Laser Physics I (PHYC/ECE 464)
FALL 2021

OPTICAL SCIENCE & ENGINEERING
University of New Mexico

Final Exam
Closed Book, Closed Notes, Calculator will be provided.

Time: 4:00 – 6:00 pm

NAME ....
last *first*

Score

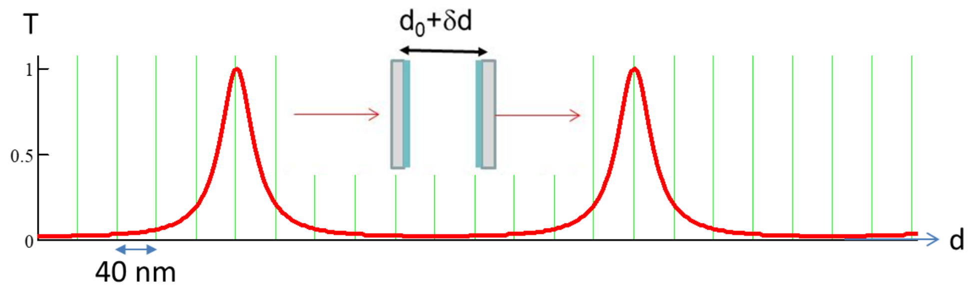
Total= 100 points

Please staple and return these pages with your exam.

Instructor: M. Sheik-Bahae

1. *(20 points)*

Drawn to scale in the graph below is the power transmission of a scanning symmetric Fabri-Perot (FP) cavity as the distance d is varied from its intial $d_0 \approx 0.5$cm. The source is a single wavelength laser fixed at wavelength λ_0. (Assume n=1).



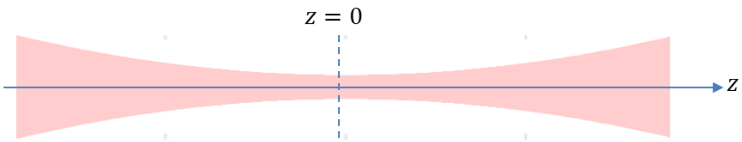
(a) What is λ_0?

(b) Estimate the *Finesse* and $\Delta\nu_{1/2}$ (in Hz).

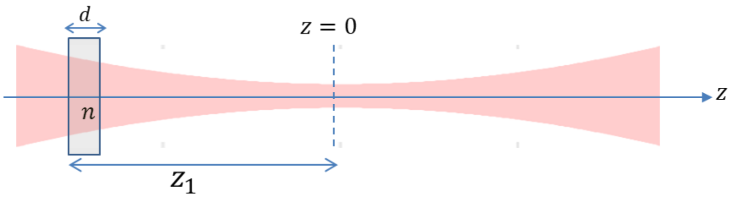
(c) What is the reflectiviety (R) of the mirrors?

(d) If refletivity R were to change to ~85%, what will be the new $\Delta\nu_{1/2}$? Draw the approximate tranmsition cruve versus d for this case on top of the graph above.

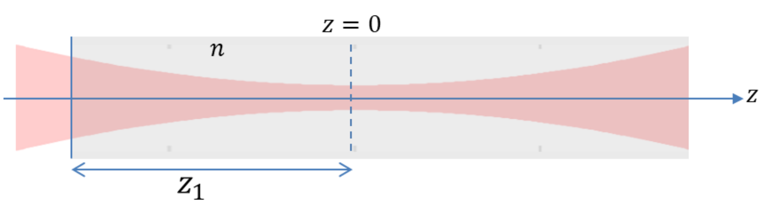
2. ***(25 points)*** Consider a fundamental Gaussian beam with known Z_0 and wavelength λ_0 travelling from *left to right*, as shown below.



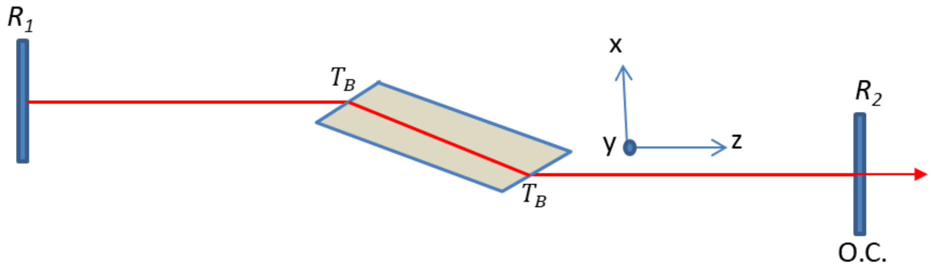
(a) A glass window of thickness d and index of refraction n is inserted at a distance z_1 prior to z=0 (focus) plane as shown. Derive the distance (***Δz***) and the direction (*sign*) by which the new focal point shifts. What is the new z_0 and the beam waist (w_0) (do they change at all)?



(b) Repeat part **(a)** for the case when the original Gaussian beam enters a material of index n with infinite thickness- as shown below. What is the new z_0 and the beam waist (w_0)?



3. ***(25 points)*** Consider the solid-state laser system below. The linear cavity parameters are: ***R_1=0.99*** and ***R_2=0.95***. The gain crystal is cut at Brewster angle to minimize reflective losses but it still has a transmission ***T_B =0.998*** per surface.



(a) What is the survival factor S of the passive cavity and the threshold integrated gain ($\gamma_{th} l_g = g_{th}$)?

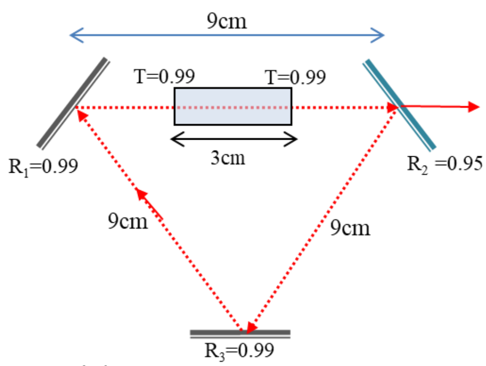
(b) Express cavity losses (1-S) as $\approx T_2 + L_i$. What is L_i? Find the needed integrated gain (g_0) for which the existing output coupling is optimum.

(c) What is the preferred direction of polarization (X, Y or Z) of this laser, and why?

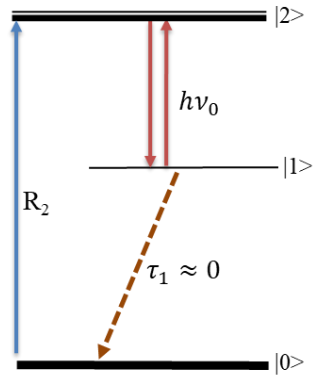
(d) <u>Estimate</u> the narrowest single-mode CW linewidth (in Hz) that can be achieved if this laser outputs *1W* after stabilization**.** Assume a cavity roundtrip time (τ_{RT}) of 1 ns.

4. (*30 points)* Consider the following *unidirectional* ring laser. Cavity parameters are given in the Fig. A. The following parameters are known for the *homogeneously* broadened gain medium:

$\Delta\nu \cong 2\times10^{13}$ Hz ; λ_0=1 μm; $\sigma_{21}(\nu_0)$=3x10^{-17} cm^2 ; $\tau_1 \approx 0$; $\tau_2 \approx 1$ μs; $g_1=g_2$
beam area A =10^{-4} cm^2; n(gain medium)=2



(A)



(B)

(a) What is the threshold upper state population (N_2^{th})?

(b) What is the cw output power if this laser were to be pumped ×9 above the threshold? Assume (and justify) high-Q cavity approximation. Ignore the transmission (leakage) through high reflectivity mirrors.

(c) Estimate the excitation pump power (in *Watts)* required to sustain the output power in (b). Assume that the lower laser state (level 1 in Fig. B) is *2 eV* above the ground state.

(d) If this laser were to be cw-modelocked, describe (and graph) the temporal behavior of the output pulse-train. Assume the shortest possible pulse and ignore dispersion. Estimate the number of longitudinal modes that are oscillating. Estimate the peak output power if pumped at ×9 above the threshold.

(e) If this laser were to be Q-switched, estimate the pulse width. Quantitatively draw a typical such pulse.

(f) Repeat part (b) if this ring laser were to operate *bi-directional*.