Homework, *set #2 – Chem. 524 – Spring 2013 (due late Feb. 2013)*

From Notes 4 – basic optics:

—read Chap 3-1, 4, 5 (then 3-2, 3, which carry over to Section 5, Special Optics)

-- to discuss: Problem 3-2, 1, 12, 19,

Problems to do: Ch 3: # 2, 7, 10, 11, 13, and

a. I have a spectrometer that I wish to illuminate. To get the maximum efficiency, I need to image the source on the entrance slit (100 μ x 5 mm). Only the amount of power incident on the opening of the slit makes it to the detector. To properly use the spectrometer, the incident light should enter with an F/4 cone. You have a quartz halogen lamp (with a filament 1 mm x 10 mm) and three lenses, each 50 mm in diameter, with focal lengths of 50, 200 and 1000 mm. What lens do you chose and where do you place it and the source to get the best throughput efficiency at the slit?. Why?

b. I want to build a sample chamber for microsampling (e.g. ~0.1-1.0 mm diam.) using an FTIR spectrometer, to collect spectra in the 3-10 micron range. Should I use lenses or mirrors to focus the output of the interferometer on the sample and collect the light again and refocus on the detector (area 1 mm^2)? Why? What kind (size, focal length, material/coating) lenses or mirrors would be needed to create an essentially straight design (i.e. compact) that will match both focusing requirements.

From Notes 5 (optics extensions)—

—read in Chap. 3, parts. 1-5 (overlaps previous Section 4, Optics) and
review the modulator tutorials in the links in Notes 5,

For discussion or thinking (these are important):

1. why are wire grids not useful in vis/uv?
2. why are polaroids not useful in farUV or mid IR?
3. what advantage might a 80% duty cycle modulator have? a 20%?
4. if you can modulate with a simple chopper (cheap, low tech) why go to polarization modulation or shutters or ATOF?
5. what is the difference between a magnetic (Faraday) rotator and a electro-optic modulator (Pockels cell) beyond one uses magnetic and the other electric fields?

Problems to hand in: # 3-14, added to assigned work from section 4 (for Prob. set #2)

Plus (look up background data on Web**):**

a. for a wire grid polarizer, if the spacing between wires is 5.0 μm, estimate the minimum wavelength for which you can usefully obtain polarized IR light (e.g. 5:1 ratio)

b. For a calcite prism polarizer, Glan Taylor like, if the cut is at 45^o, at what angles of incidence would it be useful as a polarizer (angular aperture is goal)

c. How thick must a crystalline quartz wave place be for λ/2 retardation at 400 nm and 1 μm for a multi-order plate (choose n = 10) or a single order plate?

d. What is the modulation frequency (Hz) of a wheel turning at 1800 rpm and having 5 holes?

From Notes #6 (dispersion) — read Chap. 3-5,6 as a minimal start. Read from the Richardson Grating book, see links below, and the web sites by JY and/or wikipedia

Discussion: Chap 3--#9,25,28, 30

1. why are prism monochromators not used in general spectroscopy?
2. why do prism monochromators have an advantage in the far UV?
3. Why do you want high density (small d spacing) gratings for UV but low density ones for IR?
4. What advantages do holographic gratings have over ruled ones? why?

Problems to hand in: Chap 3: 3 (previously assumed $\phi=7^o$), 20-21-22

practice: (#s : 15-16-17 and 20-21-22 are very similar, hand in only second one)

Homework—Sect 7 – part of homework #2

Reading as described at beginning of section, plus minimum *Chap 1, Griffiths and deHaseth*. Look at handouts and links

Discussion:

a. Consider experiments where an interferometer would be a better (or worse—goes both ways) choice than a monochromator, why?

b. The throughput advantage of an FTIR is always stated with regard to having no slit, but an FTIR has an aperture, and needs to make it smaller to increase resolution, why? How does this affect the Jacquinot advantage?

c. The Genzel interferometer gets retardation ~4Δx while "normal" interferometers, like classic Michelson, have retardation ~2Δx. How does retardation vary for the Bomem wishbone configuration interferometer, p.11 (Notes 7)? Why?

Problems to hand in: Chap 3 # 8, 23, 24,

a. I have an old FTIR that can get 0.5 cm^{-1} resolution with a design like that on p.13 (Notes 7). How far must the mirror move at minimum to get this resolution with an asymmetric scan (one sided interferogram)? What about for a symmetric (two-sided) interferogram? The maximum scan rate on this instrument is stated as 20 kHz, which is the frequency of modulation of the laser reference signal. Since this is a HeNe, 628 nm, how fast does the mirror move??
b. This original FTIR was upgraded with a new design, but now capable of 0.07 cm^{-1} resolution and 340 kHz scan speeds (laser modulation), how do your answers change for the upgrade (while a different design, 2Δx is still retardation)? At this resolution I cannot do a 2-sided interferogram using this design. Why not?
c. The Nyquist condition states that I need to sample a waveform at least twice every cycle (at $2 \cdot f$ in time, or $\lambda/4$ in Δx space) to properly digitize the variation in the signal. If I want to measure spectra over the range from 500-2000 cm^{-1}, how frequently must I measure the interferogram (Δx) – this is critical for step-scan experimental design – using a typical Michelson design ($\delta \sim 2\Delta x$)?