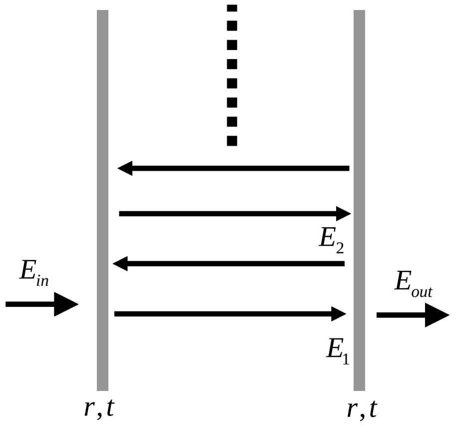
國 立 清 華 大 學 命 題 紙

一百學年度第一學期 光電工程研究所 博士班研究生資格考試

科目 光電子學一 共 4 頁第____頁 ＊請在試卷(答案卷)內作答

1) (15%) A Fabry-Perot resonator is shown in the following figure. Inside the resonator, the refractive index is denoted by n and the attenuation coefficient is denoted by .



r : *reflection coefficient*

t : *transmission coefficient*

$t^2 = 1 - r^2$ (transmittance)

α : *attenuation coefficient*

Please derive the transmittance equation given by

$$\frac{|E_{out}|^2}{|E_{in}|^2} = \frac{\left(1-r^2\right)^2 \exp(-\alpha L)}{(1-\mathrm{Z})^2 + 4\mathrm{Z}\sin^2\varphi}$$

$$\text{where } \mathrm{Z} = r^2 \exp(-\alpha L) \text{ and } \varphi = \frac{\omega}{c} nL$$

hint: $E_{out} = t(E_1+E_2+E_3+\ldots.)$

2) (10%) The e-field of a transform-limited Gaussian pulse of carrier angular frequency ω_0 can be described by:

$$e(t) = \mathrm{Re}\{a(t)e^{j\omega_0 t}\},$$

where $a(t) = \exp\left[-(t/\tau)^2\right]$ and $A(\omega) = F\{a(t)\} \propto \exp\left[-(\tau\omega/2)^2\right]$ represent the envelope functions in time and frequency domains, respectively. This means the time duration and spectral bandwidth of the pulse are about τ and $1/\tau$, respectively. If the pulse passes through a dispersive medium of refractive index $n(\omega) = n_0 + n_1(\omega - \omega_0)$ and a very long length L, the output time duration Δt_{out} can be much longer than τ. Please roughly estimate Δt_{out}. Justify your answers. (Hint: It is unnecessary to calculate the spectral phase modulation, which is only needed when $\Delta t_{out} \approx \tau$).

3) (10%) An isolator is used to block the reflected beam, which is important in protecting high-power lasers. Describe how to build an isolator by using polarizer(s) and waveplate(s). Justify your answers.

4) Consider the interference of M waves with equal intensities I_0 and phase difference ϕ between successive waves.

(a) (4%) Please derive the expression for the intensity of the superposition of M waves.

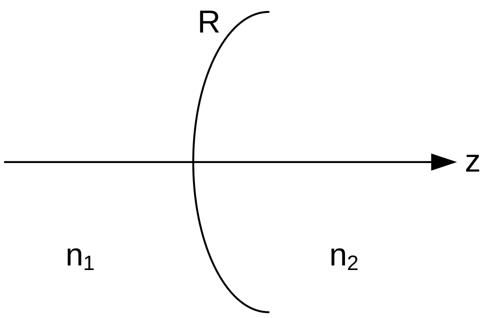
(b) (5%) Please use the equation above and derive the expression of I in terms of ϕ for M=2 (Hint: $\sin 2\theta = 2\sin\theta\cos\theta$). Under what condition of ϕ can we obtain the maximum intensity of I? What is the physical interpretation of ϕ in this case?

(c) (6%) A monochromatic light is incident on a thin film coated on a glass substrate (n_{glass}=1.5). The wavelength is scanned in the visible range. Given the observed reflected intensity vanishes only at 500nm and 700nm, please prove that the refractive index of the thin film is smaller than that of the glass.

5) Answer the following:

1. Explain the difference between the Boltzmann distribution and Fermi-Dirac distribution for an atom in energy level E. Under what situation should one use one distribution instead of the other? (2%)
2. What are the homogeneous and inhomogeneous line broadenings of a group of atoms undergoing radiation transition? (4%)
3. Plot conceptually the classical and quantum theories of the spectral energy density of blackbody radiation versus frequency. Point out the major discrepancy between the two theories and the key physics to correct the mistake in the classical theory. (4%)

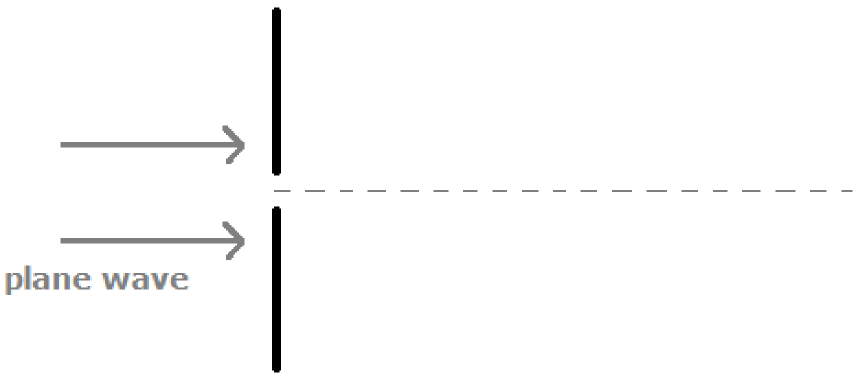
6) (a) (8%) Derive the ABCD matrix for a curved interface (R: radius of curvature) shown below. Be sure to state all of your assumptions.



(b) (7%) Use your result in (a), derive the ABCD matrix for a thin lens.

7) (5%) For a typical laser beam, there is a finite distance so within the range, the laser beam can be approximated as collimated beam. How is this distance mathematically expressed? Explain all terms within the expression.

8) (10%) Consider a one-dimensional slit as shown below.



Draw one near-field pattern and the far-field pattern after the slit.

9) (a) (5%) Show that the power spectral density, $S(\nu)$, defined as $S(\nu) \equiv \lim_{T\to\infty} \frac{1}{T} <|V_T(\nu)|^2>$, is the Fourier transform of the autocorrelation function, $G(\tau)$, i.e.

$$S(\nu) = \int_{-\infty}^{\infty} G(\tau) \exp(-j2\pi\nu\tau)\ d\tau \ ,$$

where $V_T(\nu) = \int_{-T/2}^{T/2} U(t) \exp(-j2\pi\nu t)\ dt$, and $G(\tau) = \lim_{t\to\infty} \frac{1}{2T} \int_{-T}^{T} U^*(t)\ U(t+\tau)\ dt$.

(b) (5%) 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. Derive an expression for the normalized mutual intensity $g(x_1, x_2)$ and sketch it as a function of $x_1 - x_2$. What is the physical meaning of the parameters I_0, W_0, and ρ_C ?