國 立 清 華 大 學 命 題 紙

九十九學年度第二學期 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 頁第 頁 ＊請在試卷(答案卷)內作答

1. Consider the ABCD matrix:
(a) (4%) Explain the physical meaning of each element within the matrix.
(b) (3%) Assume you have a simple imaging system, what will be the signature of its corresponding ABCD matrix?

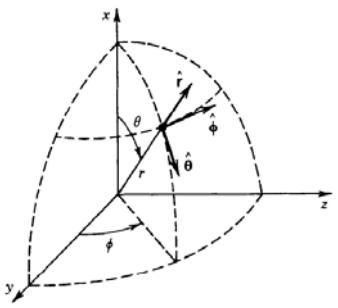
2. (a) (6%) Perform the step-by-step derivation in obtaining the paraxial Helmholtz equation. You need to state clearly the assumptions in each step.
(b) (7%) Write down the mathematical expression of the paraboloidal wave. Show it is indeed a solution to the paraxial Helmholtz equation.

3. (7%) Consider a thin film of soap with a thickness of 320nm in air under normal illumination by white light. If the film is treated as a planar dielectric slab with er =1.77, surrounded on both sides by air, what is the reflected color? (No credits for answer without explanation and calculation.)

4. (8%) Please provide justification to explain if the following math expressions (distances are in meters) represent traveling waves. And for each of the qualified expressions, please give speed and direction of motion.
(a) $f(x,t) = A\sin^2(4\pi(t+x))$ (b) $f(x,t) = A(x-t)^2$

5. (15%) Write down the field of a Gaussian beam with beam waist W_0 at wavelength λ. Derive the field distribution of this wave after it propagates a distance L. Rederive the previous question by using Fresnel propagation integral.

6. (10%) The electric field of a Gaussian beam is represented by: $\vec{E}(\vec{r}) \approx E_0 \sin\theta \cdot U(\vec{r})\hat{\theta}$,
where $U(\vec{r})$ is a scalar function satisfying the scalar paraxial wave equation, θ (inclination angle) and $\hat{\theta}$ (unit vector) are spherical coordinates quantities defined in the figure below. For the following 5 types of physical problems: (i) interference, (ii) diffraction, (iii) propagation through air, (iv) propagation through waveguides, (v) reflection and refraction at dielectric boundaries, which of them are inadequate to be described by $U(\vec{r})$? Justify your answer.



7. Jone's calculus.

(a) (5%) If the Jones vector of a monochromatic plane wave is: $\begin{bmatrix} 1 \\ -j \end{bmatrix}$

Plot the trajectory and denote the sense of rotation of the corresponding E-field.

(b) (5%) What happens if the wave passes through a quarter-wave plate (the x-component leads the y-component by a phase of $\pi/2$ during the propagation)? Justify your answer.

8. A ring cavity consists of three mirrors of R1 = 99%, R2 = 95%, and R3 = 90% in free space. To form the ring cavity, the mirrors are arranged with the following inter-mirror spacing: l_{12} = 0.5 m, l_{23} = 0.4 m, and l_{31} = 0.3 m. The only losses of this cavity are those from the transmission of the mirrors.

(a) (5%) What are the round-trip time and the longitudinal mode spacing of this cavity?

(b) (5%) Find the finesse and the longitudinal mode width of this cavity.

(c) (5%) What are the cavity decay rate, the photon lifetime, and the Q factor for l = 1 mm?

9. Plot the photon number distribution, $P(n) = |\langle n|\varphi\rangle|^2$, as a function of photon numbers for the state, $|\varphi\rangle$

(a) (2%) Number state, $|\varphi\rangle = |n = 3\rangle$;

(b) (5%) Coherent state, $|\varphi\rangle = |\alpha = 3\rangle$;

(c) (3%) Squeezed Coherent state, $|\varphi\rangle = |\xi=3,\alpha= 3\rangle$

10. (5%) Name and explain the three basic forms of interactions between photons and atoms.