Birla Institute of Technology & Science - Pilani, K.K. Birla Goa Campus
PHY F346 : Laser Science & Technology, **First Semester 2022-23**
Comprehensive Examination. Date: Dec. 22, 2022. Time: 10.00 to 13.0 hrs
Max. marks: 100   (To be normalized to 35 as Compre weightage is 35%)

Section 1 : Solve the following <u>FIVE</u> problems [8 marks each, Total 40 marks]

1.1) For a semiconductor laser of length L= 500 μm, loss α = 10 cm^{-1}, and μ=3.5, operating at 0.9 μm, calculate the following: (2 mark each for a-d)
   a) Frequency separation of the modes (Δv in GHz)
   b) Convert this to wavelength separation ($\Delta\lambda$ in nm)
   c) Reflectivity (R_1, R_2) of each facet (in %)
   d) Value of the threshold gain g. (in cm^{-1})   [$R_1R_2\exp(2\{g-\alpha\}L) =1$]

1.2) An Nd:glass laser operating at 1064 nm wavelength, is to be mode locked using an acousto-optic modulator (AOM). It has a resonator of physical length 1.0 m, with a laser rod refractive index 1.6 and length 20 cm. The AOM has a thickness of 2 cm and its refractive index is 1.5. For this mode locked laser, calculate the following: (2 mark each for a-d)
   a) The optical length of the oscillator cavity (in m).
   b) The frequency separation of the longitudinal modes (in MHz).
   c) The time separation between the mode locked pulse coming out of the cavity (in ns).
   d) The radio frequency (in MHz) to be applied to the AOM to mode lock in the fundamental mode.

1.3) The energy of the Jth level measured from the corresponding vibrational level is given by E_J = hB J(J+1). Boltzmann distribution of the population in various rotational levels is given by $N_J = N_o g_J \exp(-E_J/kT)$ where g_J is the degeneracy of a rotational level (g_J = 2J+1) and N_o is the population of the J=0 level.
   a) Find the expression for the value of J_{max} corresponding to the maximum population. [No need to show that is a maximum or a minimum]
   b) For hB = kT/20 eV at room temperature (T=300 K), show that the value of the rotational quantum number J having maximum population is J=3.
   c) Find the ratio N_J/N_o at room temperature for this value of J.   (4 marks for a, 2 for b and c)

1.4) A Free Electron Laser has the following parameters: 1) Undulator period λ_o = 0.8 cm, 2) Electron beam energy E= 80 MeV, and 3) Number of magnet periods N=70. For this laser, calculate the following:
   a) Laser wavelength (in nm),   {$m_ec^2 \equiv$ 511 keV}
   b) Laser beam divergence (in mrad),
   c) Laser pulse duration (in fs),
   d) Frequency bandwidth Δv (in THz)   [2 marks each for a to d]

1.5) For a silica based optical fibre 9/125 with core refractive index n_1=1.465 and clad refractive index n_2=1.460, find the following: [2 marks each for a to d]

a) Numerical aperture of the given optical fibre.

b) Maximum allowed angle of the incidence (in degrees) on the input surface of the fibre.

c) Intermodal dispersion per unit length (in ps/m) in this fibre.

d) Check if the fibre will be single mode fibre for a laser beam at 1.3 μm and at 1.5 μm.

Section 2 : Answer all the <u>five</u> questions. [5 marks each, Total 25 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 <u>underlined</u> word/s only and justify why the corrected statement is true.

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

2.1) The value of the M^2 parameter of a laser beam is always <u>less than</u> one.

2.2) When a right circularly polarized light goes through a <u>half wave</u> plate, it becomes left circularly polarized.

2.3) A CO_2 molecule vibrating in the asymmetric mode <u>cannot</u> decay radiatively to a lower level.

2.4) The laser emission from a wiggler based FEL is <u>narrow band</u>.

2.5) In the water window region, water transmits x-rays <u>more than</u> the proteins.

Section 3 : Answer all the <u>five</u> questions. [5 marks each, Total 25 marks]

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

3.1) What are the two main disadvantages of a large diameter rod amplifier which are removed by a disk amplifier?

3.2) Explain what happens if one propagates a short, high intensity laser pulse in a long optical fibre.

3.3) Explain the phenomenon of "ion cataphoresis" in an ion laser and why is it problematic.

3.4) What is meant by an "ASE laser"?

3.5) Explain the "key-hole effect" in laser drilling.

Section 4: Fill in <u>one word</u> in the blank space provided to make it a <u>correct statement.</u>
Choose one option from the four options provided. [1 mark each, Total: 10 marks]
{To save time, you may attempt this section only after completing earlier three sections}

1) The curve $g_1 g_2 = 1$ represents a_____. (st. line / parabola /ellipse / hyperbola)

2) When the laser gas is at low pressure, _____ discharge is used for collisional pumping.
   (positive / negative / arc / flash)

3) A laser pulse, with its frequency varying linear with time, is called a _____ pulse.
   (Lorentzian / Gaussian / linear /chirped)

4) A Gaussian beam has _____ radius of curvature at a distance equal to the Rayleigh range from the
   beam waist. (zero / infinite / minimum / maximum)

5) _____ laser (solid state) can be used a three level system as well as a four level system**.**
   (Alexandrite / Ti:sapphire / Nd:glass / Ruby)

6) A _____ semiconductor laser operated at low current is used as a light emitting diode.
   (homojunction / heterojunction / bijunction / multijunction)

7) In _____ laser, the lasing wavelength depends on the polarization allowed in the resonator.
   (Nd: YAG / Nd:YLF / Nd: glass / Er:glass)

8) In a solid state laser, the host must be essentially a _____ medium.
   (dielectric / diamagnetic / opaque / conducting)

9) $(Al_xGa_{1-x})_{1/2}In_{1/2}P$ is an example of _____ alloy.   (unitary / binary / ternary / quarternary)

10) In an FEL with _____ undulator, one gets circularly polarized light.
    (planar / circular / helical / parabolic)

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

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

{No Laptops, No Cell phones, No printouts of lecture ppts or earlier batch lecture notes, No photocopies of other's class notes}