2010 春季光電所博士班資格考 光電子學 II 總共十題 總分 100 分 總共三頁

1. (10%) A symmetric planar waveguide has a core thickness of 2 μm. Ignoring the dispersion of the waveguide material, we find the indices to be n1 = 1.50 and n2 = 1.46

(a) Is this waveguide single moded or multimoded at $\lambda = 1.5$ and 1.3 μm?

(b) What is the range of wavelength in which this waveguide is single moded?

2. (a)The numerical aperture N.A. of an optical fiber is $\sqrt{n_1^2 - n_2^2}$, wher e n_1 and n_2 are refractive indices of the fiber core and cladding, respectively. Derive it using ray optics theory. (5%)

(b) Suppose the effective index of a mode of an optical fiber is n_{eff}. Explain that n_{eff} is betwe en n_1 and n_2. (5%)

3. (6%) For an atom with homogeneous broadening transition between the energy states E_1=1 eV and E_2=3 eV, the lifetimes are $\tau_1=10^{-10}$ s, $\tau_2=5 \times 10^{-10}$ s.

(1) Determine the lineshape properties, i.e. ν_o, $g(\nu_o)$ and $\Delta\nu$.

(2) If the atom is colliding with environmental particles at frequency f = 100 MHz, estimate the overall line width $\Delta\nu$ for this atom

4. (4%)A system of hydrogen atoms is heated to very high temperature. What is the possible lineshape function? Explain your reason.

5. (10 %) Please answer the following questions briefly:

(a) What are the main differences between laser amplifiers and lasers?

(b) Under what circumstances can hole burning occur?

(c) What are the origins of gain saturation of a laser medium?

(d) What are the characteristics of amplified spontaneous emission noise?

Is there any two-level pumping schemes? If any, how does it work?

6. (a) (5%) List and explain the key characteristics of a laser versus a light bulb (an incoherent light source).

(b)(2%) How does a Q-switched laser achieve a peak power far exceeding the average power pumping the laser?

(c) (3%) How does a mode-locked laser achieve a peak power far exceeding the average power pumping the laser?

(d) (3%) Explain the gain clamping behavior of a laser at the steady state? Describe what could happen to a laser, if the laser gain does not clamp, but continues to grow or somehow drops below.

7. (a) Explain why silicon is not transparent in the visible range?(2%)
   (b) Explain why silicon is not considered to be an efficient light emitter? (3%)
   (c) Explain how does a light emitting diode work? (5%)

8. (10%) When an object gets sufficiently hot, it becomes visible to human eyes, and the power spectrum of the radiation is described by the Planck Function, called Blackbody radiation as shown in the figure, in which the spectrum that is visible to the human eyes is labeled in color bar. The Planck function is described as:

$$P_\lambda = 8\,\pi hc / \{\lambda^5 [\exp (hc/\lambda kT - 1)]\}$$

Where: P_λ = Power per area (m^2) per wavelength (m)

h = Planck 's constant (6.626×10^{-34} J.s)

c = Speed o f Light (3 x 108 m/s)

λ = W avelength (m)

k = Boltzmann Constant (1.38×10^{-23} J/K)

T = T emperature (K)

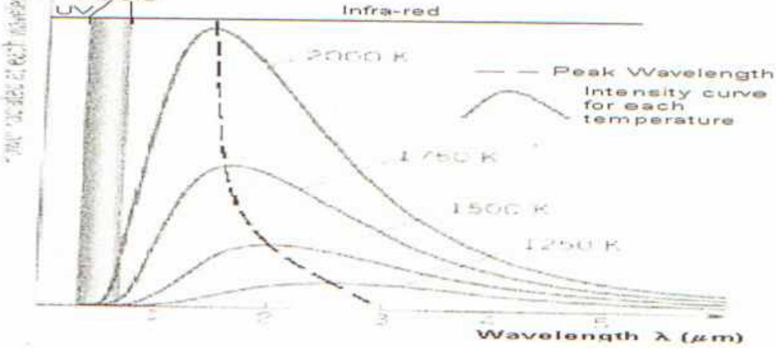
From this equation, it can be shown that the peak wavelength decreases as temperature increases, and their relationship is described by Wien's law as, $\lambda_p = 2.898 \times 10^{-3} / T$, where λ_p (m) is the peak wavelength at given temperature T (K).

Please answer the following questions:

(a) An incandescence light bulb can be considered as a blackbody radiator, (a1) explain why its efficiency is low, (a2) suggest two methods to improve its efficiency, (a3) explain the potential problems in each of these methods, and (a4) estimate the peak wavelengths for a bulb operated at temperatures of 2,500K and 5,500K.

(b) Assume that the emission spectrum of a hot object peaks at a wavelength of 650 nm, calculate the temperature of the object.

(c) Use the figure and estimate the peak wave corresponding to a human body at a body temperature of 37C.



9. (15%)

The uniaxial crystal $LiNbO_3$ belongs to the group of trigonal 3m crystals (i.e., $n_x = n_y = n_o$, $n_z = n_e$) having the tensor of electro-optic coefficients (i.e., the γ matrix)

$$\begin{bmatrix} 0 & -\gamma_{22} & \gamma_{13} \\ 0 & \gamma_{22} & \gamma_{13} \\ 0 & 0 & \gamma_{33} \\ 0 & \gamma_{51} & 0 \\ \gamma_{51} & 0 & 0 \\ -\gamma_{22} & 0 & 0 \end{bmatrix}.$$

The index ellipsoid of this crystal is

$$x^2/n_o^2 + y^2/n_o^2 + z^2/n_e^2 = 1 \quad .$$

When an external electric field E = [0, 0, E_z] applies to this crystal with the electric field pointing along the optic axis (i.e., the z axis), the index ellipsoid becomes

$$(1/n_o^2 + \gamma_{13} E_z)\, x^2 + (1/n_o^2 + \gamma_{13} E_z)\, y^2 + (1/n_e^2 + \gamma_{33} E_z)\, z^2 = 1 \quad .$$

Find the ordinary and extraordinary refractive indices of this crystal when such an external electric field exists. (Note that you may use $(1 + \Delta)^{-1/2} \fallingdotseq 1-\Delta/2$)

10. (a)(4%) An optical oscillator in its simplest sense requires the optical phase in it to accumulate an integer multiple of 2π over a roundtrip propagation. Explain why the degenerate 4-wave mixing could be considered as an oscillator. Give a physical but not mathematical explanation.

(b)(4%) Calculate the induced DC electric field (in units of V/mm) inside a second order nonlinear optical material for a pump laser intensity of 1 GW/cm^2. Assume the material's refractive index is 2.25 and the relevant nonlinear coefficient is $d = d_{eff}\varepsilon_0$, where d_{eff} = 25 pm/V and $\varepsilon_0 = 10^{-9}/(36\pi)$ F/m is the vacuum permittivity. Hint: This phenomenon is called optical rectification.

(c)(4%) (1) What is the Manley-Rowe relationship in a nonlinear frequency conversion process? (2) How do you modify the Manley-Rowe relationship for an absorptive nonlinear optical material? (Note: Showing your logic is more important than deriving a formula.)