Homework #2 - 2013 - Chem 524

Notes 4:

Ch3: #2 f/2 lens $d = 5\,cm$ $S_1 = 10\,cm$

$S_2 = ?$ $1/S_1 + 1/S_2 = 1/f$ $f = (f/\#) \cdot d$

$1/10 + 1/S_2 = 1/10$ $= 2 \cdot d = 10\,cm$

$S_2 = \infty$ ⟹ parallel beam, $m = -\infty$

$F/\# = 2$, $\Omega = \frac{\pi}{4}\left(\frac{1}{(2)^2}\right) = \pi/16$ sr

(kind of dumb question, more interesting if $S_1 = 20\,cm$)

~~then~~ $S_2 = 20$, $m = -1$, $F/\# = 4$, $\Omega = \frac{\pi}{4^3}$

3#7 - next page (p1), 3#10 (p2), 3#13 (p3) (p10)

3#11: $S_1 = 100\,cm$, $R = 80\,cm$

$1/S_1 + 1/S_2 = -2/R$ convex ⟹ R(+)/virtual image

$-2/80 - 1/100 = 1/S_1$ ⟹ $S_1 = -28\,cm$

virtual image will be erect (+)

and demagnified by ~4X

$m = -S_2/S_1 = \frac{-(-28)}{100} = 0.28$

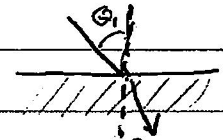
revise 2013

Homework Chem 524 - ~~2011~~ - #2

Some answers attached from previous students/graders

Notes 4 - optics

Ch 3:1 Snell's law $n_1 \sin\theta_1 = n_2 \sin\theta_2$



Extra – not assigned

$n_1 = 1$ (air)

$n_2 = 1.769$ (sapphire @ 579 nm)

$\theta_2 = \sin^{-1}\left(\frac{n_1}{n_2} \cdot \sin\theta_1\right)$

$\theta_1 = 50^\circ$ $= \sin^{-1}(0.565 \cdot 0.766) = \sin^{-1}(0.433)$

$\lambda = 579\,nm$ $= 25.6^\circ$

Reflection: $50^\circ = \theta_3$ $\rho(\lambda) = \left(\frac{n_2 - n_1}{n_2 + n_1}\right)^2$ normal

total ~ 7.7% normal $= (0.769/2.769)^2 = 0.077$

if at angle: $\rho(x) = \frac{1}{2}\left[\frac{\sin^2(\theta_1-\theta_2)}{\sin^2(\theta_1+\theta_2)} + \frac{\tan^2(\theta_1-\theta_2)}{\tan^2(\theta_1+\theta_2)}\right]$

$\theta_1 - \theta_2 = 24.4^\circ$ $= \frac{1}{2}\left[\frac{0.171}{0.938} + \frac{0.206}{15.2}\right] = \frac{1}{2}(0.182 + 0.014)$

$\theta_1 + \theta_2 = 75.6^\circ$

$\rho(\lambda)_{50} \sim 9.8^\circ$ $= 0.098$

Polarization — $\rho_\sigma = \sin^2(\theta_1-\theta_2)/2\sin^2(\theta_1+\theta_2) = \mathbf{0.091}$

$\rho_\pi = \tan^2(\theta_1-\theta_2)/2\tan^2(\theta_1+\theta_2) = 0.007$

3-7, $n_2 = 1.48$ $NA = (n_1^2 - n_2^2)^{1/2} = (2.25 - 2.19)^{1/2} = 0.24$

$n_1 = 1.50$ $NA = n_0 \sin\theta_0 \Rightarrow \theta_0 = \sin^{-1}(NA/n_0)$

$= 14.1^\circ$

(3-8) next $(F/\#) = d/f = 2\tan\theta_0 = 0.5$

Extra – not assign

3-12 $n = 1.5$ a. $f = \left[(n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)\right]^{-1}$

$R_1 = 40\,cm$ $= [(0.5)(1/20 + 1/40)]^{-1} = \mathbf{26.7\,cm}$

$R_2 = -20\,cm$ b. $1/s_1 + 1/s_2 = 1/f \Rightarrow s_2 = (1/f - 1/s_1)^{-1} = \left(\frac{1}{26.7} - \frac{1}{40}\right)^{-1}$

(3-18) ~~ff~~ $M = -s_2/s_1 = -2$ $\therefore s_2 = 80\,cm$

3-13 → see (p 10)

3-8

3-8

$d = 5.0\ mm \quad \lambda = 500\ nm$

$R = 0.95$

$$c_F = \frac{4(0.95)}{(1-0.95)^2} = 1520$$

$$m\lambda = 2d\cos\theta;\ \text{at } \theta = 0^\circ \Rightarrow m = \frac{2d}{\lambda} = \frac{2(0.005\ m)}{500\times10^{-9}m} = 20000$$

$$(FWHM)_\lambda = \frac{2/\sqrt{c_F}}{\pi m \lambda^{-1}} = \frac{2/\sqrt{1520}}{\pi(20000)(500\times10^{-9}m)^{-1}}$$

$$= 4.08\times10^{-13}\ nm$$

3-8 cont

$$F = \frac{\pi\sqrt{c_F}}{2} = \frac{\pi(1520)^{1/2}}{2} = 61.24$$

$$R_{th} = mF = (20000)(61.24) = 1.22\times10^6$$

$$\Delta\lambda_s = \frac{\lambda}{m+1} = \frac{500\ nm}{20001} = 0.025\ nm$$

3-10

3-10

$n_2 = 1.52;\ \theta_1 = 30^\circ$

using Snell's Law

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$$\Rightarrow \sin\theta_2 = \frac{n_1 \sin\theta_1}{n_2} = \frac{(1.00)(\sin 30)}{1.52} = 0.329$$

$\theta_2 = 19.2^\circ$

~~∴ wavelength range scanned is 546.2 nm → 550.8 nm~~

Notes 4 problem

3.13

(a) $F/n = \frac{f}{D}$

$f = F/n \times D$

$= 6.0 \times 1.0\ cm$

$= 6.0\ cm$

(b) $\Omega = \frac{\pi}{4} \frac{1}{(F/n)^2}$

$= \frac{\pi}{4} \frac{1}{(6.0)^2}$

$= 0.022\ sr$

(c) radiant emittance = radiant intensity × Ω

$= 1.0\ W\ sr^{-1} \times 0.022\ sr$

$A = (0.5)^2 \pi$

$= 0.022\ W / A = \sim 0.027\ W/cm^2$

Notes 5 problem 3-14

3–14

$d = 2.04 \times 10^{-5}\ cm$; $n = 1.35$

a) $\lambda_m = \frac{2dn}{m} = \frac{2(204 nm)(1.35)}{1} = 550.8\ nm$

b) $\lambda_m = \frac{2dn}{m} = \frac{2(204 nm)(1.35)}{2} = 275.4\ nm$

c) for $m = 1$, $\theta = 10°$

$\lambda = 2d(n^2 - \sin^2\theta)^{1/2} =$

$= 2(204)\left[(1.35)^2 - \sin^2 10\right] = 546.2\ nm$

∴ wavelength range scanned is 546.2 nm → 550.8 nm

Notes 4 – optics – extra problem;

(a) old problem param

slit $100\mu \times 5\,mm = 0.1 \times 5\ mm^2$

aperture F/2

source $1 \times 10\ mm$

lenses f=50, 400, 1000 mm

50 mm Diam

soln 1: use 50 mm lens – 100 mm from slit = (S_2)

source place 100 mm from lens = (S_1)

$f/2 \to 100/50 = 2$ (collect and image)

Image → 1:1 $S_2/S_1 = 1 \to 10 \times 1$ mm

soln 2: use: 400 mm lens – 100 mm from Slit = S_2

$f/2 = 100/50 = 2$ illum slit

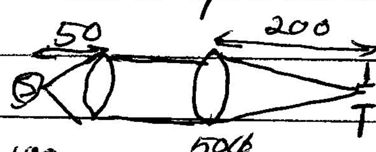
~~$S_1 = (1/400 - 1/100)^{-1} = -(0.75 \times 10^{-2})^{-1} = 133$ mm~~

Will not work at f/2 since image is: $S_2 < f$

(same for 1000 mm – sorry I meant to use shorter values)

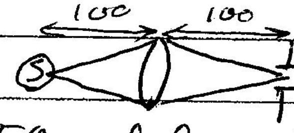
New Problem: f/4 monochromator / lens 50, 200, 1000 / d=50 mm

soln of Ralph;



$m = \frac{-S_2}{S_1} = \frac{200}{50} = 4$

alternate:



use one 50 mm = f lens, 1:1 image

image $1 \times 10 = 10\ mm^2$, slit $0.5\ m^2$

throughput 1/20 collect f/2 4× less ~ 1/80 – seems better

source image $4 \times 40 = 160\ mm^2$

slit $0.1 \times 5 = 0.5\ mm^2$

throughput ⇒ 1/320

collect at f/1

~~alternate 2:~~ (but) over fill spectrometer so only 1/4 of light used: f/4 spect / f/2 fill

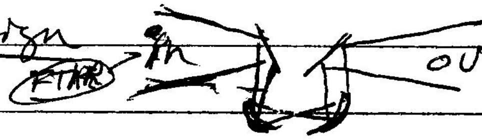
So $1/80 \cdot 1/4 = 1/320 \Rightarrow$ **same** !!

Notes 4 extra

(b) microsample in FTIR, 3–10 μm = λ,
sample 0.1 → 1 mm

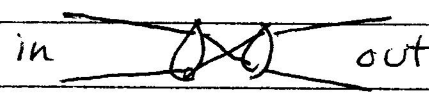
soln 1: Use mirrors – achromatic focus / no absorbance throughput

design



gold coat mirror best
need to be off axis
focus with off axis
ellipsoid or paraboloid
need to be symmetrical to use spectrometer
sample compartment – may have distort focus

soln 2: Use ~~mirrors~~ lens – define 3–10 μ – BaF_2 work



this is in-line / fit compartment
focus may vary with λ but slow

focal length should be f/1 or so – small image
with diameter to encompass beam in
sample compartment (typically 1" – 25 mm works)
Place them symmetrically, adjust position
to get focus in middle

Chap 3

3-14. $d = 2.04 \times 10^{-5}$ cm   a. Normal incidence 1st order

$n = 1.35$

$\lambda_m = 2dn/m = 2(2.04\times10^{-5})1.35$ cm

$\lambda_1 = 5.5\times10^{-5}$ cm $=$ 551 nm

b. $\lambda_2 = 276$ nm $m=2$

c. $\theta = \pm 10°$: $\lambda_\theta = 2d(n^2 - \sin^2\theta)^{1/2} \Rightarrow$ 546 − 555 nm   range ±10°

3-27. $\Delta A = 10$ L mol^{-1} cm^{-1} ellipticity $\theta = 33\,\Delta A$

$\Delta n_R = 4.0\times10^{-6}$ molar ellipticity $[\theta] = \theta/bc = 3300\,\Delta\varepsilon$

$\lambda = 400$ nm $[\theta] = (3300)(10$ L mol^{-1} cm$^{-1})$ ~~10 cm/dm~~

$b = 10$ cm $= 1$ dm $= 3.3\times10^{4}$ dL mol^{-1} dm^{-1}

(conversion of L → dL & cm → dm is in the 33 → 3300 factor)

(not assign)

Extra Notes 5:

(different values)   (old)   (new)

a. for grid to work: $\lambda > 2d$ $d = 1.0\,\mu$ (micron)   ($d = 5\mu$)

$\lambda > 2\mu$ (2000 nm) $\lambda \geq 10\,\mu$

(tricky to estimate to 5:1)
- from data in lecture if $d \sim 400$ nm get extinction 150:1 at 3μ, 300:1 at 8μ
- expect ~ 50:1 at ~1μ
- Scale this expect 50:1 at ~ 5μ for $d = 1\mu$

b. Calcite

$n_1 = 1.658$ Critical angle: $\theta_c = \sin^{-1}(n_2/n_1)$

$n_2 = 1.486$ $\theta_o = \sin^{-1}(1.658) = 37.1°$

$\theta_e = \sin^{-1}(1.486) = 42.3°$

so at 45° prism will not be a good polarizer

need to tilt off axis by ~ 5° → between above values

then get maximum angular aperture

i.e. desire cut angle ~ 40° to allow error on either side (divergence of beam)

Notes 5 extra questions:

c. Crystalline qtz: $n_o = 1.544$ $n_e = 1.553$ $\Delta n = 0.009$

$\lambda = 400\,nm$ $\delta = \left(\frac{2\pi}{\lambda}\right)\Delta n\, z$ $\lambda/2$ retard $= \pi$

$z_{\lambda/2} = (\lambda/2)/\Delta n$

single plate: $= (400\,nm/2)/0.009 = 22\,\mu m$

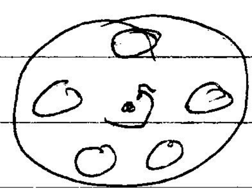
multi order $n = 10$ $z_{10.5} = (10.5\lambda)/0.009$

$= 466\,\mu m = 0.466\,mm$

$\lambda = 1\mu \Rightarrow z_{\lambda/2} = 55\,\mu m$

(mult by $2.5 = \frac{1000}{400}$) $z_{10.5} = 1.16\,\mu m$

d. wheel $= 1800\,rpm = \frac{1800}{60} = 30\,Hz$



5 holes mean chop 5x per turn

mod $f = 5 \cdot 30 = 150\,Hz$

(Gorm Yoder) Key to ~~Problem Set #2 plus added~~ Chap 3 problems ⑥

not assign **3-2**

$F/n = 2 \quad D = 5.0\,cm$

$\Rightarrow F/n = \frac{f}{D} \Rightarrow f = 2(5cm) = 10cm$

If light source is placed 10cm from lens:

$\frac{1}{f} = \frac{1}{S_1} + \frac{1}{S_2} \Rightarrow \frac{1}{10cm} = \frac{1}{10cm} + \frac{1}{S_2} \quad \therefore S_2 = \infty$ (parallel beam)

$m = \frac{-S_2}{S_1} = -\infty$

$F/n\ system = \frac{S_1}{D} = \frac{10cm}{5cm} = 2$

$\Omega = \frac{\pi}{4}\frac{1}{(F/n)^2} = \frac{\pi}{4} \cdot \frac{1}{(2)^2} = \frac{\pi}{16} = 0.196\,sr$

Notes 6 — monochromators

3-3 **3-3**

$\phi = 7^\circ$ assume

$Rd = 2.5\ nm/mm$

$f = 0.3m$

$F/n = 6.0$

Grating size: 44.33 x 44.33 mm

Groove density: 1200 grooves/mm

λ: 400 nm

a) $D_l = Rd^{-1} = \frac{1}{2.5\,nm/mm} = 0.4\,mm/nm$

$D_a = \frac{D_l}{f} = \frac{0.4\,mm/nm}{300\,mm} = 1.33 \times 10^{-3}\,nm^{-1}$

b) $\Omega = \frac{A_p}{f^2} = \frac{\pi/4}{(F/n)^2} \Rightarrow A_p = \frac{(0.3m)^2\pi}{4(6.0)^2} = 1.96 \times 10^{-3}\,m^2 = 19.6\,cm^2$

$D_p = [4A_p/\pi]^{1/2} = \left[\frac{4(1.96 \times 10^{-3})}{\pi}\right]^{1/2} = 0.05\,m$

c) slit width needed to obtain a 5 nm geometric spectral bandpass

$s_g = R_d W$

$\Rightarrow W = \frac{s_g}{R_d} = \frac{5\,nm}{2.5\,nm/mm} = 2\,mm$

Skip to next page — Alternate Soln $\phi = 7^o$

d) find the angle of incidence, α, and the angle of refraction, β

$D_a = \frac{|m|}{d\cos\beta}$ $\quad d = \frac{10^6\,nm/mm}{1200\,grooves/mm} = 833.3\,nm$

$\Rightarrow \cos\beta = \frac{|m|}{d\,D_a} = \frac{1}{(833.3)(1.3\times10^{-3})} = \frac{1}{1.11}$

$\beta = 25.8^o$

$D_a = \frac{\sin\alpha + \sin\beta}{\lambda\cos\beta}$

$\Rightarrow D_a(\lambda)\cos\beta - \sin\beta = \sin\alpha = (1.3\times10^{-3}\,nm^{-1})(400\,nm)\cos(25.8) - \sin(25.8)$

$\alpha = 2.53^o$

e) $W_d = \frac{\lambda f}{w'_D}$, $\quad w'_D = W_G\cos\beta$

$W_d = \frac{\lambda f}{W_G\cos\beta} = \frac{(400\,nm)(3.0\times10^8\,nm)}{(4.433\times10^7\,nm)(\cos 25.8)} = 3007\,nm$

$= 3.01\times10^{-3}\,mm$

$S_d = \frac{\lambda}{D_a w'_D} = \frac{400\,nm}{(1.33\times10^{-3}\,nm^{-1})(4.433\times10^7\,nm)(\cos 25.8)}$

$= 7.52\times10^{-3}\,nm$

$= \Delta\lambda_d$

(8)

3.3

(d) There are two ways:

(1) assume $\alpha = 0$

$m\lambda = d \sin\beta$

$\sin\beta = \frac{\lambda}{d} = \frac{400\,nm}{833\,nm} = 0.48$

$\beta = 28.7^\circ$

(2) assume takeoff angle, for example, $\phi = 10$.

$m\lambda = 2d \sin\theta \cos\phi$

$\sin\theta = \frac{400}{2\times 833} \frac{1}{\cos 10^\circ} = 0.2438$

$\theta = 14.1^\circ$,

$\beta = \theta + \phi = 24.1^\circ$

(e)

(1) $W_d = \lambda f / W_0'$, $W_0' = W_G \cos\beta$

$= \frac{400\,nm \times 0.30 \times 10^9}{44.33 \times 10^6 \cos 28.7^\circ} = 3086\,nm$

$= 3.1\,mm$

$S_d = \frac{\lambda}{D_a W_0'} = \frac{400}{1.33 \times 10^{-3} \times 44.33 \times 10^6 \cos 28.7^\circ}$

$= 7.73 \times 10^{-3}\,nm.$

(2) $W_d = \frac{400\,nm \times 0.30 \times 10^9}{44.33 \times 10^6 \cos 24.1^\circ}$

$= 2965.5\,nm = 2.97\,mm$

$S_d = \frac{400}{1.33 \times 10^{-3} \times 44.33 \times 10^6 \cos 24}$

$= 7.43 \times 10^{-3}\,nm$

f) $\Phi_c = B_\lambda W H \Omega T_{op} S_g$

$= (2.00 \times 10^{-4}\,W cm^{-2} sr^{-1} nm^{-1})(0.5\,cm)(0.05\,cm)(\frac{\pi}{4}\frac{1}{6^2})(0.40)(5\,nm)$

$=$ ~~$5.45 \times 10^{-7}\,W$~~ $2.18 \times 10^{-7}\,W$

*alternate solution for 3-3 d, e

$R_d = 2.5\ nm/mm$ Grating size: 44.33 x 44.33 mm

$f = 0.3\ m$ Groove density: 1200 grooves/mm

$F/n = 6.0$ $\lambda = 400\ nm$

assume $\Phi = 7.0°$

$m\lambda = 2d \sin\theta \cos\Phi$ ~~$\alpha = \theta - \Phi$ and $\beta = \theta + \Phi$~~

$$\Rightarrow \sin\theta = \frac{m\lambda}{2d\cos\Phi} = \frac{400\,nm}{2(933.3\,nm)\cos 7.0} = 0.242$$

$\theta = 14.0$

$\alpha = 14.0 - 7.0 = 7.0°$

$\beta = 14.0 + 7.0 = 21.0°$

e) $W_d = \frac{\lambda f}{W_D'}$, $W_D' = W_G \cos\beta$

$$W_d = \frac{\lambda f}{W_G \cos\beta} = \frac{(400\,nm)(3.0\times10^{8}\,nm)}{(4.433\times10^{7}\,nm)(\cos 21.0)} = 2.9\times10^{-3}\,mm$$

$$S_d = \frac{\lambda}{D_a W_D'} = \frac{\lambda}{D_a W_G \cos\beta} = \frac{400\,nm}{(1.33\times10^{-3}\,nm^{-1})(4.43\times10^{7}\,nm)(\cos 21.0)}$$

$= 7.23\times10^{-3}\,nm$

$= \Delta\lambda_d$

f)

$\Phi_o = B_\lambda W H \Omega T_{op} s_g$; $s_g = R_d W = (2.5\,nm/mm)(0.5\,mm) = 1.25\,nm$

$= (2.00\times10^{-4}\,W\,cm^{-2}\,sr^{-1}\,nm^{-1})(0.05\,cm)(0.5\,cm)\left(\frac{\pi}{4}\cdot\frac{1}{6^2}\right)(0.40)(1.25\,nm)$

$= 5.45\times10^{-8}\,W$

Solutions to Optional Problems from problem set #3 Chem 524 by G. Yoder

(10)

from set Notes 4

3.13

$f/n = 6.0$; $D = 1.0\,cm$; radiant intensity $= 1.0\ W\,sr^{-1}$

i) $f/n = \frac{f}{D} \Rightarrow f = (f/n)\,D = 6.0\,(1.0\,cm) = 6.0\,cm$

---

i) $\Omega = \frac{\pi}{4} \cdot \frac{1}{(f/n)^2} = \frac{\pi}{4} \cdot \frac{1}{(6.0)^2} = 2.2 \times 10^{-2}\ sr$

i) radiant emittance = radiant intensity $\times\ \Omega$

$= (1.0\ W sr^{-1})(2.2 \times 10^{-2} sr)$

Notes 6 – monochr $= 2.2 \times 10^{-2}\ W \sim 0.027\ W/cm^2$

Note: fundamentally The same as 15-16-17

3-20

groove density $= 2000$ grooves/mm ; $d = 500$ nm/groove , $\alpha = 20.0$

a) if $\beta = 30.0$

$m\lambda = d\,(\sin\alpha + \sin\beta) \Rightarrow \lambda = \frac{d\,(\sin\alpha + \sin\beta)}{m}$

$= \frac{500\ nm\,[\sin(20.0) + \sin(30.0)]}{1}$

$= 421$ nm

b) $m\lambda = d\,(\sin\alpha + \sin\beta)$

$\Rightarrow \sin\beta = \frac{m\lambda}{d} - \sin\alpha$

at 300nm $\sin\beta = \frac{1\,(300nm)}{500\,nm} - \sin 20.0 = 0.258$

$\beta = 15.0$

at 400 nm $\beta = 27.2$

at 500 nm $\beta = 41.1$

at 600 nm $\beta = 59.1$

3.20 c

$$\sin\beta = \frac{2 \times 280\ nm}{500\ nm} - \sin 20.0 = 0.778$$

$\beta = 51.1$

560 nm at first order overlaps this.

3.21

groove density = 2000 grooves/mm ; d = 500 nm/groove

a) $\lambda_b = d \sin 2\gamma \Rightarrow \sin 2\gamma = \frac{\lambda b}{d} = \frac{300\ nm}{500\ nm} = 0.6$

$2\gamma = 36.9°$

$\gamma = 18.4°$

b) $\Phi = 10.0°$

at 300 nm $\quad 2d \sin\theta \cos\Phi = m\lambda$

$$\Rightarrow \sin\theta = \frac{m\lambda}{2d\cos\Phi} = \frac{1\ (300\ nm)}{2\ (500 nm)(\cos 10.0)} = 0.305$$

$\theta = 17.7$

$\alpha = \theta - \Phi = 17.7 - 10.0 = 7.74°$

$\beta = \theta + \Phi = 17.7 + 10.0 = 27.7°$

$$D_a = \frac{|m|}{d \cos\beta} = \frac{1}{(500\ nm)(\cos 27.7)} = 2.26 \times 10^{-3}\ nm^{-1}$$

at 400 nm

$\theta = 24.0$

$\alpha = 14.0$

$\beta = 34.0$

$D_a = 2.41 \times 10^{-3}\ nm^{-1}$

at 500 nm

$\theta = 30.5$

$\alpha = 20.5$

$\beta = 40.5$

$D_a = 2.63 \times 10^{-3}\ nm^{-1}$

-21 c

% change 300 → 500nm $= \frac{(2.63 - 2.26) \times 10^{-3}\ nm^{-1}}{2.26 \times 10^{-3}\ nm^{-1}} \times 100$

$= 16.4\ \%$

3-22

$f = 0.30m$ for monochromator in 21b

at 300nm $\quad D_l = f D_a = (300\ mm)(2.26 \times 10^{-3}\ nm^{-1}) = 0.678\ mm/nm$

$R_d = \frac{1}{D_l} = 1.47\ nm/mm$

at 400 $\quad D_l = 0.723\ mm/nm$

$R_d = 1.38\ nm/mm$

at 500 $\quad D_l = 0.789\ mm/nm$

$R_d = 1.27\ nm/mm$

)

at 300nm

$w = 100\mu m \rightarrow \quad S_g = R_d W = (1.47\ nm/mm)(100\mu m)(10^{-3} mm/\mu m) = 0.147 nm$

$\Delta\lambda_s = 2S_g = 2(0.147 nm) = 0.294\ nm$

$w = 200\mu m \rightarrow \quad S_g = 0.294\ nm$

$\Delta\lambda_s = 0.588\ nm$

$w = 500\mu m \rightarrow \quad S_g = 0.735\ nm$

$\Delta\lambda_s = 1.47$

at 400nm

$w = 100\mu m \rightarrow \quad S_g = 0.138\ nm$

$\Delta\lambda_s = 0.276 nm$

$w = 200\mu m \rightarrow \quad S_g = 0.276 nm$

$\Delta\lambda_s = 0.552\ nm$

$w = 500\mu m \rightarrow \quad S_g = 0.690\ nm$

$\Delta\lambda_s = 1.38 nm$

± 500

(13)

$W = 100\,\mu m \rightarrow s_g = 0.127\,nm$

$\Delta\lambda_s = 0.254\,nm$

$W = 200\,\mu m \rightarrow s_g = 0.254\,nm$

$\Delta\lambda_s = 0.508\,nm$

$W = 500\,\mu m \rightarrow s_g = 0.635\,nm$

$\Delta\lambda_s = 1.27\,nm$

) $\lambda = 500\,nm$, $B_\lambda = 1.50\times10^{-1}\,W\,cm^{-2}\,sr^{-1}\,nm^{-1}$; $H = 5.0\,mm$; $T_{op} = 0.43$; $F/n = 7.0$

$\Phi_0 = B_\lambda W H \Omega T_{op} s_g \qquad \Omega = \frac{\pi}{4}\cdot\frac{1}{(f/n)^2} = \frac{\pi}{4}\cdot\frac{1}{(7)^2} = 0.016\,sr$

$W = 100\,\mu m \rightarrow \Phi_0 = (1.50\times10^{-1}\,W\,cm^{-2}\,sr^{-1}\,nm^{-1})(0.01\,cm)(0.5\,cm)(0.016)(0.43)(0.127\,nm)$

$= 6.56\times10^{-7}\,W$

$W = 200\,\mu m \rightarrow \Phi_0 = 2.62\times10^{-6}\,W$

$W = 500\,\mu m \rightarrow \Phi_0 = 1.67\times10^{-5}\,W$

d) For a line source, $t(\lambda) = 1 \therefore \Phi_0 = WH\Omega\,B\,T_{op}$

For a continuum source, B_λ and T_{op} are constant over $\lambda_0 \pm s$, not $t(\lambda)$, $\therefore \Phi_0 = B_\lambda W H \Omega T_{op} \int_0^\infty t(\lambda)\,d\lambda$

$= B_\lambda W H \Omega T_{op} s_g$

The later is $\propto$ to spectral bandpass while the former is not

e) $R_{th} = \frac{W_G\,(m)}{d} = \frac{5.0\times10^7\,nm}{500\,nm} = 1.0\times10^5$

$s_d = \frac{\lambda}{D_a W_D'}$ where $W_D' = W_G \cos\beta$ $\qquad \beta \doteq 40.5^\circ$ (from 3.21, same mono.

$D_a = 2.63\times10^{-3}\,nm^{-1}$ (also from 3.21

$= \frac{\lambda}{D_a W_G \cos\beta} = \frac{500\,nm}{(2.63\times10^{-3}\,nm^{-1})(5.0\times10^7\,nm)(\cos 40.5)}$

$= 5.0\times10^{-3}\,nm$

Notes 7 — Interferometers

3.8

$C_F = 4\rho/(1-\rho)^2$, $\rho = 0.95$

$\therefore C_F = \frac{4\times 0.95}{(1-0.95)^2} = 1520$

$m\lambda = 2d\cos\theta$, $\theta = 0°$ (normal incidence)

$m = 2d/\lambda = \frac{2\times 5.0\times10^6\,nm}{500\,nm}$

$= 20000$

$(FWHM)_\lambda = \frac{4}{\sqrt{C_F}} \frac{\lambda^2}{4\pi d}$

$= \frac{4}{\sqrt{1520}} \frac{500^2}{4\pi\, 5.0\times10^6}$

$= 4.082\times10^{-4}\ nm$

$F = \frac{\pi\sqrt{C_F}}{2} = \frac{\pi\sqrt{1520}}{2} = 61.24$

$R_{th} = mF = 20000\times 61.24$

$= 1224800$

$= 1.22\times10^6$

$\Delta\lambda_f = \frac{\lambda}{m+1} = \frac{500}{20001}$

$= 0.025\ nm$

Solutions to Homework #3 by Gorm Yoder Chem 524
(To be turned in)

15

3.23

$f = 2v\bar{\nu}$ $v = 1.5$ cm/s

a) at 400 nm $\rightarrow$ $\bar{\nu} = 25000$ cm^{-1}

$f = 2(1.5\text{ cm/s})(25000\text{ cm}^{-1}) = 7.5\times10^{4}$ Hz

b) at 800 nm $\rightarrow$ $\bar{\nu} = 12500$ cm^{-1}

$f = 2(1.5\text{ cm/s})(12500\text{ cm}^{-1}) = 3.75\times10^{4}$ Hz

c) at 10μ $\rightarrow$ $\bar{\nu} = 1000$ cm^{-1}

$f = 2(1.5\text{ cm/s})(1000\text{ cm}^{-1}) = 3.0\times10^{3}$ Hz

3.24

a) $10.15\,\mu = 985.2$ cm^{-1}
$10.18\,\mu = 982.3$ cm^{-1}

$\therefore$ $\Delta\bar{\nu} = 2.903$ cm^{-1}

$$\Delta x = \frac{1}{2\Delta\bar{\nu}} = \frac{1}{2(2.903)} = 0.172\text{ cm}$$

This assumes $\delta = 2(\Delta x)$ optical retardation and that must go one full wave out of phase but everyone used $\Delta x = \frac{1}{\Delta\bar{\nu}}$

b) 725 nm = 13793.1 cm^{-1}
730 nm = 13698.6 cm^{-1}

$\therefore$ $\Delta\bar{\nu} = 94.5$ cm^{-1}

$$\Delta x = \frac{1}{2\Delta\bar{\nu}} = \frac{1}{2(94.5\text{ cm}^{-1})} = 5.29\times10^{-3}\text{ cm}$$

3.24

(a) $10.15\,\mu m = 985.22\ cm^{-1}$

$10.18\,\mu m = 982.32\ cm^{-1}$

$\Delta\bar{\nu} = 2.9\ cm^{-1}$

$\Delta\bar{\nu} = \frac{1}{2\,\delta_{max}}$ where δ_{max} is the maximum distan ~~do~~ the mirror travel.

$2.9 = \frac{1}{2\delta_{max}}$

$\delta_{max} = 0.172\ cm$

(b) $725\ nm = 13793.1\ cm^{-1}$

$730\ nm = 13698.6\ cm^{-1}$

$\Delta\bar{\nu} = 94.5\ cm^{-1}$

$\Delta\bar{\nu} = \frac{1}{2\delta_{max}}$

$\delta_{max} = \frac{1}{2\Delta\bar{\nu}}$

$= 5.3 \times 10^{-3}\ cm$

$= 5.3\ \mu m$

Notes 7 interferometer extra / PLUS

(a) res 0.5 cm^{-1} → ideal $\Delta\nu = 1/2\Delta x_m$

scan 20 KHz $\Delta x_m = 1$ cm

λ_{HeNe} 628 nm   (symmetric do ±1 cm total 2 cm)

~~Speed: $f = 2v/\lambda$ ⇒ $v = \frac{1}{2} \cdot f \cdot \lambda$~~

$= \frac{1}{2} \cdot 2 \cdot 10^4 s^{-1} \cdot 628$ nm $= 0.63 \frac{cm}{s}$

(6280 μs^{-1} → 6.3 mm s^{-1} → ↗)

b. 0.1 cm^{-1} res → $x_m = 5$ cm

$v_{120kHz} = 3.7$ cm/s

old parameter

sym interferogram cause mirror 5 cm toward ~~more~~ beam splitter and could hit it

(c) 500 – 2000 cm^{-1} central is shortest λ

sample twice in Δx for oscillation   2000 cm^{-1} → ~~Δx~~

$\lambda = 5\mu$ ⇒ sample every $\lambda/2$ but ($\lambda = 2\Delta x$) since folded → 1.25 μ

(b) upgrade 0.07 cm^{-1} = $1/2\Delta x_m$

$\Delta x_m = 1/2 \cdot 0.07$ cm^{-1} = 7.14 cm

340 kHz ⇒ $2v/\lambda$ $v = 340$ kHz $\cdot$ 628 nm/2

= 107 mm/s