Determine the Distribution Temperature of a Source

INTRODUCTION
In this lab you will determine the spectral power distribution of an unknown light source. A computer program is required to do the necessary calculations. Any language is acceptable (IDL, C, C++, FORTRAN, Basic, Pascal, etc.). Software is unacceptable (e.g., Excel). Each person must write her or his own program but may seek technical assistance from lab partners. You may be asked to demonstrate the program’s operation to the instructor or T.A. so don’t be tempted to turn in someone else’s code.

BACKGROUND AND THEORY
As we already know, sources emit energy in the form of a spectral distribution. Depending on the type of source (gas, solid, etc.) the distribution can vary significantly in shape. In this lab, you will try to determine the “shape” (and ultimately the temperature) of a distribution from an unknown source, given data from a real world source measurement scenario.

The setup for such a source measurement can be seen in Figure 1. We first establish an area source of radiance, $L(\lambda)$. We will make the assumption that this diffuse source is “lambertion”. That is, it “looks” exactly the same when viewed from any direction. We will cover this concept more in lecture. With this assumption we can relate radiance to exitance through the relation $M = L \pi$. A certain amount of flux is then captured by the monochromator which has a field of view (FOV) of 10 degrees. This FOV is established by the lens and entrance aperture (with area, $A_{\text{slit}} = 1.5 \text{ mm}^2$) at the front of the monochromator. The FOV is typically reported by the manufacturer. The entire setup is aligned on-axis such that $\theta = 0$.

The energy then makes its way through the monochromator with efficiency $\varepsilon(\lambda)$. The exiting flux is entirely captured by the area of the detector, with responsivity $\beta(\lambda)$, producing a spectral signal in amps, $S(\lambda)$ which is then amplified by a factor of $\alpha = 1,000,000$ to produce the signal $S_{\text{amp}}(\lambda)$. We will assume that transmission effects between the lens-to-monochromator and monochromator-to-detector are negligible.
The set up illustrated in Figure 1 is used to sample the source spectrum. We can control what wavelengths to sample by adjusting the monochromator to a specific wavelength value. One drawback, however, is that the monochromator is not 100% efficient. As a matter of fact, its efficiency varies with wavelength. Additionally, the detector does not have an ideal responsivity and also varies with wavelength. Therefore, when one obtains the spectral distribution of the unknown source, buried in the measurement is the spectral response of the detector and efficiency of the monochromator. These have to be “backed out” in order to see the behavior of the source alone.

**PROCEEDURE:**
For this experiment, you will be given the spectrally dependant signal, $S_{\text{amp}}(\lambda)$ in units of amperes (see Figure 2) as well as the spectral efficiency of the monochromator and responsivity of the detector. It is your job to “back-out” all the effects of the system, using your knowledge of radiometry, in order to convert your signal reading into a source distribution in units of exitance, $M(\lambda)$ [W/m$^2$ µm].

Once the source distribution is obtained you will have to estimate what the color temperature of the source is in degrees Kelvin. This can be achieved by writing a program that curve fits various Planckian functions to your data. The function that matches best, in a least squares sense, has a color temperature that is representative of the unknown source.
RESULTS:

1. Derive an expression that relates the output signal $S_{\text{amp}}(\lambda)$ [A] to the source exitance $M(\lambda)$ [W/m² µm]. Show this derivation.
2. You will need to know the solid angle formed by the monochromator. You can use the relation $\Omega = 2\pi(1-\cos(\text{FOV}/2))$.
3. Use your derived expression to convert your spectral signal to spectral exitance. It is this “curve” you will be estimating the color temperature form.
4. In this lab we are not really concerned with the absolute value of exitance, only the spectral shape of the source. We wish to find the color temperate and will do so using a least-squares program (that you will write). You will have to “adjust” your data ($i.e.$, normalize) so you can fit the shapes to one another (ideal vs. measured). Include a plot of your measured results. That is, overlay the best fit Planckian function to your exitance data.
5. Report the color temperature as well as the “minimum error” fit value. This should be an RMS value. Are these values what you would have expected? That is, are they reasonable? Why or why not? Why are we using a Planckian function to begin with? Can we do this type of set up with all sources? Why or why not? What kind of source do you think this is ($i.e.$, fluorescent, tungsten, sodium vapor, mercury vapor, etc.)
6. Plot the error vector from the least-squares fitting.
7. Include your code used to generate the color temperature.