Ministry of Higher Education & Scientific Research
University of Technology
Laser & Optoelectronic Eng. Department
Branch: Laser Eng.
Class: 3rd Year
Subject: Laser Physics

Final Examination
Time: 180 minutes
Date: 29 May 2016
Examiner: Assist. Prof.Dr. Mohammed Jalal
Code: LE 3309
Academic Year 2015-2016

Attempt only (5) questions

Q_{1A}: What are the procedures that could be taken to reduce the number of longitudinal modes in a laser output beam? **(4Marks)**

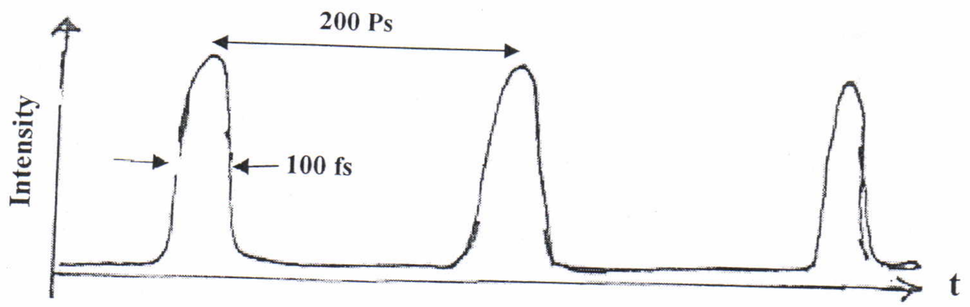
Q_{1B}: An argon ion laser is operating at 488 nm in a confocal cavity in the TEM_{00} mode with a mirror separation of 0.6 m. Assume that the gsin medium is 0.4 m long, the beam radius (the effective limiting aperture) for the laser beam is 0.5 mm at each mirror, and the only losses in the cavity are the diffraction losses given by the following table. What must the gain coefficient be for the laser to operate at threshold with mirror reflectivities of 99.99% at the laser wavelength? **(8Marks)**

Fresnel No.	Internal losses
1	0.0008
0.85	0.0025
0.70	0.01

Q_{2A}: On what parameters do the appropriate technique for creating short pulses depend? **(4 Marks)**

Q_{2B}: For the intensity versus time measured below for a mode-loked laser, determine: **(8 Marks)**

í. Gain bandwidth of the gain medium.
íí. The spacing between mirrors.
ííí. Number of locked modes.
iv. Coherence length



Q_{3A}: What is the beam parameter product? On what parameter it depends? What is the relation to M squared parameter? **(4 Marks)**

Q_{3B}: A laser operates in threshold condition. The HR mirror is a perfect mirror , all the losses in a round trip is 0.8% , the reflection coefficient of the OC is 0.96 and the length of the laser is 40cm. Find:

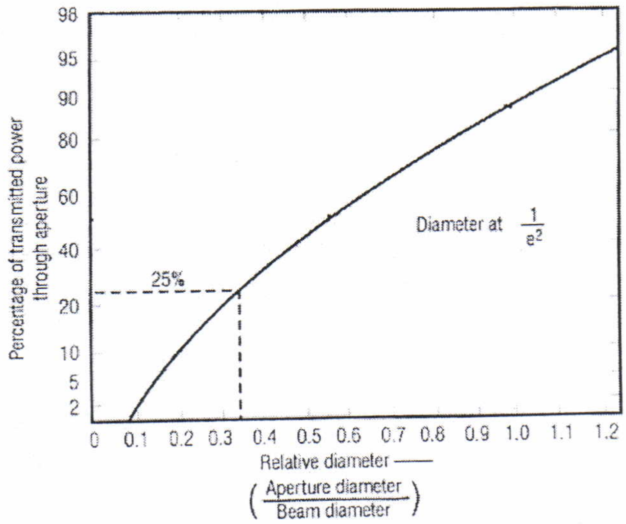
i- The loss coefficient .
ii- The threshold gain coefficient.
~~iii- The fluorescent linewidth.~~
iv-The bandwidth of a single mode.

(8 Marks)

P.T.P

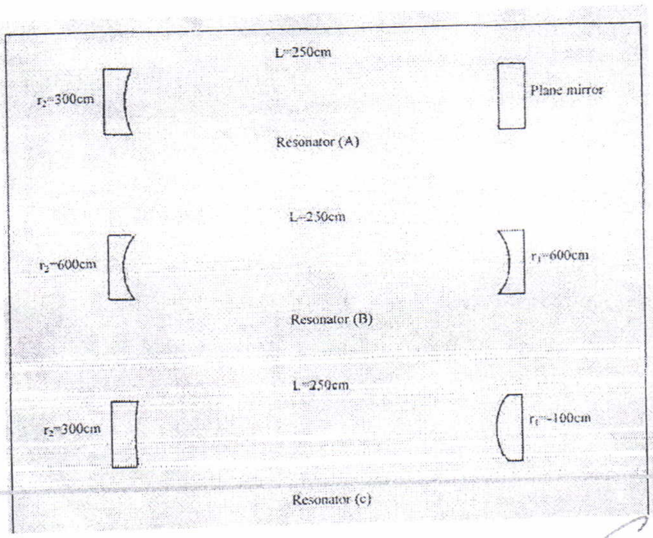
Q_4: An Nd:glass laser λ=1.06μm and (n=1.5) in which the mirrors are very close to the ends of the rod. Suppose there are no losses except that of the mirrors whose reflectivities are 100% and 85% respectively. The laser is Q-switched and has the following parameters: average power (10W), period ($2x10^{-3}$s) and duty cycle ($2x10^{-4}$). Find the Pmax, pulse duration, length of the laser cavity and the quality factor. **(12 Marks)**

Q_{5A}: A beam from He-Ne laser with power of 1mW is passing through a circular hole of 3mm diameter. The transmitted power is 0.25mW. Use the graph below to find the diameter of the laser beam. **(6 Marks)**



Q_{5B}: On what parameters do the beam waist of a stable optical cavity depend? **(6 marks)**

Q_6: Find the location and radius of the beam waist in each of the following resonators. Each one of the given resonators can be used to a certain laser. So assign each resonator to one of the following lasers: high power gas laser, high power flashlamp pumped Nd:YAG laser and diode pumped Nd:YAG laser. **(12Marks)**



Good Luck

Q1A :

1. Cooling the active medium.
2. Reducing the length of the active medium.
3. Using Q-switching technique.

Q1B :

$$N = \frac{a^2}{\lambda L}$$

$$= \frac{(0.0005)^2}{488 \times 10^{-9} \times 0.6} = 0.85$$

From table, internal losses = 0.0025

$$\therefore k_{th} = \frac{1}{2l} \ln\left[\frac{1}{R_1 R_2 (1-S)^2}\right] + \alpha$$

$$\because \alpha = 0 \quad \text{(no absorption loss)}$$

$$\therefore k_{th} = \frac{1}{2(0.4)} \ln\left[\frac{1}{(0.9999)^2 (1 - 0.0025)^2}\right]$$

$$k_{th} = 6.5 \times 10^{-3} \, m^{-1} = 0.0065 \, m^{-1}$$

Q2A:

1. Laser type

2. The characteristics of the pulse required.

Q2B:

i. $\Delta t_{1/2} = \frac{1}{\Delta \nu}$

$\Delta \nu = \frac{1}{100 \times 10^{-15}} = 10^{13}$ Hz

ii. $\Delta t_{sep} = \frac{1}{\Delta \nu_{ms}} = \frac{2L}{c}$

$L = \frac{c}{2} \Delta \nu_{sep} = \frac{3 \times 10^{8}}{2} \times 200 \times 10^{-12}$

$L = 3 \times 10^{-2}$ m $= 3$ cm.

iii. $l_c = c \Delta t_{1/2}$

$= 3 \times 10^{8} \times 100 \times 10^{-15} = 3 \times 10^{-5}$ m

iv. $N = \frac{\Delta t_{sep}}{\Delta t_{1/2}} = \frac{200 \times 10^{-12}}{100 \times 10^{-15}} = 2000$ modes

Q3A: The beam parameters product (BPP) is the product of waist radius and far-field divergence angle of Gaussian beam and equal to $2\lambda / n\pi$. It depends on the wavelength when the Gaussian beam is propagating through the free space. Laser beam quality is quantified by the beam parameters product where the ratio of the BPP of the real beam to that of an ideal Gaussian beam at the same wavelength is known as M^2. The M^2 for a Gaussian beam is one. All real laser beams have M^2 values greater than one, although very high quality beam can have values very close to one.

Q3B:

1. $S = \alpha L$

$$\therefore \alpha = \frac{S}{L} = \frac{0.008/2}{40} = 0.0001\,cm^{-1} = 0.01\,m^{-1}$$

2. $$k_{th} = \frac{1}{2l} \ln\left[\frac{1}{R_1 R_2 (1-S)^2}\right] = 0.0006\ cm^{-1}$$

$$= 0.06\ m^{-1}$$

3. $$\Delta\nu = \frac{1}{2\pi t_c} = \frac{1}{2\pi \times 5.6\times10^{-9}} = 2.8\,MHz$$

4. $\Delta\nu_{mbw} = \Delta\nu_{ms}(T + L_0)$, $T = 1 - R = 0.04$

$= \frac{c}{2L}(T + L_0)$ $\qquad L_0 = 0.008$

$\therefore \Delta\nu_{mbw} = 18\,MHz$

Q4:

(1) $$D.C = \frac{P_{av}}{P_{max}}$$

$$\therefore \quad P_{max} = \frac{P_{av}}{D.C} = \frac{10}{2\times10^{-4}} = 5\times10^{4}\ W$$

(2) $$D.C = \frac{\Delta t_{1/2}}{T}$$

$$\therefore \quad \Delta t_{1/2} = D.C \times T$$
$$= 2\times10^{-4} \times 2\times10^{-3}$$
$$= 4\times10^{-7}\ s = 400\,ns$$

(3) $$\Delta t_{1/2} = t_c = \frac{2nL}{c(1-R_1R_2)}$$

$$\therefore \quad L = \frac{4\times10^{-7}\times 3\times10^{8}\,(1-(1\times0.85))}{2\times1.5}$$

$$= 6\ m$$

(4) $$Q = 4\pi\nu t_c = 4\pi\nu \frac{2nL}{c(1-R_1R_2)}$$

$$Q = \frac{8\pi nL}{\lambda(1-R_1R_2)} = \frac{8\pi\times1.5\times6}{1.06\times10^{-6}\,(1-(1\times0.85))}$$

$$= 1.42\times10^{9}$$

Q5A :

$$T = \frac{0.25\ mw}{1\ mw} = 0.25 = 25\%$$

The point 25% from the graph represents

$$\frac{2a}{2W} = 0.35$$

$$\therefore 2W = \frac{2a}{0.35} = \frac{2(1.5\times10^{-3})}{0.35}$$

$\therefore W = 8.6$ mm (diameter of laser beam)

Q5B : The beam waist in a stable optical cavity is determined by:

1. The geometrical shape of the resonator, that is:
   i. radius of the end mirrors (r_1, r_2)
   ii. distance between mirrors (L)
2. The wavelength of the Laser (λ).

Q6 :

$$z_1 = \frac{L(r_2-L)}{r_1+r_2-2L}$$

$$z_2 = \frac{L(r_1-L)}{r_1+r_2-2L}$$

$$w_0^4 = \left(\frac{\lambda}{\pi}\right)^2 \frac{L(r_1-L)(r_2-L)(r_1+r_2-L)}{(r_1+r_2-2L)^2}$$

(1) $r_1 = \infty$
$r_2 = 300\,cm$ « diode-pumped Nd:YAG laser)
$L = 250\,cm$

$\therefore$ $z_1 = 0$
$z_2 = L = 250\,cm$
$w_0^4 = \left(\frac{\lambda}{\pi}\right)^2 L(r_2-L) = 0.6\,mm$

(2) $r_1 = 600\,cm$
$r_2 = 600\,cm$
$L = 250\,cm$

$$\therefore\ z_1 = z_2 = \frac{L(r-L)}{2(r-L)} = \frac{L}{2} = 125\,cm$$

$$w_0^4 = \left(\frac{\lambda}{2\pi}\right)^2 L(2r-L) = 28\,mm$$

used for high power gas Laser

③

$r_1 = -100$ cm

$r_2 = 300$ cm

$L = 250$ cm

$z_1 = -250$ cm

$z_2 = 1750$ cm

$w_0^4 = 0.3$ mm

used for high-power flashlamp pumed Nd: YAG Laser