

Birla Institute of Technology & Science - Pilani, K.K. Birla Goa Campus
PHY F346 : Laser Science & Technology, First Semester 2022-23
Mid-semester Examination. Date: Nov. 1, 2022. Time: 4.00 to 5.30 hrs
Max. marks: 60 (To be normalized to 30 as Mid-sem weightage is 30%)

Section 1 : Solve the following TWO problems [10 marks each, Total 20 marks]

1.1) A CW CO₂ laser giving a power of 100 W at $\lambda = 10.6 \mu\text{m}$, has a frequency bandwidth of 60 MHz. For this laser, calculate the following: [$h = 6.626 \times 10^{-34}$ J-s, $e = 1.6 \times 10^{-19}$ C] *[2 marks each for a - e]*

- a) The wavelength bandwidth ($\Delta\lambda$) of the laser.
- b) The coherence length of the laser.
- c) The photon energy in joules.
- d) The photon energy in eV.
- e) The photon flux emitted by the laser (number of photons per second).

1.2) An Nd:glass laser resonator has two mirrors of radii of curvature of $R_1 = 5$ m and $R_2 = 3$ m, and the optical separation between the mirrors is $d = 2$ m. The laser is operating at $\lambda = 1054$ nm. For this laser, calculate the following : *[2 marks each for a - e]*

- a) The product of g_1 and g_2 of the resonator and comment on its stability.
- b) Using the condition that the radius of curvature of the beam [given by $r(z) = z + Z_R^2/z$] should match with that of the mirror at each mirror, find the Rayleigh range of the beam.
(Hint: z is the distance measured from the beam waist. Let the beam waist be at a distance of Z from one mirror and $d-Z$ from the other. Solve for Z . Using this value of Z , find Z_R)
- c) From the Rayleigh range, find the beam waist diameter ($2\omega_0$) of the beam.
- d) From the beam waist, calculate the full divergence (θ) of the beam.
- e) Find the beam diameters at each of the two mirrors.

Section 2 : Answer all the three questions. [5 marks each, Total 15 marks]

State whether the each of the following statements is true or false.

If true, justify why it is true;

If false, write down the corrected statement by modifying the underlined word/s only and justify why the corrected statement is true.

In either case, justification should be at least 3-4 sentences.

2.1) One can have a laser resonator with both mirrors 100% reflecting.

2.2) It is possible to get amplification by stimulated emission in a two level system.

2.3) In mode locking using a dye, the relaxation time of the dye should be much longer than the cavity round trip time.

(Please turn over for Sections 3 and 4)

Section 3 : Answer all the three questions [5 marks each, Total: 15 marks]

Give brief (3-4 sentences) correct explanation for the following.

- 3.1) Explain how the anti-reflection coating on an optical surface works (principle only, no derivations)
- 3.2) How does a double pass amplifier work?.
- 3.3) Two Fabry-Perot etalons are made using glass plates of same thickness and refractive index, but one has high reflectivity coatings and the other one has low reflectivity coatings. Comment on their 1) Free spectral range ($\Delta\nu_{FSR}$) and 2) Width of the transmission bands ($\Delta\nu_c$). [No formulae required in answer]

Section 4: Fill in one or two words in the blank space provided to make it a correct statement

Choose words from the options provided. [1 mark each, Total: 10 marks]

{To save time, attempt this section only after completing earlier three sections}

- 4.1) _____ hole burning can take place only in inhomogeneously broadened medium. (Spatial / Spectral)
- 4.2) _____ is mostly used to generate short laser pulses in a semiconductor laser. (Q-switching / Gain switching / Mode locking)
- 4.3) The output power v/s input power curve for a laser gives its _____ efficiency. (slope / quantum / pump)
- 4.4) Materials with negative n_2 (second order refractive index) give rise to the phenomenon of self _____. (focussing / blooming/phase modulation/filamentation)
- 4.5) For a transform limited Sech^2 pulse, the product of band-width and pulse duration is _____. (0.541 / 0.441 / 0.351 / 0.315)
- 4.6) The frequency broadening in a glass host is called _____ field broadening. (electromagnetic / magnetic / electric / crystal / local / amorphous)
- 4.7) The concept of _____ absorption was first demonstrated using magnetic field switching. (spontaneous / stimulated / positive / negative)
- 4.8) _____ broadening of a line can be homogeneous or inhomogeneous. (Doppler / Natural / Field / Phonon / Pressure)
- 4.9) The second Barkhausen condition enables one to determine the _____ modes in a laser cavity. (longitudinal / transverse / waveguide)
- 4.10) _____ can be used to actively frequency stabilize a gas laser. (Ni-chrome rods / Invar rods / Hole burning / Lamb dip / F-P etalon)

----- Wish you all the best -----

Syllabus: First 19 lectures (L-1 to L-19: i.e. up to Masers)

Examination Type: Off-line, Open Books/Handwritten notes (unlimited pages)

{No Laptops, No Cell phones, No printouts of lecture ppts or earlier batch lecture notes}