Laser Physics I (PHYC/ECE 464)
FALL 2010

Final Exam, Closed Book, Closed Notes
Dec. 16, 2010
Time: 5:30 – 7:30 pm

NAME ............................................. .............................................
last first

Score

Total= 100 points

Please staple and return these pages with your exam.

Happy Holidays!

Instructor: M. Sheik-Bahae
1. (20 points) Using the method of matching phase fronts (beam curvatures), find $Z_0$ and the location of the beam waist in the following cavity. Qualitatively, show the location of the beam waist on the graph. (Do not use the matrix method).
2. (10 points) Drawn to scale on the graph below is the relative power transmission of a monochromatic light source of unknown wavelength through a Fabry-Perot when the distance $d$ is slightly increased.

![Graph with two peaks and a label $850 \text{ nm}$]

a. Estimate the wavelength of the source?

b. Estimate the reflectivity of the cavity mirrors?
3.a (20 points) Write the rate equations for this 4-level system assuming optical pumping from levels $0 \rightarrow 3$ and laser action from levels $2 \rightarrow 1$. Lifetimes $\tau_3$, $\tau_2$, $\tau_1$, and branching ratios $\phi_{32}$, $\phi_{31}$, $\phi_{30}$, $\phi_{21}$, $\phi_{20}$ are known.

3.b (10 points) The above system is to be used as a laser amplifier. Assume $\nu_p = 3\nu_{12}$, $\phi_{31} \sim \phi_{30} \sim \phi_{20} \sim 0$, $\phi_{32} = 0.7$, $\tau_1 \sim 0$. If 10W of pump power is absorbed, what is the maximum power that can be extracted from this amplifier. (*This problem is simpler than it may appear!*)
4. (30 points) A solids state laser (centered at \( \lambda_0=1 \, \mu m \)) is constructed using a simple linear cavity. The laser crystal is Brewster-cut to reduce reflection losses to only \( R=0.2\% \) per surface. The homogenous lineshape is shown on the left. The following information is also given: Refractive index \( n=1.5 \), \( \tau_2=1 \, ms \), and spontaneous lifetime \( t_p=3 \, ms \). The beam area inside the gain medium is \( A=0.01 \, mm^2 \).

![Diagram of laser cavity with gain medium and reflectors]

- a) Estimate the threshold gain \( (\gamma_{th}) \) and threshold population inversion \( (\Delta N_{th}) \)
- b) Estimate CW power output at 9x above threshold (justify any approximations made).
- c) Is the output linearly polarized? If so, along which axis? Explain.
- d) If Q-switched, estimate the pulsewidth. Name a practical method of Q-switching.
- e) If cw-modelocked, graph the pulse train and quantify the repetition rate and the shortest possible pulsewidth. At 9x above threshold, what is the peak power in the (shortest) pulse?
5. *(10 points)* Describe the essential features of *(only 1 out of 3)* following lasers:
   - A CO$_2$ laser
   - A semiconductor diode laser
   - A Kerr-lens modelocked Ti:sapphire laser

*Use drawings and be brief (less than 50 words).*