EECE7105 Final Exam

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Logistics

Schedule In fairness to all, I must insist on adhering strictly to the schedule. The exam is due electronically on Blackboard before 11:59:59pm (23:59:59) Wednesday 10 December.

Format: Please submit exactly one .pdf file with all the problems answered in sequence. Other formats can lead to font variations, lost artwork, and other unpleasant events.

Filename: Please include some recognizable portion of your name in the filename.

Copy: Please keep a copy yourself, in case any electronic problems occur. I plan to download your work and check that I can open your file shortly after the submission deadline, and I will contact you if there is any problem.

General Instructions

Please do not collaborate with other students or seek help from outside experts. However, you may use any reference book, journal articles, or other readily available resources. Please cite references if you do so.

Please contact me if you are confused about the wording of a problem. I will will clarify the wording of the problems, or correct an error in the questions if someone should find one. Keep an eye on the announcements on the course web site for such updates.

Draw a figure for each of the problems. Usually in my problems, the first

step is to generate a layout of the optical system. I give points for figures.

You will want to use a computer for some of the problems. You may use any language you like, but make sure that the equations and graphs are presented in such a way that I don't need to look at your code. When I ask for a plot, I am looking for a correctly labeled one, with correct numerical values. A sketch is not sufficient.

Present your work as clearly as possible. I give partial credit if I can figure out that you know what you are doing. I do not give credit for putting down everything you know and hoping I will find something correct in it. In previous years, many students typeset the whole exam in Word or LaTeX, which made it easy to follow. These exams are usually the easiest to grade, particularly when I sought to understand the reasoning in order to assign partial credit.

1 Partial Polarization

Here we consider sunlight incident on the side of a tall glass–walled building. Think of the Hancock Building in Boston, for example. Assume (contrary to fact for this building) that the windows are uncoated glass.

Let's begin by assuming that the side of the building faces south, and that, at solar noon, the sun is due south at a zenith angle of 45 degrees. Also assume that the sunlight is randomly polarized. In other words, the degree of polarization is zero.

We want to look both at the reflected light as seen from outside the building, looking up and north, and also at the transmitted light, seen from inside, looking up toward the sun. For the reflection problem, assume that we only worry about the first–surface reflection, just to keep things a little simple.

1.1 Definitions and Basic Calculations

a) What is the plane of incidence? Specify its direction with enough words to make it unambiguous.

b) Describe the directions of the electric field for P and S polarization of light.

c) Write the coherency matrix, $\mathcal{C}_{in}$ for the input sunlight.

d) Compute the reflection and transmission coefficients (for power).

e) Write the Jones matrices for transmission, $\mathcal{M}_T$, through the window and reflection, $\mathcal{M}_R$, from its first surface. Use a coordinate system in which the bottom element of the Jones vector is the polarization in which the electric field oscillates from east to west.

1.2 Effects of the Glass

a) Calculate the coherency matrix and then the Stokes vector for the reflected light. What fraction of the incident light is reflected? What is the degree of polarization?

b) Calculate the coherence matrix and then the Stokes vector for the transmitted light. What fraction of the incident light is transmitted? What is the degree of polarization?

1.3 Sunglasses

Now assume that we view the reflected light and the transmitted light through sunglasses that have an insertion loss of 8% and an extinction ratio of 100. Repeat the previous section, finally reporting the fraction of sunlight seen through the glasses and the degree of polarization.

a) Reflected.

b) Transmitted.

2 Optical Coherence Tomography

Let's design an OCT instrument at a center wavelength of 1300 nm.

2.1 Linewidth

In this section, be careful to think about the distinction between round–trip distance and distances to be measured.

What is the approximate linewidth of the source required for an axial resolution of 5 μm? Express the answer in nanometers.

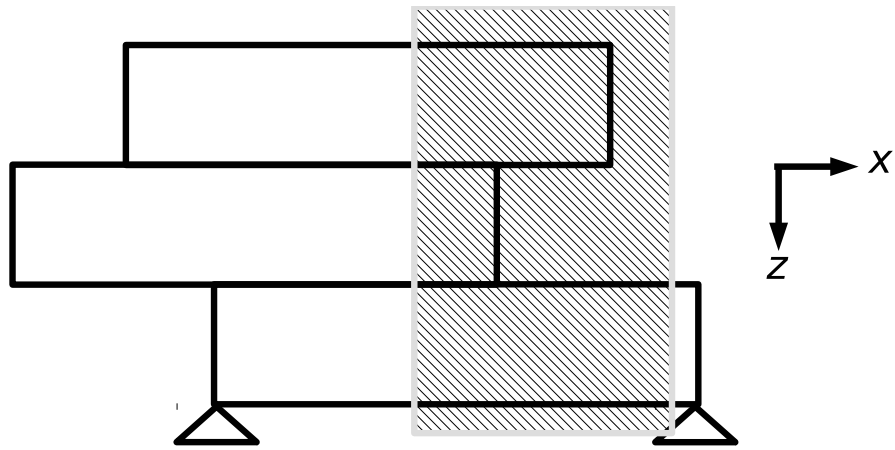
Suppose that I add a glass element of thickness 1 centimeter to the optical path between the instrument and the target. What is the change in optical path length across the spectrum of the source?

2.2 Imaging

Now we arrange a stack of glass coverslips having a thickness of 0.170 millimeters as shown in the figure below. The bottom coverskip is placed on two supports and the whole thing is surrounded by air.

The OCT instrument scans slowly along the x direction, while the mirror in the instrument itself moves rapidly to generate the z scan to produce an image of the shaded region.

Draw the image you expect to see, accounting for the various reflections (assume the glass–glass interface is sufficiently smooth that no reflection occurs there.



3 Gaussian Beams

3.1 Resolution and Depth of Field

Let's continue with our OCT system from Problem 2. Resolution and field of view are important instrument parameters, as they are in any imaging system. The useful field of view in the z direction is limited by the depth of focus of the light source. Let's suppose we have a Gaussian beam focused to a waist at some depth. We would like to have the beam diameter always be less than twice the waist diameter throughout the working depth.

a) What is the required waist diameter?

b) What is the resolution in the x direction.

c) Discuss the implications of this relationship for imaging with OCT in contrast to confocal microscopy.

3.2 Design Problem

Assume that our light source has a waist diameter of 1 millimeter. Design the OCT system with appropriate lenses to produce the desired beam. There is more than one possible answer for this problem. Start with the simple design on Page 18 of the slides for Chapter 10.

4 Radiometry

Let's begin with sunlight falling on a white wall that diffusely reflects 3% of the incident light, as discussed in Tuesday's lecture (2 December). Assume the scattered light is Lambertian. We'll then point a laser beam at the wall, and ask how visible it will be against the bright background. Throughout this problem, you may make reasonable approximations if you can justify them. There are parts that require numerical integration, but a good approximation is sufficient. Using good engineering skills to choose approximations is part of the task.

4.1 Scattered Sunlight

a) Compute and plot the spectral radiance of the wall as viewed by a camera.

b) Next, compute the number of electrons collected by one pixel of a camera viewing this wall. The pixels size is 7 μm, and the lens is f/22. Assume the camera has 70% quantum efficiency (70 electrons per hundred photons). The exposure time is 1/30 second.

4.2 The Laser

Next, we point a 1 mW green laser laser pointer (532 nm at the wall, with a Gaussian beam diameter at the wall of 2 cm. Assume that there many pixels on the laser beam so that we can observe the brightest part of the beam with several of them.

a) How many electrons will be detected in one of the pixels with the laser beam?

b) Will the laser be visible in the image?