ECE 4300, Fall Semester 2016
Lasers and Optoelectronics

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Assignment 7

Present your solutions *neatly*. Do not turn in rough unreadable worksheets - learn to **take pride in your presentation**. Show the relevant steps, so that partial points can be awarded. BOX your final answers where applicable. Draw figures wherever necessary. **Please print out the question sheet(s) and staple to the top of your homework.** Write your name, email address, and date/time the assignment is turned in on the cover.

Note: Assignment 1 has additional directions on deadlines, and rules for collaborative work.

Posted on: Monday, 11/30/2016. Lab 2 Reports are due on: 12/09/2016, Friday.
Do *not* turn in Problems 7.1-7.5. They are for practice and survey.

Problem 7.1 (Mode profile of a Diode Laser)
Verdeyen Problem #11.10.

Problem 7.2 (Beam Divergence in Gain-Guided Diode Laser)
Verdeyen Problem #12.6.

Problem 7.3 (Reflectivity of DBR Mirrors)
Verdeyen Problem #12.20.

Problem 7.4 (Radiation Damping)
Verdeyen Problem #13.1.

Problem 7.5 (Quantum Optical Dipole Elements for Particle-in-a-Box)
Verdeyen Problem #14.2.

Problem 7.6 (Lab Assignment 2 by Prof. Pollock, Due date: 12/09/2016, Friday)

Ti:Sapphire Laser Design for ECE 4300 Fall 2016
Problem: You are to design a Ti:Sapphire Laser, then go into the lab and physically implement your design.

Specifications:

- You are able to pump the laser with up to 5W of λ_{pump} =532 nm light from a frequency-doubled Nd:YAG laser.
- Output power should be 1W continuous wave. With 5W of pump power this should be feasible, but it is not trivial. It will require a good design and excellent alignment.

- If you are successful getting your cw design to lase, you may have time to try mode-locking the laser with a saturable absorber.

- The laser should be tunable from 760-850 nm. A birefringent filter will be available, your job is to make sure there is a place in the cavity for it. This simply means that the cavity must have a collimated beam in at least one arm of the cavity.

- There are no restrictions on the type of cavity you build (ring, linear, stable, etc.) nor how many mirrors you use. We would recommend a 4 mirror bow-tie configuration.

- Assume that the available mirror curvatures include R = 5 cm, 10 cm, 25 cm, and flat. Assume all high reflectors have a 99.7% reflectivity, and the output coupler can be 1%, 3%, or 8%.

- Specifications can be found in the literature, but here are some numbers I find useful.

  $\sigma_{em} = 3.8 \times 10^{-19}$ cm^2
  n=1.76
  $\tau = 3.2 \times 10^{-6}$ sec
  $\lambda = 0.8 \times 10^{-4}$ cm
  $\lambda_{pump} = 0.532 \times 10^{-4}$ cm
  $\delta\nu = 128 \times 10^{12}$ Hz

- A 1 cm Ti:sapphire laser rod will be available to meet your specs. The rod we have absorbs about 85% of the pump power at 532 nm. Knowing this can you estimate the Ti concentration in the rod?

Process: There are many ways to do this, but a good starting point is to base your design around the intracavity intensity. Once you know how small the beam needs to be inside the gain medium to achieve your desired intensity, you can figure out the optics. Try to establish a set of formulae which will predict the output power as a function of these four parameters: ω_0, I_{sat}, N/N_{th}, and T_{output}.

To get started, choose a cavity design, say for example a 4 mirror bowtie. A beam travelling a round trip will bounce off 5 HRs and go through the gain crystal twice, and giving each of those bounces a 99.7% transmission, you can estimate the "L" in the cavity. If you know the output coupler, the "T", you can compute the threshold gain needed to lase. The optimum T depends on how hard you pump it. Recall the discussion on intracavity intensity and saturation. A good rule of thumb is to operate at 4-6 I_{sat} inside the cavity. Given that, you should be able to find the optimum T, and then you know N_{th}, and N_2, and then given the available pump power you can figure out the mode volume in the crystal.

This is how you should choose the desired beam waist of the cavity. You will find smaller waists lead to better power, but there is the limiting case that the crystal should be shorter than $2z_0$.

Pumping is done coaxially with the cavity mode. You need to use a single lens to focus the green beam through a cavity mirror, which c a n act as a negative lens if the mirror is curved, and into the Ti:sapphire crystal. Ideally the spot size of the pump should match or be slightly smaller than the spotsize of the laser. You will need to develop an ABCD analysis of how to convert the beam you measured in lab into a spot within the Ti:sapphire crystal.

Saturable Absorber and Mode-Locking: We can possibly modelock the laser using a SESAM, which is a SEmiconductor Saturable Absorber Mirror. It will replace one of the end mirrors in the cavity, and requires the beam be tightly focused to achieve the necessary high intensity to saturate the absorption. To use the SESAM, it is good if your laser design has an arm of the cavity that is collimated and retroreflects on a HR. We will replace the HR with a curved focusing mirror, and place the SESAM at the focus of that mirror. If you can get the laser aligned again, it should break into modelocked operation. We will try to set up some diagnostics so you can appreciate the short pulses.