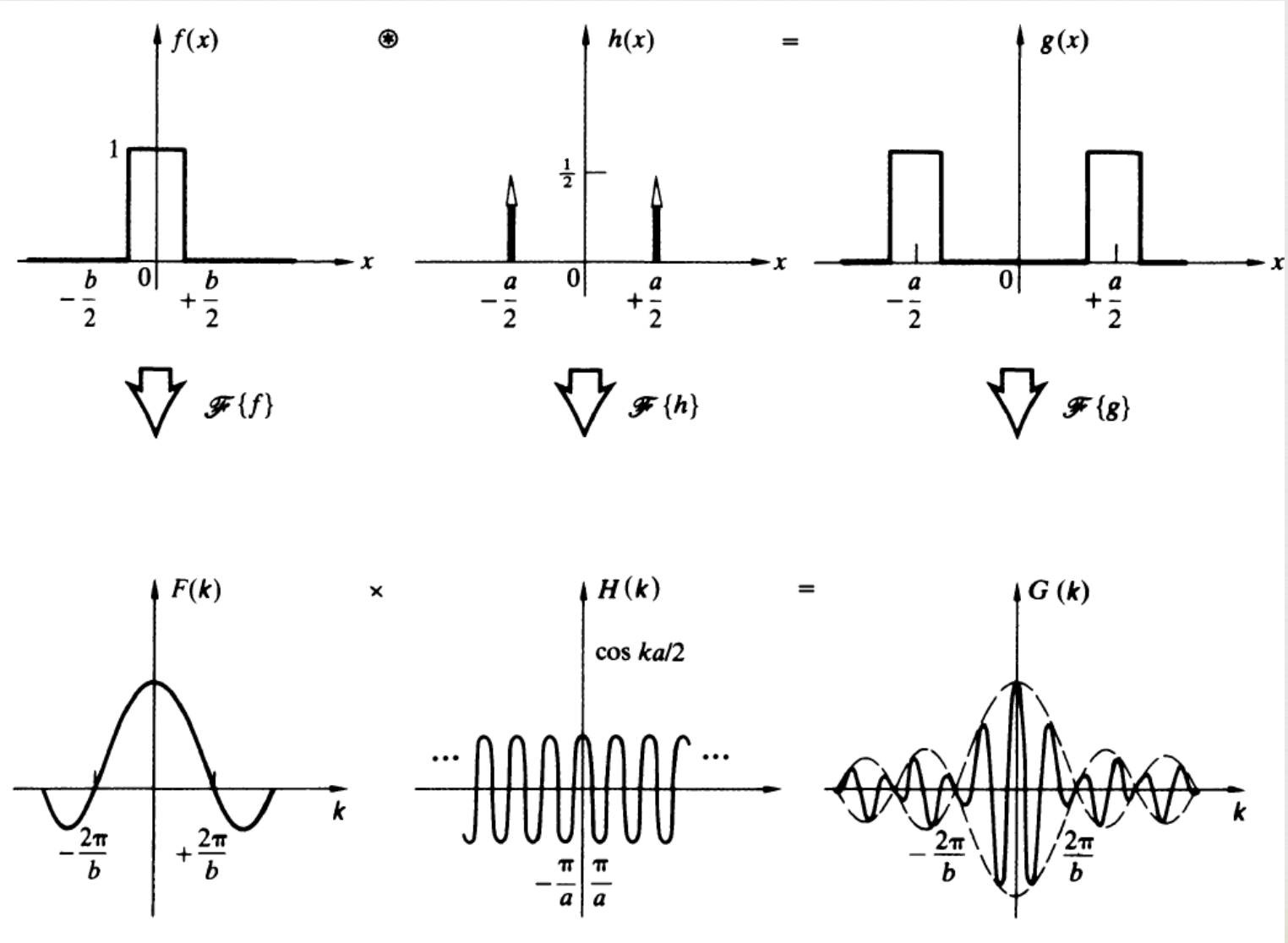
$$E(k_X) = \mathcal{F}\{A(x)\} = A_0 a \,\mathrm{sinc}\, k_X a/2$$

2D:

$$E(k_X, k_Y) = \mathcal{F}\{A(x,y)\}$$
$$= A_0 ab \,\mathrm{sinc}(\frac{k_X a}{2}) \,\mathrm{sinc}(\frac{k_Y b}{2})$$



Young's Double Slit



Three Slits

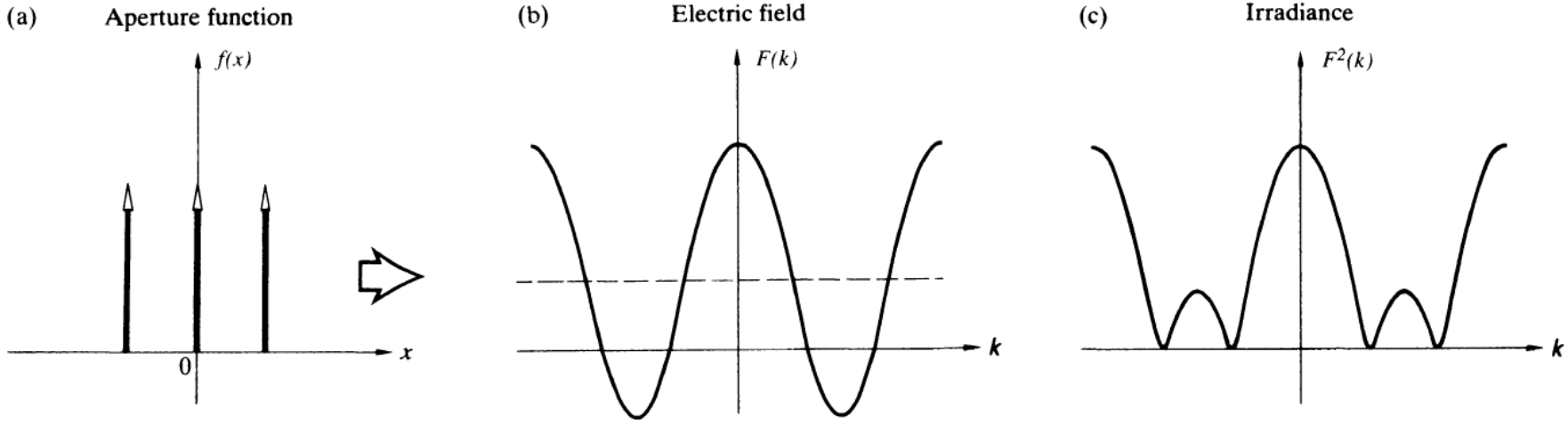
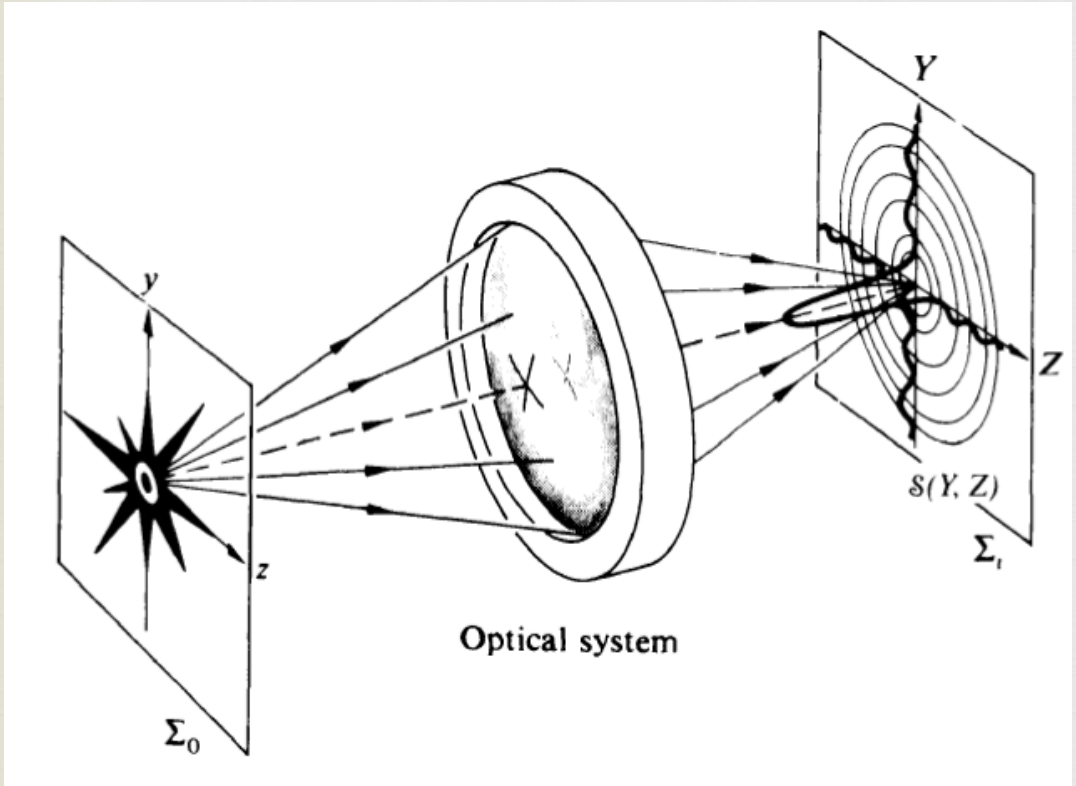


Figure 11.32 The Fourier transform of three equal δ-functions representing three slits.

11.3.5 Transfer Functions



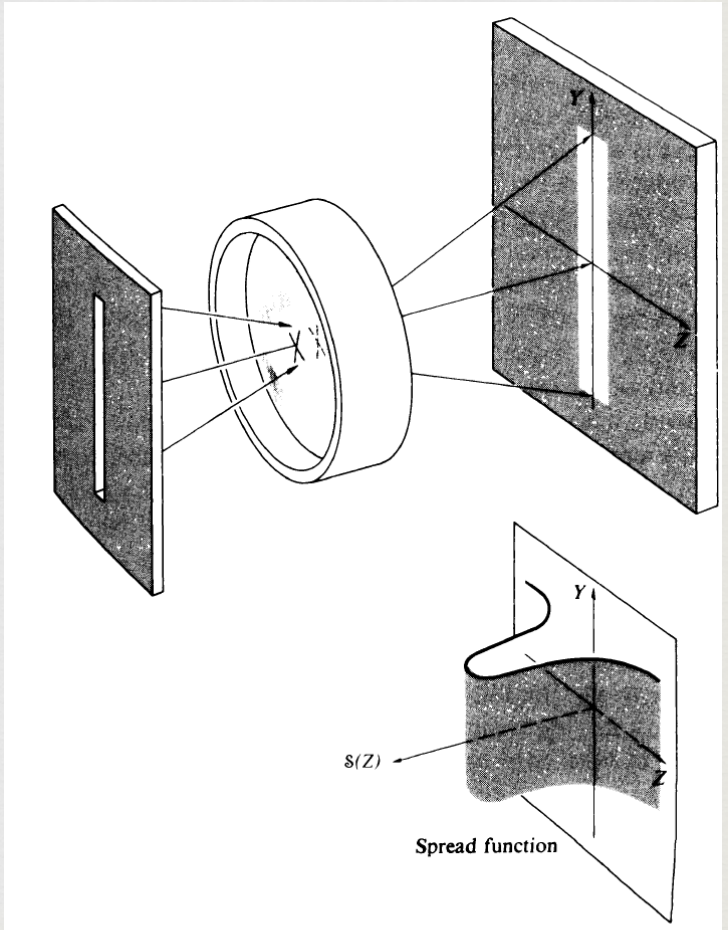


Figure 11.43 The line-spread function.

Final Review

- Ch2. Wave motion (L2)
- Ch3. EM theory (L3-L4)
- Ch5. Geometrical optics (L5-L6)
- Ch6. Geometrical optics (L7-L8)
- Ch4. Light propagation (L9)
- Ch7. Superposition (L10)
- Ch8. Polarization (L11-L12)
- Ch9. Interference (L13-LL16)
- Ch10. Diffraction (L17-L20)
- Ch11. Fourier Optics (L21-L22)

Ch2 Wave Motion

- Concept of wave
- Wave equation
- Superposition principle
- Complex representation

Ch3 EM Theory

- Maxwell equations (in vacuum/medium)
- EM Wave (connenctions between wavelength, frequency, K number/vector, phase velocity…)
- Enrgy & Momentum: Time-averaged energy, intensity (irradiance), power
- Photon
- Light in bulk (dielectric) matter

Ch5-6 Geometry Optics

- Ray optics
- Thin Lens & Lens combination
- Imaging with lens: How, AS, FS, Entrance & Exit pupils…
- Mirrors: Plane, Aspherical, Spherical
- Prisms, Fibers, Optical systems
- Thick lens & lens systems (focal planes, principle planes)
- Analytical ray tracing: ray vector and matrix
- Aberrations

Ch4 Light Propagation

- Light in bulk (dielectric) matter
- Dispersion
- Reflection & Refraction

Ch7 Superposition

- Phasor addition
- Stabnding waves & beats
- Group velocity & phase velocity

Ch8 Polarization

- Polarizations: linear, circular, … (graphic + Mathematica)
- Polarizers
- Retarders (wave plates)

Midterm Exam

- Jones vectors & Matrix operations

Ch9 Interference

- Math & Physics
- Temporal & spatial coherence
- Wavefront-splitting interferometers
  - Young's experiment
  - …
- Amplitude-splitting interferometers
  - Dielectric films
  - Haidinger & Newton fringes
  - Michelson interferometer
  - Mach-Zehnder Interferometer
  - Sagnac Interferometer
  - Fabry-Perot Interferometer
- Applications: coating

Ch10 Diffraction

- Fraunhofer diffraction
  - Single-slit
  - Double-slit
  - Many slits
  - 2D Aperatures
- Diffraction limited resolution
- Beam propagation & diffraction
- (Quaso) Bessel beam generation
- Diffraction gratings (grating equation) & grating spectroscopy
- Fresnel Diffraction
  - Obliquiy
  - Fresnel zones
  - Circular Apertures & Obstacles
  - Fresnel zone plates

Ch11 Fourier Optics

- Fourier transform (1D & 2D)
  - FT and IFT of the standard waveforms
  - Displacements & Phase shifts
- Lens as a FT
- Free-space transform function
- Point spread function (concept)
- Fourier method for Fraunhofer diffraction