Ay 105 Lab Experiment #8: Infrared Array Camera

Purpose In this week's lab, you will study the characteristics of an InSb near-infrared to thermal-infrared array camera, take pictures, set up an infrared spectrograph and examine features in a near-infrared spectrum. The camera is sensitive from $\sim 2-4\mu$m. In the first part, you will acquire images of various infrared sources, including a cooling cup of water, and analyze them on the computer. In the second part, you will image the spectrum of a hot wire seen through the atmosphere in a lab, using a simple grating spectrograph. As there is a single camera, both groups can acquire the first set of images together. Then, while one group is analyzing the first set of images, the other group can obtain the wire spectrum images.

Pre-Lab

- What is significant about the temperatures 310 K and 77 K?
- What is the ratio of radiant energy at 2.5 microns between a 310 K and 77 K blackbody? How about at 4.5 microns?
- Review your work in previous labs:

  - planck function (Expt 1)
  - spectrographs and the grating equation (Expt 3)
  - infrared detector (Expt 7)

Equipment

IRC-160 camera dewar
liquid nitrogen
vented funnel
mirror
plexiglass
2 coffee cups with water, one heated
thermometer

lightbulb and post
collimating mirror
translational stage
diffraction grating
rotational stage

pc and image analysis software
Ay105user account

Setup The IRC-160 camera will need a fresh fill of its dewar with LN_2. Use the "vented" funnel, and take care not to freeze any part of yourself with the nitrogen. Make sure that camera is connected and powered up (see p. C4 of the manual). Leave the gain and offset controls at their default settings to start. The chip, if previously warm, takes several minutes to cool down. Two fills of the camera dewar are typically required to obtain a steady temperature.

The camera has two outputs, a VGA video output and a parallel port. When the camera was new back in the mists of the early 1990's, a coal-burning PC with a dedicated parallel input card converted the camera output into data files. Now, a "modern" VGA-USB converter and software are used to capture images. The downside of this is that captured images have (modest) additional noise, and have a format of 640×480, rather than the native 120×160 array size of the camera.

Part A Measurements This is the time to explore, but wisely informed. Try putting various objects in front of the camera – including yourself. Record your experiments and observations, using words, saved images, or both.

In order to analyze your data, you will want to evaluate the response of the array to zero incident radiation. This is like a "bias" or reference frame, but in this case really a combination of bias, dark current, and thermal background signal. It turns out that finding a source of zero radiation is not easy in the thermal infrared. Think about the problem at hand for a moment.

One possible source of zero infrared energy would be a 100% reflectivity mirror, to force the camera to "look" at its cold interior. Real mirrors are not that efficient, however. Using what you can find, which is probably a mirror with a roughly uniform 97% reflectivity at room temperature, compute its effective temperature over the wavelength range the camera is sensitive. (That is, what temperature would a blackbody need to be to have the same power received by the detector?) There is a mirror/lens labeled "Ge" around, which may be of some interest.

One good source for a low background emitter is probably the cold side of the lid from the dewar, if it has been filled for a while, or the fill funnel. Experiment.

Also explore the VGA2USB software application and learn how to save an image. Files are stored in .bmp or .jpg format. From the msdos command prompt window, these files can be converted to .fits using Imagemagick's `convert XX.bmp YY.fits` command. You can then run ds9 to display images on the PC. Check that the background level in a captured image is small and not negative. Adjust the offset if necessary. Would it make sense to take an average of several images?

Take your pick of observatory coffee mugs and walk around to the front hallway of the Cahill lab floor to the kitchen area. Fill a coffee cup with water at roughly $\sim 30°C$. In another coffee cup, use the microwave to heat the water. Go back to the lab, find the thermometer for calibration purposes, and take some images. You might want to image the cups up close but with the focus set to infinity (this tends to blur out detailed structure and give you a local average, which is what we want here). Take a frame or two of each source. Repeat this process for many different water temperatures, as the heated cup cools, or as you warm up the room temperature cup. You may have to experiment with an appropriate temperature and distance from the camera in order to not saturate the detector. Also, a quick Planck function calculation or estimation might save you some time. At the hot end the detector may have been saturated. What happens if you slide e.g. a sheet of Plexiglas between the camera and the coffee cup?

Part A Analysis

Use your knowledge of IRAF to analyze images under Unix. Copy them over to your own astro or the ay105user astro account using SSH Secure File Transfer.

Using IRAF subtract the reference frame from each of the data frames. (It is a good idea to keep a copy of your raw images, in case you make a mistake.)

We may be getting tired of this by now, *but*: Estimate the mean and standard deviation for a $\sim 10 \times 10$ camera-pixel analysis box; try to make many measurements over various regions, avoiding those with bad pixels. Get at least 10 of these, in areas with different mean levels, and plot the mean vs. the variance. Compute the gain (in photoelectrons per digital number)! Is the camera limited by photon (shot) noise?

How does the signal change as a function of temperature? Does this correspond with what you predict? As always, pay attention to errors.

Part B Configuation Using knowledge of the lab equipment from previous experiments, make yourself a spectrograph for infrared light. Use as a radiation source the hot wire/lamp. You can set up as in the optical spectroscopy lab a collimating mirror and a grating leading into the infrared camera but the configuration need not be that complex. You might want the collimator on a translational stage and you will definitely want to set the grating on top of a rotational stage so that you can make some accurate angle measurements. What do you notice when the grating is directly facing the camera ($\beta = 0$)?

Part B Measurements

Find the zero-order image and first-order spectrum of the wire lamp. Note that you may be able to see, with your eye, some optical light shining to the side of the camera lens, with the (of course not visible) infrared spectrum entering at the center. You may need to put the Plexiglas at various positions (and/or walk around) to block stray infrared light emitted by hot sources from entering the camera. Also remember from Part A that there are lots of sources of infrared radiation in the room, including your lab partners.

Investigate the configuration and the spectrum of the wire lamp you see. Record the zero-angle of the grating (at which the camera sees its own reflection), the angle at which the zero order (reflection) appears at the array center, and the angle where the first order spectrum begins.

Part B Analysis

Describe the spectrum qualitatively. What are the measured quantities along the "x" and "y" axes of the image? What are their units in these uncalibrated images? What would they be if we could calibrate them? If you can, make a plot of a cut along the spectral direction. If you have advanced knowledge of IRAF, go ahead and trying "extracting" the two-dimensional spectrum to produce a one-dimensional intensity vs pixel position (wavelength) plot.

Measure the position angles of any absorption lines (or sets of lines) you see, and also the point where the spectrum cuts off. This provides you with a chance to check the reported specifications of the camera against the detected spectrum. Identify any absorption lines you can see with those expected from the atmospheric spectrum.