

## PHTN1306 Lasers III

### Assignment 1

#### Gain Saturation Review

The following assignment is to be word processed (not handwritten) and following the usual simple format: include a title page with the assignment title and student name, and submit the entire assignment in a bound folder (not a pile of loose papers or a binder).

Concepts covered are all review from PHTN1400.

*In this assignment the pass-by-pass model will be applied to a high-gain gas laser.*

Following the approach outlined in section 3.9 of Laser Modeling (REQUIRED READING in which a complete model is presented for a HeNe laser), modify the simple pass-by-pass model predicting the growth of power in the HeNe laser to reflect the power development in the MPB IN-100 carbon-dioxide laser (including saturation). The simulation must begin with the power of a single photon (equation 3.38 in Laser Modeling) and continue until equilibrium CW output is achieved. Inhomogeneously-broadened media must be assumed (see section 3.4 in the text). The model must also utilize different gain and attenuation lengths (so you will have an additional anchored parameter at the top of the spreadsheet): the laser resembles that of figure 2.5 in the text and you can assume each of the two amplifier tubes has a gain length of 1.25m and an attenuation length of 1.45m. Specifications for optics may be found in the SOP. You may not use a "round trip" model since this is a higher-gain laser: calculate the gain four times on a round trip (once for each amplifier tube) as shown in the lecture. Hand in the following:

- Hand-in a screen shot of the spreadsheet model showing the numerical results for at least the first ten passes of the simulation as well as any anchored parameters at the top (such as saturation power, small-signal gain, etc) - so at least 20 rows must be shown. All columns must be shown (this may require more than one screen-shot) and cell references ("ABC" columns and "123" rows) must be visible. This will resemble figure 3.11 in the text.
- Submit a graph showing both intra-cavity power growth and saturated gain vs. number of passes (preferably on the same graph using primary and secondary axes, as per the example simulation provided).
- Include a separate page showing the calculation of  $P_{\text{saturation}}$  for the carbon-dioxide laser (and note that there is an error on page 228 of the text: the cross-section of  $\text{CO}_2$  is given in  $\text{cm}^2$  not  $\text{m}^2$ ). The beam diameter may be assumed to be 4.75mm (as discussed in lecture).
- Include a separate page showing all formulae in EACH CELL for at least the first four rows (simply show these as, for example, "AA6=+AC6\*exp(\$C\$7\*C6)" on a separate page). All cell references must be shown. The easiest way to do this is to select "Show Formulas" and print another spreadsheet (see the image below).
- Using parameters determined for this simulation calculate output power using the simple model (see section 3.6 of the text).

Done properly, you will have at least three printouts from the spreadsheet: one printout showing the numerical values (including anchored values at the top), one graph showing how power develops and gain saturates, and one printout showing all formulae which correspond to each cell in the first printout.

	A	B	C	D	E	F
1	<b>Power Development in a HeNe Laser (Simulation)</b>					
2	<b>PHTN1400 (Laser Systems)</b>					
3	© Professor M. Csele, Niagara College, 2009-2015					
4						
5		Gain (go) =	0.15	m <sup>-1</sup>		
6		Psat =	152	mW		
7		Atten (gamma) =	0.005	m <sup>-1</sup>		
8		Length =	0.275	m		
9		Loss (optics) =	0.01	per round trip		
10						
11	<b>Round trip</b>					
12	<b>Pass #</b>	<b>Pin</b>	<b>Gain</b>	<b>Actual Gain</b>	<b>P<sub>AMP-OUTPUT</sub></b>	<b>P<sub>OC</sub></b>
13		(mW)	(m <sup>-1</sup> )	(m <sup>-1</sup> )	(mW)	(mW)
14	0	0.001	0.149998	0.14499803	0.001072185	1.08302E-05
15	1	0.001072185	0.149998	0.14499788	0.00114958	1.16119E-05
16	2	0.00114958	0.149998	0.14499773	0.001232563	1.24501E-05
17	3	0.001232563	0.149998	0.14499757	0.001321535	1.33488E-05
18	4	0.001321535	0.149997	0.14499739	0.001416929	1.43124E-05
19	5	0.001416929	0.149997	0.1449972	0.00151921	1.53456E-05
20	6	0.00151921	0.149997	0.144997	0.001628873	1.64533E-05
21	7	0.001628873	0.149997	0.14499679	0.001746452	1.76409E-05
22	8	0.001746452	0.149997	0.14499655	0.001877518	1.89143E-05

The complete spreadsheet showing all numerical output. You must include a screenshot like this in the lab (as per part a above) and be sure it includes row (1,2,3...) and column (A,B,C...) references visible. Your simulation will include separate gain and attenuation lengths, four calculations of gain and power per round-trip, and will use an inhomogeneous solution (as expected for a gas laser).

	A	B	C	D	E	F
1	<b>Power Dev</b>					
2	<b>PHTN1400 (L</b>					
3	© Professor					
4						
5		Gain (go) 0.15		m <sup>-1</sup>		
6		Psat = 152		mW		
7		Atten (ga) 0.005		m <sup>-1</sup>		
8		Gain Len 0.22		m		
9		Loss (op) 0.01		per round trip		
10						
11	<b>Round trip</b>					
12	<b>Pass #</b>	<b>Pin</b>	<b>Gain</b>	<b>P<sub>AMP-OUTPUT</sub></b>	<b>P<sub>NEXT-PASS</sub></b>	<b>P<sub>OC</sub></b>
13		(mW)	(m <sup>-1</sup> )	(mW)	(mW)	(mW)
14	0	0.001	=B5/(1+(2*B14)/C6)	=B14*EXP(2*(C14-C7)*C8)	=D14*(1-C9)	=D14*C9
15	=A14+1	=E14	=C5/(1+(2*B15)/C6)	=B15*EXP(2*(C15-C7)*C8)	=D15*(1-C9)	=D15*C9
16	=A15+1	=E15	=C5/(1+(2*B16)/C6)	=B16*EXP(2*(C16-C7)*C8)	=D16*(1-C9)	=D16*C9
17	=A16+1	=E16	=C5/(1+(2*B17)/C6)	=B17*EXP(2*(C17-C7)*C8)	=D17*(1-C9)	=D17*C9
18	=A17+1	=E17	=C5/(1+(2*B18)/C6)	=B18*EXP(2*(C18-C7)*C8)	=D18*(1-C9)	=D18*C9
19	=A18+1	=E18	=C5/(1+(2*B19)/C6)	=B19*EXP(2*(C19-C7)*C8)	=D19*(1-C9)	=D19*C9
20	=A19+1	=E19	=C5/(1+(2*B20)/C6)	=B20*EXP(2*(C20-C7)*C8)	=D20*(1-C9)	=D20*C9
21	=A20+1	=E20	=C5/(1+(2*B21)/C6)	=B21*EXP(2*(C21-C7)*C8)	=D21*(1-C9)	=D21*C9
22	=A21+1	=E21	=C5/(1+(2*B22)/C6)	=B22*EXP(2*(C22-C7)*C8)	=D22*(1-C9)	=D22*C9

The complete spreadsheet showing all formulae: to do this in EXCEL™ simple select "Show Formulas" from the "Formula" tab. You must include a screenshot like this in the lab (as per part d above) and be sure it includes row (1,2,3...) and column (A,B,C...) references visible.

*Be sure you understand the methodology of this approach as it will be on the first test.*