LAB 13: THE CAMERA LENS--RADIOMETRY

DEFINITION

Radiometry is the science of the measurement and calculation of radiant energy transfer. For our purposes, we will consider radiant energy to be in the visible portion of the electromagnetic spectrum. More generally, radiometry deals with energy in any part of the spectrum$_1$ from the ultra-violet to the far infrared and even beyond to radio waves. Radiometry attempts to answer the questions of how much energy is transferred from one point in space to another, and how accurately this energy can be measured. It is an old science rich with history and careful detail to experimental technique.

INTRODUCTION

Up until now, the entire course has dealt with the geometry of optical systems. We have discussed in detail how a lens or mirror changes the direction of a ray of light. This was done using the geometrical shape of the lens or mirror to calculate its power. The power was used to then locate the paraxial image of an object. Rays were traced, heights and angles were calculated to relate image points to object points. All of this was based on geometry. (Note also that the concept of a ray is itself a geometrical one. A ray of light is defined as the line, which is normal to a wavefront in any plane in an optical system. This allows the wavefront, which is what really travels through the optical system, to be talked about in geometrical terms.)

The question that has not been addressed yet is HOW MUCH LIGHT passes through a particular optical system, (perhaps just a simple lens). Consider the ray traces you have done throughout the course. From a given object point, you probably traced one, maybe two rays through an optical system to the corresponding image point. These rays were but a couple of many rays that could have been traced from this object to image point. In fact, there is an infinite number of rays that can be traced from one object point to its corresponding image point. These rays merely describe the smooth, continuous 3-dimensional wavefront that travels from this object to image point. It is this wavefront that physically carries ENERGY or the AMOUNT OF LIGHT from one object point to its image point. By considering all of the points in an object plane, and the wavefronts that each point emits, we can calculate the AMOUNT of light energy that the optical system will pass through to the image plane. The ability to calculate and measure this energy is the basis of the science of radiometry.

In the SLR camera lens, how much light that reaches the film plane is controlled by (a) the size of the aperture stop, and (b) the shutter speed. In turn, the size, or area, of the aperture stop is controlled by the setting of the F-stop ring at the back end of the lens. Keep in mind that this determines the working F/# of the lens. The goal of this lab is to understand the F-stop numbers marked on the ring, by measuring the amount of light transmitted through the lens as you vary the F-stop. In particular, your investigation should answer the following question:

"Given that the working F/# of the lens is 4 when the aperture stop is wide open, what is significant about the other F-numbers marked on the lens?"
(NOTE: The F/4 setting is located one "click" beyond that for F/3.4)

You will need the following simple relationships for this lab:

*** The amount of light reaching the film plane is directly proportional to the area of the aperture stop.**

*** The detector turns light into a measurable voltage. The detector responds in a linear manner--if you double the amount of light on it, you get twice the output voltage.**

EXPERIMENT:

(1) Set the lens to have a 70mm focal length, focused at ∞.

(2) Autocollimate the source to place the source at ∞.

(3) Adjust the height of the lens to make sure that the collimated beam of light completely fills the lens.

(4) Make sure that the light distribution in the collimated beam is as **uniform** as possible. Adjust this by moving the pinhole around.

(5) Take a reading of the output voltage of the detector with NO LIGHT on the detector. This is your dark reading, a number which should be subtracted from your data.

(6) Take readings of the DC output voltage of the detector assembly with light through the lens, as a function of the working F/#. Do this for all of the F-stop "click-settings," including the intermediate unmarked ones. **Start at F/4, located one "click" beyond the setting for F/3.4.**

(7) Process your data in the following manner:

--subtract the dark reading from your data points
--normalize your data to the value at F/4 (divide all of your voltage readings by the largest voltage reading, namely the one obtained at F/4)

(8) Plot your data using a computer. Plot your normalized values of measured light (i.e. normalized voltages) as a function of the F/# of the lens, for all of the marked F/#'s.

(9) On the same graph, plot the corresponding theoretical y-values, for all of the marked F/#'s (think about this--just as for your measured values, these should represent a ratio, with the value at F/4 being 1. The question is, a ratio of what?).

(10) What are the other intermediate (unmarked) F/#'s? Base this answer on your **measured data** using 2 approaches:

Use the known theoretical relationship that should describe this curve to predict the corresponding x-values (F/#'s).

Curve-fit your measured data, and find the corresponding x-values (F/#'s) from the equation predicted by the curve-fit (NO polynomials are to be used!!!). How well does your curve-fit match the theoretical relationship?