

Micro-optics

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Exercise 9

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Discussion sections: Jan 16 & 17, 2008

1 General grating issues (35)

- A plane wave is propagating through a transmission grating (**thin** glas) at normal incidence. Make a clear and detailed drawing of the diffraction pattern.
- Now, consider an angle of incidence θ_i . Again, each grating slit is a source of a new train of waves. According to θ_i the grating period Λ will be modified to Λ' . Why does the diffraction pattern differ from the pattern with Λ' at normal incidence? From where does the interference pattern know that one wave comes perpendicular and the other one angular?
- In numbers: $\theta_i = 35^\circ$, $\lambda = 550 \text{ nm}$, $\Lambda = 1.5 \mu\text{m}$, distance between grating and screen: $L = 20 \text{ mm}$. Calculate the angles for the diffraction orders 0, ± 1 and the positions of the orders ± 1 with respect to the zero order principal ray on the screen. What is the maximum angle of incidence for the order -1?
- The grating will be coated with an Au layer and the wave enters at same angle of incidence. Describe and sketch the new situation and compare to the transmission grating.

2 Linear grating (25)

A transmission grating with an ideal two-level binary profile is etched into the backside of a fused silica glass substrate ($n = 1.457$). The grating has a duty-cycle (ratio between profile width and period) of 0.5 and a period of $\Lambda = 3 \mu\text{m}$. It is illuminated under normal incidence by a HeNe laser ($\lambda = 633 \text{ nm}$) and forms a diffraction pattern on a screen located 2 m behind the grating.

The efficiency of this grating in m -th diffraction order ($m \neq 0$) is given by

$$\eta_m = \left[\frac{\sin\left(\frac{\pi m}{2}\right)}{\frac{\pi m}{2}} \right]^2. \quad (1)$$

- Calculate the spacing between the first set of spots.
- What is the efficiency of the first set of spots?
- What is the spacing between the next pair of spots?
- What is the maximum number of spots and how far away is the furthest set from the center? (Hint: Check the diffraction efficiency for each order.)

3 Grating spectrometer (40)

A grating with period of $\Lambda = 7.2 \mu\text{m}$ is illuminated at an area of $1 \times 1 \text{ cm}^2$ under normal incidence. A screen is placed 320 cm behind the grating. For the yellow Sodium D emission line, the distance s from the central spot (zero order) to the second order spot is 532 mm.

- What is the wavelength of the Sodium light?
- How many periods does the grating exhibit?
- What is the lateral size of the 2nd-order spot?
- What is the minimum resolvable wavelength difference $\Delta\lambda_{\text{min}}$, if the grating is used at 5th diffraction order?

Hint: You will need formulae for the angular width of a monochromatic spectral line and for the resolving power of a grating spectrometer to solve the third and fourth part of this exercise. Look them up in E. Hecht's textbook *Optics*.

