Physics Comprehensive Exam Spring 1993
Special Topic: Optics

Work three out of the four problems. Start each problem on a new sheel of paper.

1. Optically active materials such as sugar water, quartz, and cinnabar (HgS) have different refractive indices for right-handed, ***R***, and left-handed, ***L***, circularly polarized light. This is one form of birefringence. When ***R*** progates through an optically active medium, it remains in the ***R*** state; likewise for ***L***. A sample of sugar water is characterized by refractive indices n_R=1.333 and n_L=1.334 at the wavelength of 1μm. Consider a cell with a path length of 250mm.

   (a) What are the optical path lengths of ***R*** and ***L***?

   (b) What is the transmitted polarization state when horizontally linearly polarized light, H, is incident? Describe the optical path length associated with this beam.

   (c) How does the polarization state propagate when the incident light is linearly polarized light ***LP(θ)*** initially oriented at an angle θ from the x-axis?

   (d) What is the retardance of the 250mm long device?

2. Consider a 1cm by 1cm aperture illuminated by light with a wavelength of 0.5μm. The left half of the aperture is covered by a horizontal linear polarizer, the right half by a vertical linear polarizer.

   (a) A plane wave of horizontally polarized light is incident on the aperture. Determine the (intensity) diffraction pattern of the aperture in the far field (Fraunhofer diffraction). Please explain all notation and assumptions carefully.

   (b) A plane wave of vertical linear polarized light is incident. Determine the diffraction pattern.

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(Problem 2. continue)

(c) A plane wave of unpolarized light is incident. Determine the diffraction pattern. What can you say about the polarization state in the diffraction pattern?

3. A 1cm diameter disk is 5 meters in front of a planar detector with an active area of $0.25cm^2$. The normals of the disk and detector are in the same direction. The disk is a "greybody" with an emissivity of $\epsilon=0.9$ and a temperature of 1000°K. When the detector is irradianted with a incidence of $E=1x10^{-6}W/cm^2$, its resulting signal is 1.5mV rms. Recall that the Steffan-Boltzmann constrant is $\sigma=5.67x10^{-8}W/m^2/°K^4$.

(a) What is the exitance [W/m^2] of the disk?

(b) What is the irradiance on the detector? What is the resulting signal?

(c) If the disk is translated in a plane perpendicular to the surface normal so that it makes and angle of θ with repsect to the surface normal what is the new irradiance on the detector? Evaluate the signal for $\theta=60°$.

(d) You are told that the main source of noise on the detector is from background thermal radiation. The detector effectively sees a lambetian source @ temperature 300°K that extends over a full hemisphere of 2π steradians. Find the rms noise voltage on the detector due to this background radiation.

4. You have worked for two months on Code V optimizing a high speed photographic lens. Your objectives were to design a system with an image field numerical aperture of *NA*=0.5, exit pupil diameter of 2cm, and 1cm diameter image field. The system operates nominally at 500nm. Code V reports that the system is aberration free except for 50 waves of forth-order distortion at the full field of view, that is

$$W(h,\rho,\Phi) = W_{311}\ h^3 \rho\ cos(\Phi) = W_{311}\ h^3\ \rho_y \qquad (1)$$

where we assume that the object is along the y-axis. h is the normalized object height (*i.e.* $0 \leq h \leq 1$), ρ is the normalized radial pupil coordinate (*i.e.* $0 \leq \rho \leq 1$), and Φ is polar coordinate angle in the pupil measured with respect to the y-axis.

(a) Find the point spread function and MTF of the aberration free system.

(b) Find the point spread function at the full field of view for your system with distortion.

(c) Given that the transverse aberration function in the y-direction and the wavefront aberration function are related by

$$\epsilon_y = - \frac{Z_{E'k}}{n} \frac{\partial W}{\partial y} = - \frac{Z_{E'k}}{nY_{E'}} \frac{\partial W}{\partial \rho_y} \tag{2}$$

where $Z_{E'k}$ is the distance from the entrance pupil to the image plane and $Y_{E'}$ is the exit pupil radius. Compute the transverse aberration function of the system. Find the transverse aberration at full field. Compare this result with that of part (b). Fully discuss this result.