Homework Set #2 **Due: 1-25-12**

1) *Review problem / tutorial on gratings.* A grating is an optical component that modulates light spatially so that the outgoing diffracted light comes out at an angle that depends on its wavelength. Gratings can be designed so that the diffracted light is transmitted through the grating or, as shown in Fig. 1, reflected. Reflection gratings are the most common. Gratings are made by imposing a periodic, spatial modulation of some property of the substrate. The modulated quantity can be the absorption, reflectivity, transmission, thickness, or index of refraction. Although somewhat less common, a substrate with spherical curvature is sometimes used so the grating can form images. The first grating that students usually encounter in class is an array of slits on a screen. This is a transmission grating and the modulated quantity is the transmission (either 100% or 0%), as shown in Fig. 2.

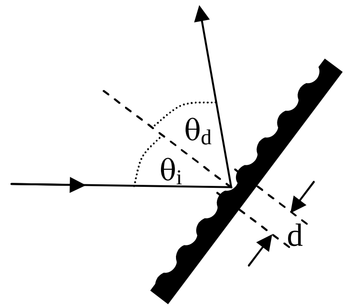

Fig. 1

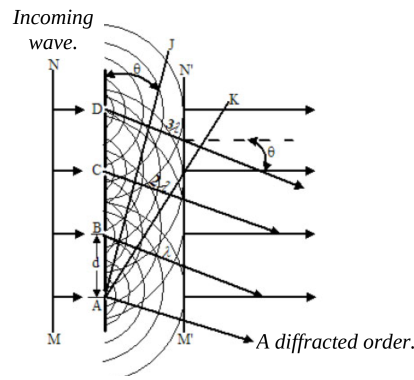

Fig. 2. Grating formed using multiple slits. (Picture: http://blog.cencophysics.com/2009/07/diffraction-grating/)

Suppose you have monochromatic light incident on a flat substrate, reflection grating. There will, in general, be many diffracted beams each at a different angle, called orders, coming from the grating simultaneously (only one is shown in the figures). The amount of power in each order is determined by the choice of modulation. A sinusoidal modulation tends to put most of the power into the first order diffracted beam (m=1), whereas the modulation shown in Fig. 3 can be used to place more power is a high order mode.

Referring back to Fig. 1, and still assuming monochromatic light, the input and output rays are related via the grating equation, one variant of which is: $\mathbf{d(\sin\theta_i + \sin\theta_d) = m\,\lambda}$. Here, d is the "wavelength" of the spatial modulation, called the groove spacing, θ_i and θ_d are the incident and diffracted angles, λ is the light wavelength and m is an integer. Note that the angle of the incident and diffracted rays is measured with respect to the normal, as is usually the case in optics. Different values of m select the different possible output angles or diffraction orders. Note that for the m = 0 order, the grating acts like a mirror <u>independent of wavelength</u>.

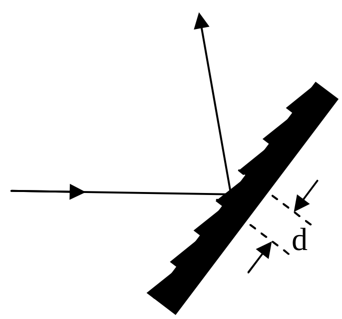

Fig. 3. Gratings with a groove shape like this are said to be blazed.

(a) Explain the sign convention for the angles in the grating equation. According to this convention, what is the sign of θ_i and θ_d for the case shown in Fig. 1? [Hint: consider the m=0 case.]

(b) A grating used in "Littrow" configuration operates so that a specified diffraction order is retro-reflected back onto the incident beam. Short pulse laser systems frequently employ gratings at or near Littrow, as do some narrow line tunable lasers, including some diode lasers. What is the incident angle for a Littrow grating with 500 grooves/mm operating in first order (m=1) with 800 nm light?

(c) For short pulse work, it is often best to not permit orders higher than m=1. Energy appearing in higher orders is usually wasted. Rework (b), but use a value for d that is just sufficiently small to eliminate orders with m>1.

2) Text problem 2.7

(n can be taken to be close to unity.)

3) Consider the transition between the groundstate and first excited state of a system. Assume no degeneracy, exact resonance and that radiative broadening dominates. Show that the cross-section is given by $\lambda^2/2\pi$, where λ is the wavelength in the medium corresponding to the resonance frequency.

(This is a good rule of thumb to remember.)

4) The lower level (#1) of a transition is triply degenerate and the upper level (#2) is non-degenerate. The cross-sections $\sigma_{1i,2}$ for transitions between sub-levels is 1.0 x 10^{-20} cm^2, 2.0 x 10^{-20} cm^2, and 1.0 x 10^{-20} cm^2. What is the overall cross-section σ_{12}? What is σ_{21}?

(Hint: Recall how the 2-level and general multi-level cross-sections are defined and use $W=\Sigma W_{ij}$.)

5) Text problem 2.11

(This involves ASE, which we'll cover on Monday. The text has many worked examples that are useful. Note example 2.13.)