Ministry of Higher Education & Scientific Research
University of Technology
Laser & Optoelectronic Eng. Department
Branch: Laser Eng.
Class: 4th Year
Subject: Laser Design

Final Examination
Time: 180 minutes
Date: 5 June 2016
Examiner: Assist. Prof.Dr. Mohammed Jalal
Code: LE4307
Academic Year 2015-2016

Attempt only (5) questions

Q_{1A}: Define the fractional thermal loading and calculate the theoretical lower limit of thermal loading and its actual for an Nd:YAG lasing at 1.06 μm and pumped with a laser diode pump source at 808 nm.

(5 Marks)

Q_{1B}: In the laser-diode-pumped systems analyzed in Fig. 1, an output of 7 W is produced by a 5-cm-long Nd:YAG rod with an absorption coefficient of 10^{-3} cm^{-1}. If the resonator has an output coupler with a reflectivity of 90%, calculate waste heat, radiation loss, total heat load and fluorescence/absorption loss.

(7 Marks)

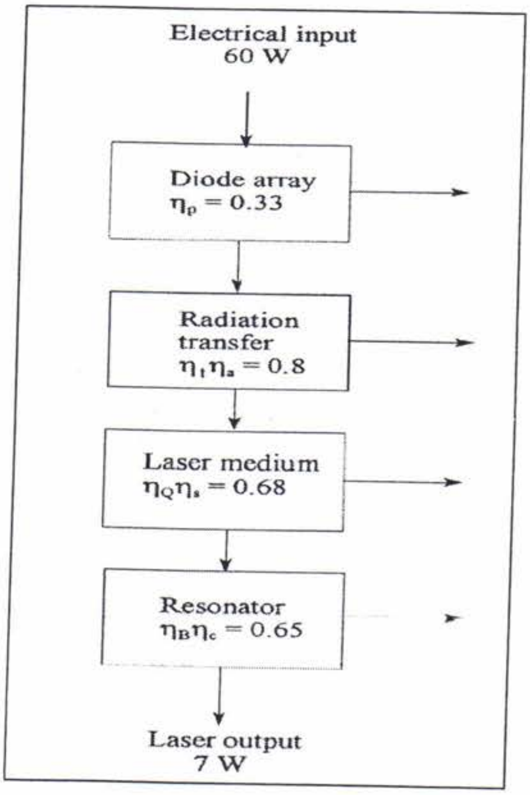


Fig.1. Energy flow in a typical diode pumped Nd:YAG laser

Q_{2A}: Explain with a diagrams if necessary the most common laser configurations that can be used to transform the pump light emitted from the laser diode into a possibly circular shape of the appropriate size within the laser rod.

(6 Marks)

Q_{2B}: Due to its relatively small sensitive to mirror misalignment a nearly hemispherical resonator (plane-spherical resonator) with $R=L+\Delta$ and $(\Delta<<L)$ is often used for He-Ne laser at λ=630nm, if the cavity length (L=30cm) calculate:

1. The radius of curvature of the spherical mirror, so that the spot size at this mirror is (0.5mm).
2. The spot size at the plane mirror.

(6 Marks)

Q_{3A}: Can we use a (0.62cm) diameter Nd:YAG laser rod as the limiting aperture to produce TEM_{00} mode output in a (50cm) long resonator? If we cannot explain the limitation and give your suggestion to generate TEM_{00} mode output from solid-state lasers as limiting aperture. **(6 Marks)**

Q_{3B}: A flashlamp with a lamp-impedance parameter of (13 ohm-ampere$^{1/2}$). One desires to discharge 100 joules of energy through this lamp in a pulse of 500μs duration. According to these informations, design a single mesh pulse forming network. **(6 Marks)**

Q_4: An output power of (250W) was obtained from an Nd:YAG laser rod of length (75mm) and (0.64cm) in diameter pumped by a linear flashlamp at an input power of (12KW). The heat generated within the laser rod by pump light absorption is removed by a coolant tube with inside diameter of (14mm) extended along the cylindrical rod surface with a fluid temperature entering the cavity of (T_F=20C°). With the assumption of uniform internal heat generation and cooling along the cylindrical surface of an infinitely long rod, the heat flow is strictly radial, and end effects and the small variation of coolant temperature in the axial direction can be neglected, calculate:

1. The maximum radial temperature and its position in the rod.
2. The temperature of the rod surface.
3. The compression and tension components of the stress, if you know that the Nd:YAG material parameters are:

Thermal Conductivity	0.11 W/cm.C°
Young's Modulus	3.2 x 103 Kg/cm^2
Poisson's ratio	0.3
Thermal coefficient of expansion	7.9 x 10-6 1/C°
Tensile Strength	2.1 Kg/cm^2

(12 Marks)

Q_{5A}: Use an information and design equations to design a slow flow CO_2 laser with an output power of (50W) at TEM_{00} mode. Assume that the (cavity length = active length x 1.1). For this laser determine the cavity length, active length beam diameter to $1/e^2$ points on each mirrors, if you know that HR mirror has a radius of curvature of (10m) and the tube diameter which give a loss of 2%. **(6 Marks)**

Q_{5B}: List the three basic elements of a pulsed power supply for flashlamp operation, and describe the function of each element. **(6 Marks)**

Q_6: Answer the following questions: **(12 Marks)**

1. Calculate theoretical thermal loading of Yb:YAG crystal lases at 1.03μm that can be diode-pumped at 943nm.
2. Calculate the expected flashlamp life time for the lamp operated at 20% of its explosion energy.
3. Calculate the fraction of gallium and the fraction of aluminum in GaAlAs laser diode that emits a radiation at 808nm wavelength.
4. How can be checked the condition of the gas in a flashlamp.

Good Luck

حلول أسئلة مادة تصميم الليزر / الدور الأول 2015-2016

Q1A: The fractional thermal loading η_h is defined as the ratio of heat produced to absorbed pump power or energy. The theoretical lower limit of ηh for Nd:YAG lasing at 1.064μm and pumped with a laser diode pump source at 808 nm is $\eta_h = 1 - \lambda_p/\lambda_L = 0.24$, where $\eta_S = \lambda_p/\lambda_L$ is the Stokes factor and λ_p and λ_L are the wavelengths of the pump and laser beam, respectively. Heat generation is created by nonradiative sites. So-called "dark neodymium ions" or "dead sites" are ions that absorb pump photons but do not contribute to inversion. This leads to a pump quantum efficiency of less than unity we have combined the losses due to nonradiative processes in the *quantum efficiency* η_Q. For Nd:YAG we use $\eta_Q = 0.9$, which gives a heat load of $\eta_h = 1 - \eta_Q\eta_s = 0.32$ for diode pumping.

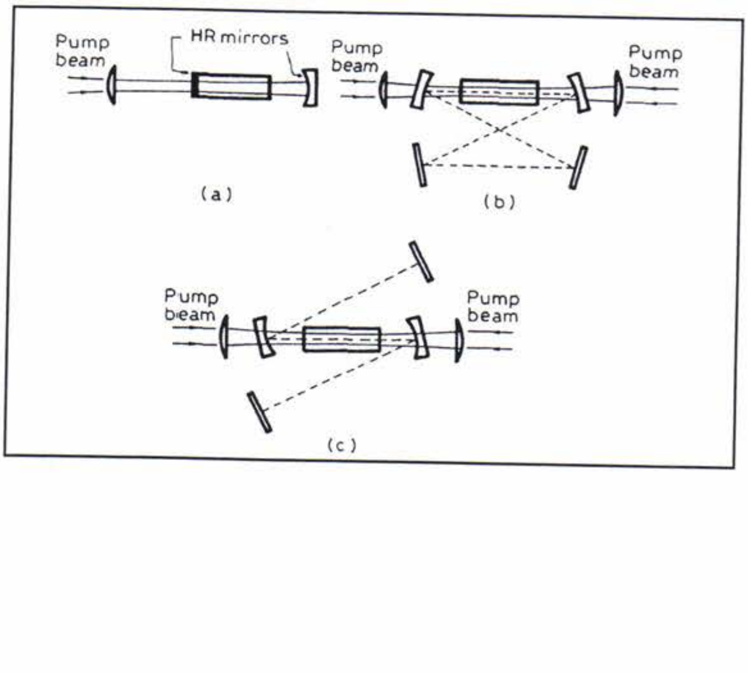
Q1B: 1. Waste heat=40W

2. radiation loss=4W

3. heat load=5W

4. fluorescence/absorption loss= 4w

Q2A: For longitudinal pumping, the beam emitted by the laser diode generally needs to be concentrated in a small 100μm- 1 mm diameter) and possibly circular spot in the active medium. Three of the most common laser configurations are shown in Figs. 6.11a-c. In Fig. 6.11a the laser rod is shown in a plane-concave resonator; the plane mirror is directly deposited on one rod face, with the pump beam focused on this face. In Fig. 6.11b-c two pump beams from two different diode systems are focused, on the rod center, from the two sides of the rod. The laser resonator can consist of either a folded ring configuration (Fig.6.1 lb) or a z-shaped folded linear cavity (Fig. 6.1 lc). For these latter two configurations, the resonator axis is also indicated by a dashed line. Given these resonators, we now address the question of how to transform the pump beam into a possibly circular shape of the appropriate size within the laser rod.



Q2B: $g1 = 1$

$g2 = \frac{\Delta}{L}$

$w2 = \left(\frac{\lambda L}{\pi}\right)^{0.5}\left(\frac{g1}{g2(1-g1g2)}\right)^{0.25} = \Delta = 28.1cm(neglected), \Delta = 1.86cm$

R= 31.86cm

g1=1, g2=0.058

$w1^2 = w2^2\frac{g2}{g1}$, $w1 = 0.121mm$

Q3A:

No we can't because the Fresenel no. is $N = \frac{a^2}{\lambda L} \approx 18$, so we can use

1. long radius resonator.
2. concave-convex resonator.

Q3B:

C = [0.09 x 100 x (500 x 10^{-6})2/(13)4]$^{1/3}$ = 0.199 x 10^{-3} farads = 199 microfarads.

Then the inductance L = (500 x 10^{-6})2/(9 x 0.199 x 10^{-3}) = 1.40 x 10^{-4} henry = 140 microhenrys.

Finally, the voltage V = (2 x 100/0.199 x 10^{-3})$^{1/2}$ = 1002 volts.

Q4:

$$T(0) = T_F + P_h\left(\frac{1}{4\pi K\ell} + \frac{1}{Ah}\right)$$

$$P_h = P_{out} \times 2.5 = 625W$$

$$A = 2\pi r\ell = 15.08cm^2$$

$$h = 10.47 \times 10^{-3}\frac{(D_2 / D_1)^{0.53}}{(D_2 - D_1)(D_2 + D_1)^{0.8}} f_r^{0.8} = 0.58W / cm^2 K$$

$$\therefore T(0) = 151.53C^o$$

$$T(0)-T(r_o)=\frac{P_h}{4\pi K\ell}\Rightarrow T(r_o)=91.24C^o$$

$$Atrodcenter,\delta_r=\delta_\phi=-1.6\times10^{-4}\,Kg/cm^2$$
$$\delta_z=-3.2\times10^{-4}\,Kg/cm^2$$
$$Atrodsurface, r=r_o$$
$$\delta_r=0$$
$$\delta_\phi=\delta z=3.2\times10^{-4}\,Kg/cm^2$$

Q5A:

$$P_o=50\,W/m$$
$$L_c=1m$$
$$L_a=\frac{L_c}{1.1}=91cm$$
$$w_f^4=\left(\frac{\lambda}{\pi}\right)^2 L_c\left(R-L_c\right)$$
$$w_f=3.18mm$$
$$w_s^4=\left(\frac{\lambda R}{\pi}\right)^2\left[\frac{R}{L_c}-1\right]^{-1}$$
$$w_s=3.35mm$$
$$\ell_d\exp\left(\frac{-2r^2}{w_s^2}\right)$$
$$r=4.7mm\approx0.5cm$$

Q5B:

1. charging unit
2. pulse forming network (PFN)
3. Triggering circuit

Q6:

1. $1-(\lambda p/\lambda L) = 1-(943/1030)$ $1-0.91=0.09 = 0.1$

2. $N=(E_o/E_{exp})^{8.5}= (1/0.2)^{8.5} = 873464$ pulse $= 10^6$ pulse

3. $\Delta E=1.424+1.247(x)$ [eV]

   $(hc/\lambda)= 1.424+1.247(x)$ [eV]

   1.54[eV]$= 1.424+1.247(x)$ [eV]

   $X=0.091$ (fraction of Al)

   $Y=1-X=0.908$ (fraction of Ga)

4. Condition of the gas in a flashlamp can be checked by removing the lamp from the laser, connecting one electrode to ground or some large metal mass, and exciting the other electrode with a Tesla coil (a high-voltage, high-frequency but low-current transformer). A good lamp will ionize with one or more thin, blue-white arcs dancing around inside the envelope. If, however, the arcs are very white or clear, or the tube glows violet, or no ionization occurs, the lamp is probably faulty or contaminated. Although not infallible, the Tesla coil test is a very easy, quick indicator of lamp quality.