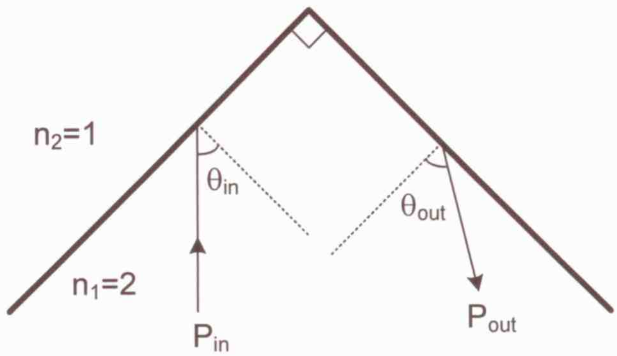
2008年秋季光電所博士班資格考 光電子學 I 總共十題四頁 總分 100分

1. You are to solve double refraction/reflection for an input ray within a right-angle prism. The prism with refractive index of $n_1=2$ is embedded within air, as shown in the figure below. The surfaces between prism and air are smooth and no loss is assumed. In the following, you should show your works and explicitly state your reasons.

(A) (5%) Find out the range of the incident angle θ_{in} so that output power P_{out} (still within the prism) is equal to the input power P_{in}.

(B) (5%) Following your result in (A), express the output ray angle θ_{out} in terms of the input angle θ_{in}. How are the two rays related? For simplicity, you may use $\theta_{in}=45^{o}\pm\alpha$ to help your derivation.



2. Consider the interference of M waves with equal intensities I_0 and phase difference ϕ between successive waves. The expression for the intensity of the superposition of M waves is :

$$I = I_0 \frac{\sin^2(M\phi/2)}{\sin^2(\phi/2)}$$

(a) (4%) The total intensity I is strongly dependent on the number of waves M and phase difference ϕ. Please use the equation above and derive the expression of I in terms of ϕ for M=2. (Hint: $\sin 2\theta = 2\sin\theta\cos\theta$)

(b) (4%) From (a), under what condition of ϕ can we obtain the maximum intensity of

I? What is the physical interpretation of ϕ in this case?

(c) (7%) A monochromatic light is incident on a thin film coated on a glass substrate. The wavelength is scanned in the visible range. The observed reflected intensity vanishes only at 500nm and 700nm. Assume the refractive index of the thin film is 1.3 and that of the substrate is 1.5. Please find out the thickness of the thin film d. For calculation simplicity, assume lights are normal to the interface. (Hint: use the equation derived in (a).)

3. A plane wave with wavelength $\lambda = 10\ \mu m$ is incident on an optical aperture with diameter D = 1 mm.

(1) Find the Rayleigh range for the beam after the aperture. (3%)

(2) Find the radius and size of the beam at 50 mm away from the aperture. (4%)

(3) If a thin lens with focal length f = 10 mm is attached directly on the back of the aperture, find the beam radius of the beam just after the lens. (4%)

4. An optical beam is propagating in an atomic system. The absorption cross section of the atomic transition is $5 \times 10^{-8}\ cm^2$. Find the concentration of the atoms for the beam intensity to decay 1/2 in a length of 1 m. (4%)

5. (15%) A phase object ($t = e^{i\phi(x)}$) varying in the x direction is difficult to study its detailed content. Show that the phase information can be extracted by using a 4-f system with a small stop on the origin of the frequency (Fourier) plane.

6. (10%) The scalar e-field of a transform-limited Gaussian pulse under slowly varying envelope approximation is of the form:

$$e_{in}(t) = \mathrm{Re}\{a_{in}(t)e^{j\omega_0 t}\},\ \ a_{in}(t) = \exp\left[-\left(t/\tau\right)^2\right]$$

(a) Sketch a curve for $e_{in}(t)$, denote ω_0 and τ conceptually. (4 %)

(b) Describe how to get the output e-field $e_{out}(t)$ if the pulse passes through a medium of length L and has an ω -dependent refractive index $n(\omega) = n_0 + n_1(\omega - \omega_0)$? (6%)

7. (10%) Consider a time-harmonic plane wave. The corresponding vector phasors of EM fields $\vec{E}$, $\vec{D}$, $\vec{H}$, $\vec{B}$ are proportional to $\exp\left(-j\vec{k}\cdot\vec{r}\right)$, where $\vec{k}$ and $\vec{r}$ represent wave vector and position vector, respectively.

(a) If the wave propagates in an electrically anisotrpic medium, show that the power density vector (Poynting vector $\vec{S}$) is NOT in parallel with $\vec{k}$ (Hint: Use Maxwell's curl equations). (6%)

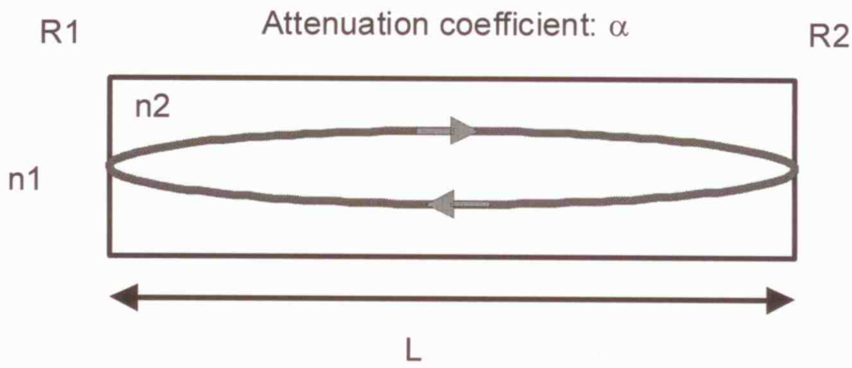
(b) According to the fact in (a), sketch $\vec{S}$ and the corresponding phase fronts conceptually. (4%)

8. (15%) Consider electromagnetic waves resonating inside a Fabry-Perot cavity as shown in the figure below. R1 and R2 are the reflectivity at the two end of the cavity. α is the attenuation coefficient and n1, n2 are the refractive indices.

(1) (5%) What is the finess?

(2) (5%) What is the photon life time?

(3) (5%) What is the quality factor?



9. (6%) The ***mutual intensity*** of an optical wave at points on the x axis is given by

$$G(x_1, x_2) = I_0 \exp[-\frac{(x_1^2 + x_2^2)}{W_0^2}]\exp[-\frac{(x_1 - x_2)^2}{\rho_c^2}],$$

where I_0, W_0, and ρ_C are constants.

(a) Derive an expression for the normalized mutual intensity $g(x_1, x_2)$ (2%) and sketch it as a function of $x_1 - x_2$ (2%).

(b) What is the physical meaning of the parameters I_0, W_0, and ρ_C? (2%)

10. (4%) Consider the following three basic hypotheses:

(a) For sufficiently small Δt, the probability of a single impulse occurring in the time interval t to $t + \Delta t$ is equal to the product of Δt and a real nonnegative function $\lambda(t)$; thus $P(1; t, t + \Delta t) = \lambda(t)\Delta t$.

(b) For sufficiently small Δt, the probability that more than one impulse occurs in Δt is negligibly small (i.e. there are no "multiple" events); hence $P(0; t, t + \Delta t) = 1 - \lambda(t)\Delta t$.

(c) The numbers of impulses in nonoverlappling time intervals are statistically independent.

Then by using the three fundamental hypotheses above show that the photocount statistics for light from a single-mode, amplitude-stabilized laser radiations obeys the ***Poisson process***.