Lecture 12 11/20/07

Schedule

Today: Begin Lab 6

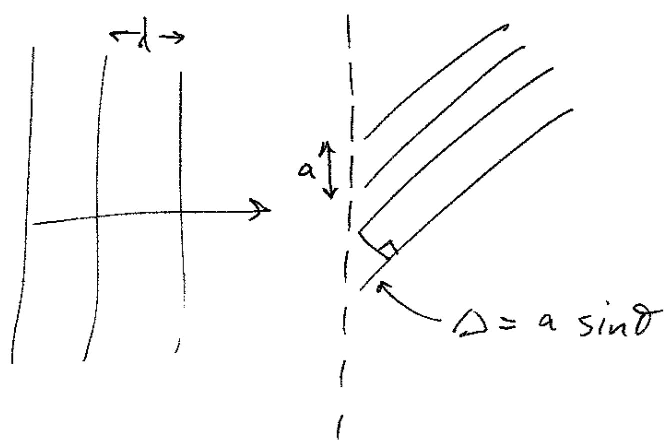
11/27: Finish Lab 6 - turn in homework #7

12/4: Exam Review - Lab 6 due

12/11: Final Exam?

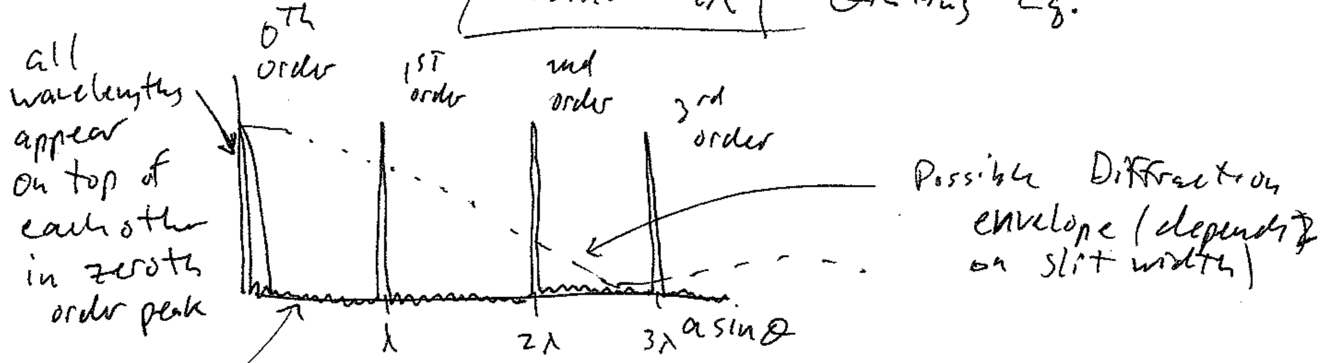
12/17: Final Exam

Diffraction Grating



Maxima occur when $\Delta = n\lambda$

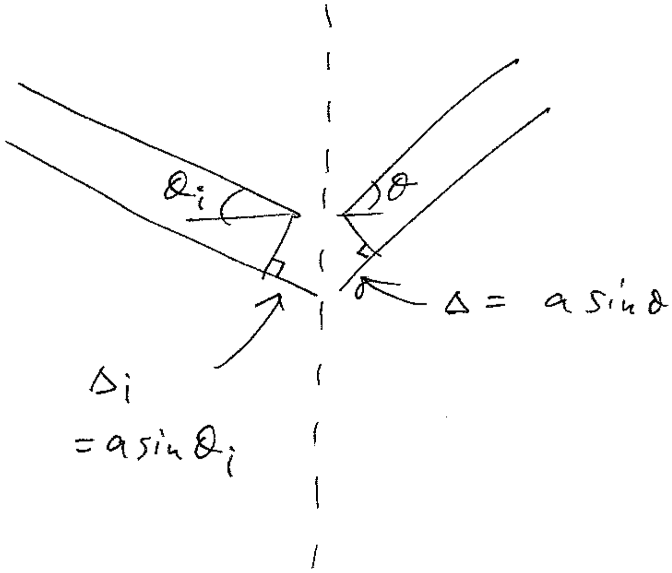
$$\boxed{a\sin\theta = n\lambda}$$ Grating Eq.



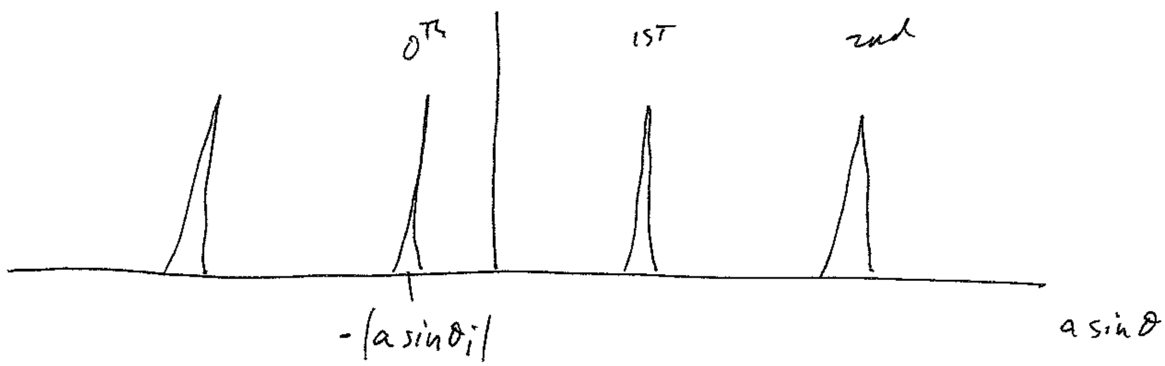
Today's lab:

- use known wavelength of Hg lamp to measure grating spacing a
- use measured grating spacing to measure wavelengths of H₂ lamp & Na lamp.

Non-zero angle of incidence



maxima when $a(\sin\theta_i + \sin\theta) = n\lambda$

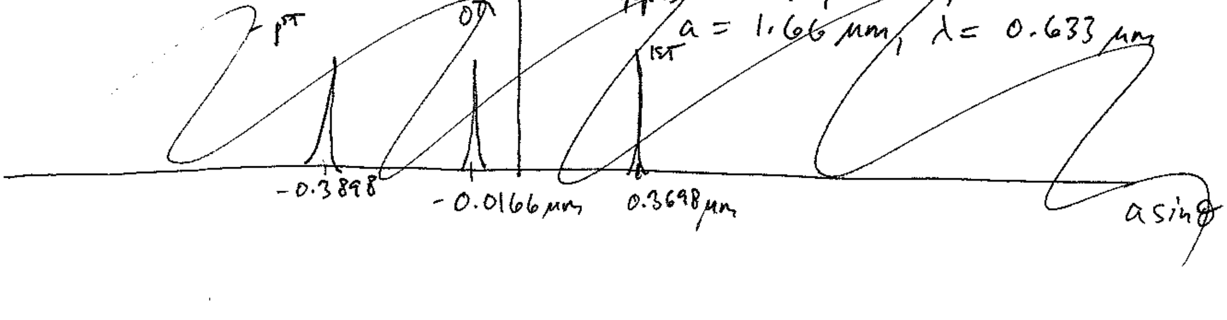


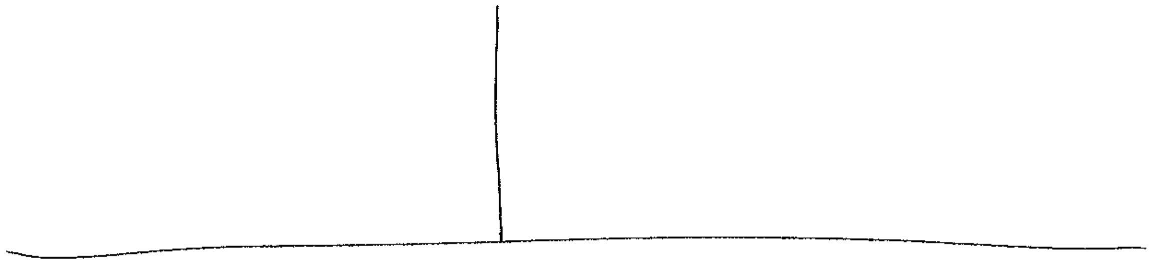
θ is measured from the normal to the grating.

But we only know roughly what angle corresponds to normal.

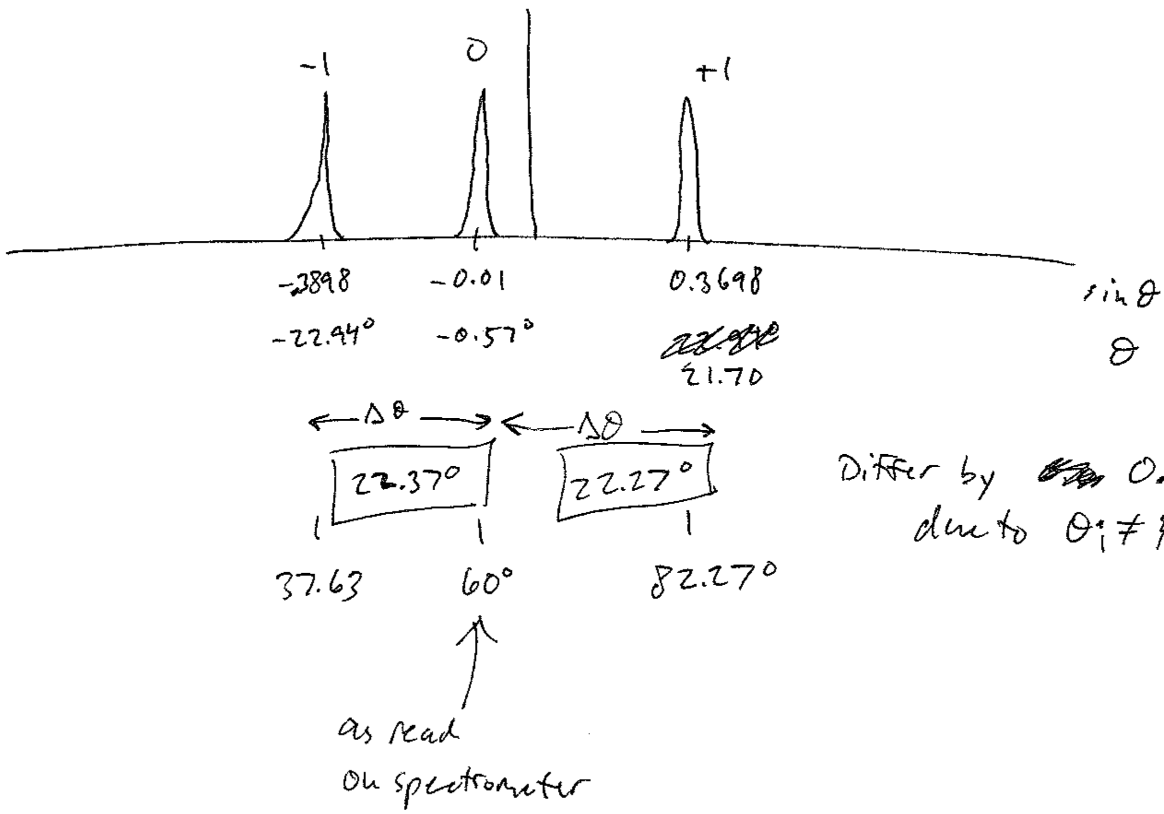
⇒ Measure angular position of 1st & −1st order peaks.
When ~~angle~~ $\Delta\theta(n=1) = -\Delta\theta(n=-1)$, grating is perpendicular

Suppose $\sin\theta_i = 0.01$, $a = 1.66\ \mu m$, $\lambda = 0.633\ \mu m$





Suppose $a = 1.66\,\mu m$, $\lambda = 0.633\,\mu m$, and $\theta_i = 0.01$



Differ by 0.1° due to $\theta_i \neq 0$.

$\Rightarrow$ Adjust angle of grating until +1 and -1 peaks appear at equal angular distance from $n = 0$.

Hydrogen Energy Levels

$$E_n = \frac{-13.6\,eV}{n^2}, \quad n = 1, 2, 3, \ldots$$

$$\Delta E = -13.6\,eV \left(\frac{1}{n^2} - \frac{1}{n'^2}\right) = h\nu$$

(ν ← frequency; h ← Planck's constant)

$$\frac{1}{\lambda} \equiv \tilde{\nu} = \text{wavenumber}$$
$$= \frac{\nu}{c} = \frac{\Delta E}{hc} = R\left(\frac{1}{n^2} - \frac{1}{n'^2}\right)$$

$hc = 1240\ eV \cdot nm$

R = Rydberg Constant, units of cm^{-1}

For transitions to $n=1$, ν is UV (invisible) (Lyman Series)

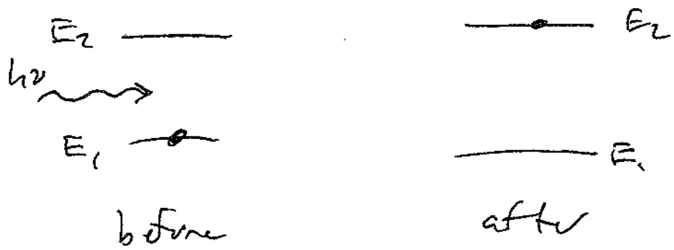
transition to $n=2$, ν is visible (Balmer Series)

- Measure Balmer series wavelengths
- Guess which wavelength correspond to which n'
- Extract Rydberg Constant.

Lasers

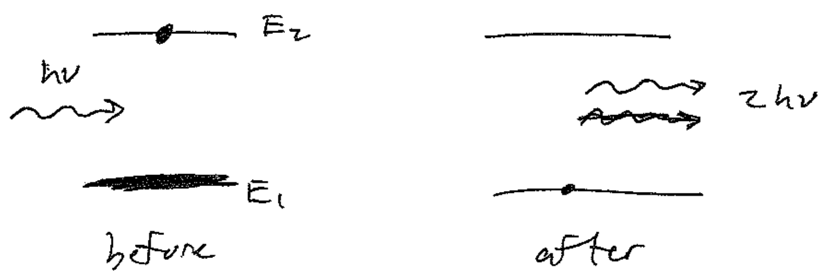
Three interactions between light and atoms:

- Stimulated absorption



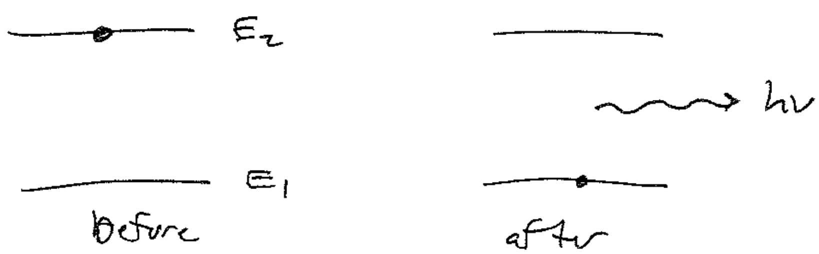
$h\nu = E_2 - E_1$

- Stimulated emission



same direction & phase

- Spontaneous emission

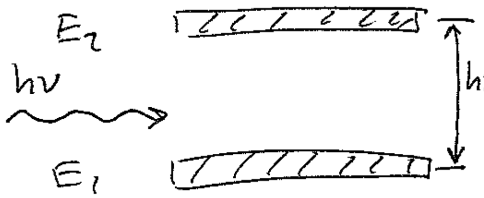


random phase & direction

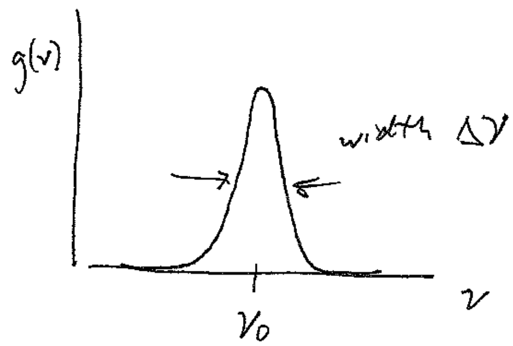
Conventional light sources rely on spontaneous emission.
Lasers use stimulated emission.

Lineshape Function

Real atomic energy levels have a small spread:



The probability that a photon will interact with the atom is called the lineshape function. $g(\nu)$



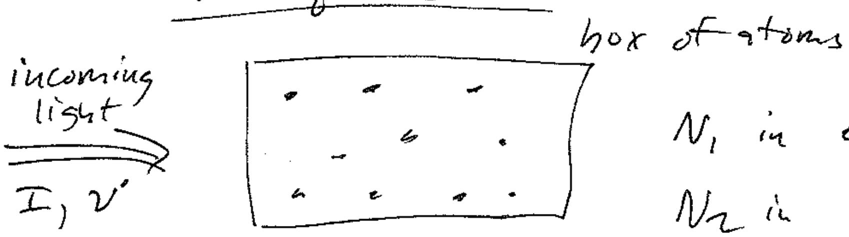
Typically for an atom in vacuum,

$$\frac{\Delta\nu}{\nu_0} \approx 10^{-8} \text{ to } 10^{-5}$$

$$\int g(\nu)\, d\nu = 1 \quad \text{(normalized)}$$

→ Stop Here

Rate Equations



N_1 in energy level E_1

N_2 in energy level E_2

Rate of Stimulated Absorption per unit volume:

$$R_{stim.abs} = B_{12}\, g(\nu') \left(\frac{I}{c}\right) N_1$$

↑ proportionality constant (Einstein coeff.)

Rate of Stimulated Emission per unit Volume:

$$R_{stim.emis} = B_{21}\, g(\nu') \left(\frac{I}{c}\right) N_2$$

↑ Einstein coeff.

Rate of Spontaneous Emission per unit volume:

$$R_{spon.emiss} = A_{21} N_2$$ ← Einstein coeff.

A_{21}, B_{12}, B_{21} can be calculated with quantum mechanics.

Einstein showed that in thermal equilibrium,

$$\frac{A_{21}}{B_{21}} = \frac{8\pi h \nu^3}{c^3} \quad \text{and} \quad B_{21} = B_{12}$$

But these ratios must also be true out of thermal equilibrium, because A_{21}, B_{12}, B_{21} are fundamental properties of the atoms.