PHTN1300
Midterm #1
Practice Questions

Photonics 2.0 Curriculum 2016F

Test Problems …

You really _do_ need to try these questions BEFORE the test.

Many problems are from previous tests and so will at least give you a clue as to what to expect next week.

Material Covered …

Quantum mechanics (review)

Thermal Response of devices (LEDs and Laser Diodes)
- Optical properties of devices
  - Egap, Epeak, I/V plots
  - Electrical properties of devices
  - Junction temperature calculations
- Lab #1 and Prelab #1

Threshold Gain Equation:
- Development of the equation
- Non-standard cavity arrangements (e.g. 3+ mirrors)
- Numeric solutions of threshold gain

Atomic Processes

Practice Question:

Calculate the energy (in eV) of a red photon at 656nm and a blue photon at 486nm.

Boltzmann Distribution

Practice Question:

Compute the percentage of atoms which thermally populate an energy level 0.1eV above ground at (a) room temperature and (b) 1000K.

Semiconductor Sources:

An infrared LED at 300 K is observed to have a bandgap voltage of 1.412 V (measured using the same technique as will be used in lab #1).

1) Calculate the wavelength of peak emission. Be sure to factor thermal energy into the picture.
2) What is the expected FWHM of the emission spectrum, ignoring effects from impurities in the semiconductor material?

Spectroscopy:

From the text, questions 2.1, 2.3, 2.4, and 2.5

All calculations and procedures from LAB #1 including:

- ✓ Using a spectrometer
- ✓ Calibration
- ✓ Reading Lines and converting wavelengths

Spectroscopy

Practice Question:

The zeroth order of a manual spectrometer (which uses a 300 line/mm grating) is seen at 355.2 degrees. A red line is then observed at 6.1 degrees. Compute the wavelength of the line and then the probable RANGE of wavelengths assuming a tolerance of plus-or-minus (+/-) 0.1 degrees in all readings.

HINT: The tolerance of readings is on both the “zero” reading as well as the actual observed line angle.

Quantum:

Practice Question:

From the diagram to the right, the copper-vapour laser is seen to have two transitions producing yellow (578nm) and green (510nm) radiation. Assuming the actual energies of the two upper-levels are 30783cm^{-1} and 30535cm^{-1}, calculate, in eV, the energies of the two lower-levels ('D') shown on the diagram.

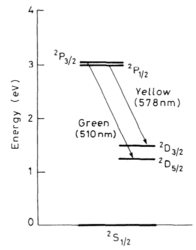


FIG. 10.4. Energy levels of copper atoms relevant to laser operation.

Hints:
Convert the energies of the upper levels in cm^{-1} to eV (use a converter e.g. "highpressurescience.com"), then calculate energy of the photons emitted, also in eV, to deduce the energy of the lower levels.

Quantum:

Practice Question:

From the question on the previous page:

As with any laser, PUMP energy is absorbed to bring the electron to the upper energy level and this energy is always larger than the emission energy.

Calculate the quantum efficiency (defined as ENERGY out / ENERGY in) for the 510nm line of this laser.

For energy in, use the energy of the ULL and for energy out, use the energy of the emitted photon

Selection Rules:

The copper-vapour laser has the following energy levels:
(Diagram from Svelto, Principles of Lasers)

Deduce, given nothing more than the data in the diagram, why each of the two transitions is allowed and why each of the two transitions NOT shown (e.g. $P_{3/2} \rightarrow D_{3/2}$) is forbidden.

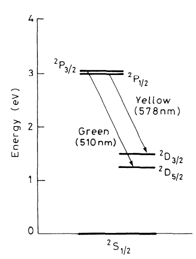


FIG. 10.4. Energy levels of copper atoms relevant to laser operation.

Quantum:

From the Fundamentals text, questions 3.3 and 3.5

Franck-Hertz experiment and interpreting results

Junction Temperature

A 2N3440 NPN transistor operates with 200V across the device (V_{CE}). The device has a Junction-to-case thermal resistance of 35C/W and a maximum junction temperature of 200C. The transistor is on a heatsink so the case temperature is more-or-less constant at 50C.

What is the maximum current that can flow through the device and still maintain the junction temperature at a safe value?

Useless Trivia: The 2N3440 is used on the high-voltage regulator of late 1970's and early 1980's Stern and Bally pinball machines.

Power Gain

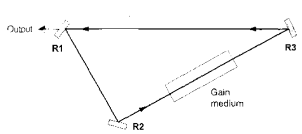
Practice Questions:

#1:
If 1mW enters a HeNe laser amplifier, 30cm in length and with a gain of $0.15m^{-1}$, what is the expected output power?

#2:
If a 15cm long amplifier amplifies a 100mW input signal to a power of 300mW, what is the gain?

Alternative Cavity Arrangements

Practice Question:



Formulate the threshold gain equation for the above laser (assume x is the length of the amplifier and γ is the attenuation)

Alternative Cavity Arrangements

Solve the following unity gain equations:

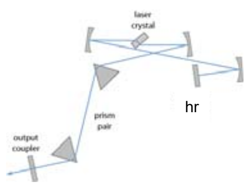
$$1 = e^{2gx}e^{-3\gamma x}R_1R_2R_3$$

$$1 = e^{3gx}e^{-3\gamma x}R_1R_2R_3$$

$$1 = e^{4gx}e^{-4\gamma x}R_1{R_2}^2{R_3}^2R_4$$

Alternative Cavity Arrangements

Practice Question:



Assuming the OC is 2% transmitting, all other mirrors are 99% reflecting, the crystal is 1cm in length (and has essentially zero attenuation), and each prism absorbs 5% per pass due to absorption of the glass …

Formulate the threshold gain equation for the above laser and solve, numerically, for g_{th} (answering in units of m^{-1})

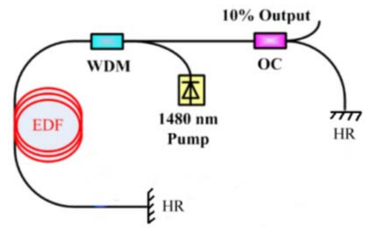
Alternative Cavity Arrangements: Fiber Lasers

Practice Question:

Compute the threshold gain of the fiber laser.

The EDFA consists of 10m of fiber. The attenuation is $0.2m^{-1}$.

Each HR is 100%R.



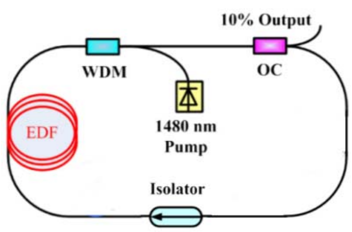
Note how the OC is different in this case – with a fiber laser it is frequently a coupler (and often measured in dB's … 3dB=0.5, 10dB=0.1, etc).

Actual gain is variable and is dependent on pump power.

Alternative Cavity Arrangements: Ring Lasers

Practice Question:

Does the fact that this laser is now a ring configuration change anything??



The isolator ensures lasing occurs in only one direction and can be considered lossless for this particular example.

Threshold gain equation (basic solution)

Practice Question:

A helium-neon (HeNe) laser has the following parameters:

HR = 100% R, OC = 95% R, Attenuation $0.05m^{-1}$, Length = 30cm.

Using a simple model (assuming the gain and absorption length are the same), solve for the threshold gain and determine if it will oscillate if the known gain of the HeNe laser is $0.15m^{-1}$.

Answers:

<u>Answer:</u>

Red:
1.89eV
Blue:
2.55eV

<u>Answer:</u>

At room temp:
2.09%

At 1000K:
31.3%

<u>Answer:</u>

Peak is
864nm

If you failed to account for thermal energy, the wavelength will be longer

FWHM is
60nm

<u>Answer:</u>

631nm center but range is 11.1 to 10.7 deg (641.7nm to 618.9nm)

<u>Answer:</u>

1.639EeV &
1.384EeV
63.7%

<u>Answer:</u>

3/2→3/2,
ΔS
violated

1/2→5/2,
ΔS
violated
ΔJ violated

<u>Answer:</u>

200C=50C+
35C/W*P
P=4.29W,
I=21.4mA

1.046mW
$7.32m^{-1}$

$g_{th}=\gamma+1/x \ln(1/r_1r_2r_3)$

$g_{th}=3/2\gamma+1/2x \ln(1/r_1r_2r_3)$

$g_{th}=\gamma+1/3x \ln(1/r_1r_2r_3)$

$g_{th}=\gamma+1/4x \ln(1/r_1r_2^2r_3^2r_4)$

$g_{th}=0+1/2x \ln(1/r_{HR}^7r_{OC}p^4)$

$0.148cm^{-1}$

$g_{th}=0.205m^{-1}$
(T=0.9 kept in cavity)

$0.135m^{-1}$

If you did NOT get these answers, ask in the next class (the review class) for a review of the required procedure