POSSESSION OF MOBILES IN EXAM IS UFM PRACTICE.

Name__________________ **Enrollment No.** __________

Jaypee Institute of Information Technology, Noida

T2 Examination, 2024

B.Tech, V Semester (Odd 2024)

Course Title: Laser Technology and Applications
Course Code: 16B1NPH533

Maximum Time: 1 Hr
Maximum Marks: 20

CO1	Defining the properties and principle of lasers
CO2	Understanding of various applications of lasers
CO3	Ability to apply the concepts of standard techniques for the pulsed operation of laser and stability of laser resonator
CO4	Analysis of types of lasers

Note: Attempt all the questions.

Q1. (a) Plot the intensity and beam patterns of TEM_{03} and TEM_{11} modes.

(b) An Ar^+ ion laser has emission wavelength 514.5 nm, cavity of length 100 cm and refractive index 1. Calculate the number of longitudinal modes that the laser can sustain if the FWHM Doppler-broadened line width is 3.5 GHz and what should be the resonator length to achieve a single longitudinal mode operation?

(c) Sketch the variations of loss, Q value, population inversion and the laser output power with time.

(d) Imagine a two-level atomic system with E_1 = -13.6 eV and E_2 = -3.4 eV. If $A_{21} = 6\times10^{8}\ s^{-1}$. Calculate the frequency of light emitted due to transition from E_2 to E_1 and FWHM of the emission due to natural broadening.

[CO2 (Understanding), 2+2+2+2=8 Marks]

Q2. (a) For a cavity (cavity length = 500 μm) of GaAs semiconductor laser with the following values of various parameters: $n_0 = 3.5, R_1 = 0.3, R_2 = 0.3, \alpha_{eff} \approx 0$, calculate cavity lifetime and FWHM of the spectrum. Symbols used have their usual meanings.

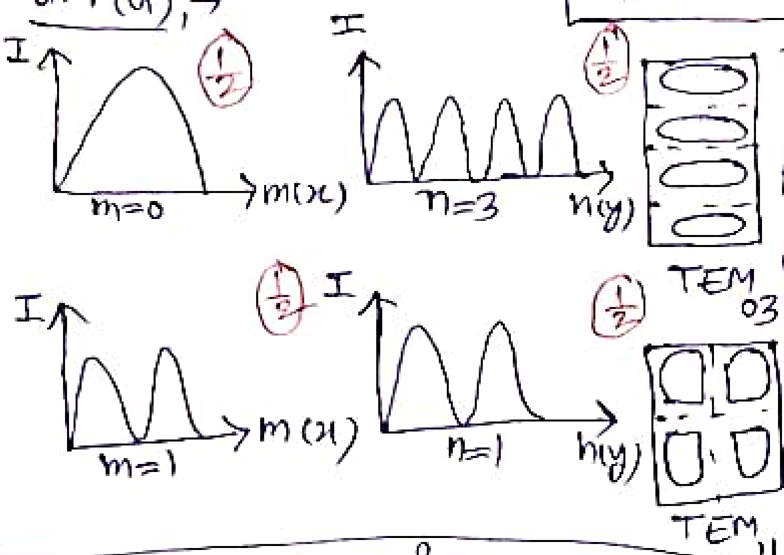
(b) A laser with a cavity length of 20 cm and mirror reflectivities of 98% each is filled with He-Ne gases (refractive index = 1). Assuming negligible losses in the cavity, calculate the threshold gain coefficient, line-shape function and threshold population inversion (N_2-N_1). It is given that λ = 632.8 nm, $t_{sp} = 10^{-7}$ s and $\Delta v = 10^{9}$ Hz.

(c) Calculate the maximum Q-switched power output from a ruby laser (wavelength = 694.3 nm, refractive index = 1.75) with a chromium concentration of 1.6 x 10^{25} ions/m^3. The length of ruby rod (cavity length) is 0.4 m and the reflectivity of each mirror is 90%. The diameter of the multi-mode laser mode volume within the rod is approximately 2 mm. Determine the Q-switched power output form the laser if it is pumped to a factor of 7 times the threshold inversion density.

[CO4 (Analyzing), 4+4+4=12 Marks]

Soln. T2_ Laser Technology and Application of [illegible]

Q.1 (a) :→



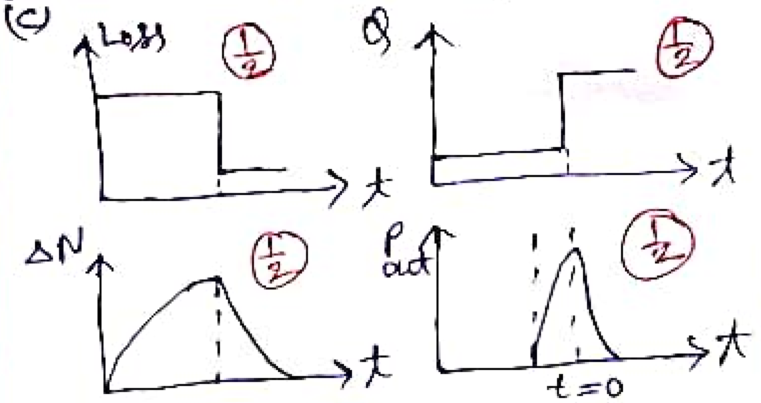
(b) $\Delta\nu_{sep} = \frac{c}{2\eta L} = \frac{3\times10^8}{2\times1\times1} = 1.5\times10^8$ Hz $\frac{1}{2}$

(i) No. of modes $= \frac{FWHM}{} = \frac{3.5\times10^9}{1.5\times10^8} = 23.33 \simeq 23$ $\frac{1}{2}$

(ii) $\frac{c}{2n_0L'} = \Delta\nu_{sep} = 3.5\times10^9$ $\frac{1}{2}$

$\Rightarrow \frac{3\times10^8}{2\times1\times L'} = 3.5\times10^9 \Rightarrow L' = 0.0428$ m $= 4.28$ cm $\frac{1}{2}$

(c)



(d) i) $E_2 - E_1 = h\nu$ $\frac{1}{2}$

$\Rightarrow (-3.4+13.6)eV = h\nu$

$\Rightarrow \nu = \frac{10.2\times1.6\times10^{-19}}{6.626\times10^{-34}} = 2.463\times10^{15}$ Hz $\frac{1}{2}$

(ii) $\Delta\omega = A_{21} = 6\times10^8$ $\frac{1}{2}$

$\Rightarrow 2\pi\Delta\nu = 6\times10^8$

$\Rightarrow FWHM = \Delta\nu = \frac{6\times10^8}{2\times3.14} = 0.955\times10^8$ Hz $\frac{1}{2}$

Q.2 (a) :→ $g_{th} = \alpha_{eff} + \frac{1}{2L}\ln\left(\frac{1}{R_1R_2}\right)$ (1)

$= 0 + \frac{1}{2\times500\times10^{-6}}\ln\left(\frac{1}{0.09}\right) = 2.40\times10^3\ m^{-1}$ (1)

$t_c = \frac{n_0}{c\,g_{th}} = \frac{3.5}{3\times10^8\times2.40\times10^3} = 4.86\times10^{-12}$ s (1)

$FWHM = \Delta\nu_p = \frac{\nu_0}{Q} = \frac{1}{2\pi t_c} = 3.28\times10^{10}$ Hz $\simeq 3.3\times10^{10}$ Hz (1)

(b) $g_{th} = \alpha_{eff} + \frac{1}{2L}\ln\left(\frac{1}{R_1R_2}\right)$ (1)

$= 0 + \frac{1}{2\times0.20}\ln\left(\frac{1}{0.98\times0.98}\right) = 0.101\ m^{-1}$

$g(\nu) = \frac{1}{\Delta\nu} = \frac{1}{10^9} = 10^{-9}$ s (1)

$g_{th} = \frac{c^2 g(\nu)(N_2-N_1)}{8\pi n_0^2\nu^2 t_{sp}}$ (1)

$(N_2-N_1) = 8\pi n_0^2\left(\frac{\nu^2}{c^2}\right)\frac{t_{sp}\,g_{th}}{g(\nu)}$

$\Rightarrow (N_2-N_1) = \frac{8\pi n_0^2}{\lambda^2}\,\frac{t_{sp}\,g_{th}}{g(\nu)}$ (1)

$= \frac{8\times3.14\times1\times10^{-7}\times0.101}{(632.8\times10^{-9})^2\times10^{-9}} = 6.336\times10^{14}\ m^{-3}$

(c) $P_{max} = \frac{h\nu}{2t_c}\left[n_{th}\ln\left(\frac{n_{th}}{n_0}\right) - (n_{th}-n_0)\right]$ (1)

$n = 1.6\times10^{25}\times\pi(1\times10^{-3})^2\times0.4 = 2.0096\times10^{19}$ ions $\frac{1}{2}$

$n_{th} = \frac{n}{2} = 1.0048\times10^{19}$ ions $\frac{1}{2}$

$\frac{n_0}{n_{th}} = 7 \Rightarrow n_0 = 7n_{th} = 7.0336\times10^{19}$ ions

$g_{th} = \alpha_{eff} + \frac{1}{2L}\ln\left(\frac{1}{R_1R_2}\right)$

$= 0 + \frac{1}{2\times0.4}\ln\left(\frac{1}{0.9\times0.9}\right) = 0.2634\ m^{-1}$ $\frac{1}{2}$

$t_c = \frac{n_0}{c\,g_{th}} = \frac{1.75}{3\times10^8\times0.2634} = 22.15\times10^{-9}$ s $\frac{1}{2}$

$h\nu = \frac{hc}{\lambda} = \frac{6.626\times10^{-34}\times3\times10^8}{694.3\times10^{-9}} = 2.863\times10^{-19}$ J $\frac{1}{2}$

$P_{max} = \frac{2.863\times10^{-19}}{2\times22.15\times10^{-9}}\left[n_{th}\ln\left(\frac{1}{7}\right) - (n_{th}-7n_{th})\right]$

$= 6.46\times10^{-12}\left[n_{th}\ln\left(\frac{1}{7}\right) + 6n_{th}\right]$

$= 6.46\times10^{-12}\times4.054\,n_{th}$

$= 6.46\times10^{-12}\times4.054\times1.0048\times10^{19}$

$= 26.314\times10^7$ W $= 263.14$ MW $\frac{1}{2}$