Assignment #1B (PHTN1400 2019W)

This assignment is due at the beginning of your lab period – for group A on the week beginning 2019/02/04 and for group B on the week beginning 2019/01/28. Work on this assignment on the week you are not completing lab 1A.

Q1: Homogeneous and Inhomogeneous models

Use the simple model (i.e. based on the gain saturation formula and assuming $g_{sat}=g_0$) to predict the output power of the MPB IN-100 laser using the following three different assumptions

a. Using the normal assumption of a homogeneously-broadened medium (the formula used last term as well as for solid-state medium)
b. Using the expected assumption that a gas is an inhomogeneously-broadened medium
c. Using the assumption that n=0.8 in equation 3.11 (which is actually a good assumption for a CO_2 laser)

The laser has two amplifier tubes and four mirrors (resembling that on page 34 of Laser Modeling). Refer to Laser Modeling section 3.4 for details on types of media and be aware that you must formulate a new expression for the simple model using the assumptions for (b) and (c) above. Show all work and calculations including saturation power (and note that there is an error on page 228 of the text: the cross-section of CO_2 is given in cm^2 not m^2). Physical parameters of this laser can be found in the SOP for this laser (a link can be found on the technology server course home page) and for the purposes of this question assume x_g=1.25m (for a single tube), x_a=1.5m (also for a single tube), and tube diameter is 19mm.

You might well have to refer back to your notes from PHTN1300 ("Cross-section and Gain" presentation) for details on how to solve for output power of a laser: you begin by computing g_{th} for the laser as configured (the notes give a complete example for a HeNe laser, you will also need to change the saturation formula accordingly).

Q2: Longitudinal Modes in a Laser

The output power calculated in question 1 varies radically based on which assumption of the medium (homogeneous or inhomogeneous) is used. As discussed in the text, one factor affecting the assumption of medium behaviour is the number of longitudinal modes oscillating in the cavity. Calculate, showing all work for all parts below:

a. the FSR of the cavity using the lengths given (remember that there are two tubes, and they are separated by 30cm)
b. the Doppler-broadened spectral width of the CO_2 gas laser (expect an answer under 500MHz)
c. the number of modes which will oscillate in this particular laser

Q3: Resonator Stability

Read "Resonator Stability" (section 6.9 in FLL by Csele) which describes how to compute geometric parameters (g-parameters) for optics - as a secondary reference you might also read the section "Useful Formulas for CO2 Laser Optics" on the page entitled "Homebuilt CO2 Lasers" on SAM's Laser FAQ detailing how spot size is affected by optics. Given the optic specifications from the SOP for our MPB laser, compute (showing all formulae used and all mathematical work) the predicted spot size at the OC and at the HR - you will need to compute the geometric-parameters first, be sure to outline this as well (with resulting values between 0 and 1). If you chose the HR to be mirror #1, then it will have parameter g_1 and the spot size at that optic will be w_1. Use the formulae below since they are "generic" and work with all cavity arrangements:

$$AtMirror\#1: w_1^2 = \frac{L\lambda}{\pi}\sqrt{\frac{g_2}{g_1(1-g_1g_2)}}$$

$$AtMirror\#2: w_2^2 = \frac{L\lambda}{\pi}\sqrt{\frac{g_1}{g_2(1-g_1g_2)}}$$

Outline all calculations involved including calculation of g-parameters for each optic (show the formulas used and all substitutions made). Expect an answer between 1mm and 8mm and expect the OC spot to be smaller than the HR spot for this "long radius" cavity (ref LM pp.22 ... this is one of the most popular cavity configurations).

As well as the calculations of spot size above, consider that the beam radii above (w) are computed based on the "$1/e^2$" criteria. Describe what this is and how it is defined with respect to beam profile (i.e. explain in terms of how the edges of the diameter are even defined in the first place: again, this is discussed in SAM's laser FAQ).

Q4: Applying the above formulae to laser design

a. Calculate both spot sizes (at the HR and at the OC) at the output assuming that the same IN-100 CO_2 laser above uses a 10m radius of curvature HR and a flat OC. Outline all calculations (formulae used, and all numbers substituted including all used to calculate the g-parameters). Does this seem reasonable given that a TEM_{00}beam should fill about a quarter of the amplifier volume?
b. Calculate the spot size for the WPR-252 HeNe lasers used last term in PHTN1300. These lasers featured a flat OC and a 60cm radius-of-curvature HR. Estimate the cavity length and show all formulae, substitutions, and calculations.
c. Using those same optics for the WPR-252, calculate explicitly and mathematically the range of distances possible between the mirrors for a stable cavity configuration. This will show why it was required to keep the entire laser on one bench.