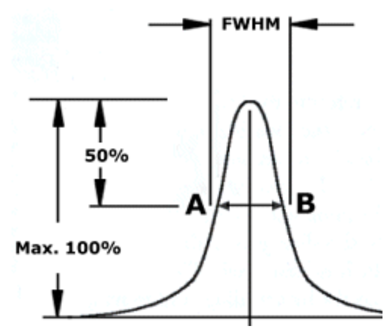
Week #10 – Emitters & Detectors

You can use photos instead of diagrams/or drawings in your lab report where ever it is appropriate and where they can be properly labeled/understood. You will again need to use the spectrometer. Like last week, be sure to store dark spectrum 1st, which removes background noise and light. You will need to turn the lights out for any experiment where room light will show up on the spectrometer (don't rely on storing the dark spectrum alone, eliminate as much stray light as possible).

YOU NEED TO RECORD ALL EXPERIMENTAL DETAILS, INCLUDING THE SPECTROMETER SETTINGS ALSO!

1. Types of Light Emitters **–** Goal: explore several types of light emission. Procedure:

(1) Setup the spectrometer, with the fiber input to the spectrometer held by an LCA. Record all spectrums from 400 nm to 700 nm. Make sure the integration time is set high enough to get a strong signal, but low enough that it does not amplify noise or saturate the spectrometer (if the peak of the recorded spectrum looks like a flat line and goes beyond the measurement scale, then you are saturating the detector inside the spectrometer).

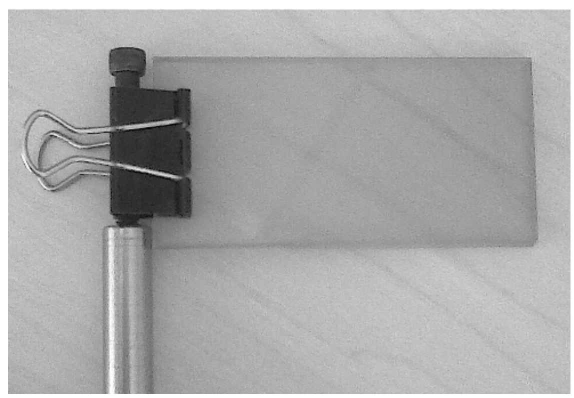


(2) Place the red pen-lamp (LED) in a second LCA, and mount the LCA at a distance of several inches where the signal is strong but does not saturate the spectrometer. Screw down the pen-lamp switch until the LED is on even without pushing the button (so you don't have to hold it on). Using the spectrometer, record the spectrum of the LED. Calculate the width of the spectrum at half of the maximum intensity (in units of nm, referred to as full-width at half-maximum or FWHM, see diagram at right).

(3) Now, measure the spectrum of the HeNe laser in the lab (shine the laser on a white card just point the spectrometer fiber toward the laser reflection off the white card). Try to calculate FWHM again (it may be difficult!). Comment on the FWHM for lasers vs. LEDs.

(4) Use what you have just observed about FWHM to explain why for the highest-speed fiber communications we prefer laser light instead of LED light (also, lasers are all in phase which allows creation of binary 1's and 0's by interference).

(5) Now, measure the spectrum of the large pink lamps we use in the lab or the white pen-lamp (LED + yellow phosphor). The blue portion of the spectrum should be similar to a LED. Next, look at the datasheets for the Xicato Artist Series LED Module (provided with the online lab documents this week). Comment on why inexpensive white LEDs (like this pen-lamp) are not used in art museums.



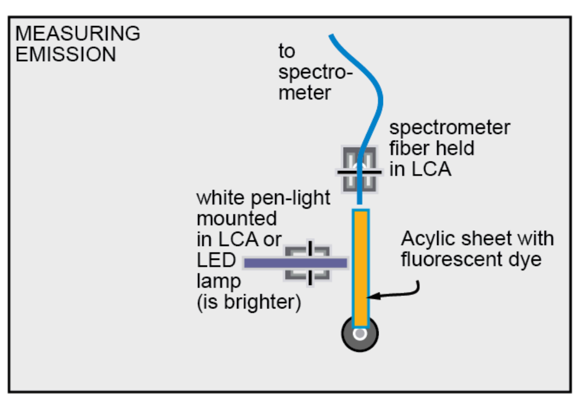
(6) Lastly, measure the spectrum of the ceiling lights in the room (many UV and visible Hg plasma peaks + many phosphors).

(7) Place all these plots in your lab report and comment on them. The plots should be plotted from 400-700 nm for easy comparison.

2. Fluorescence Emission vs. Absorption **–** Goal: experimentally explore how fluorescent dyes and phosphors work, and calculate absorption curves.

Note: OLED displays are light emitting polymers. They are similar to the fluorescent acrylic, except that they are also semiconducting (acrylic is electrically insulating).

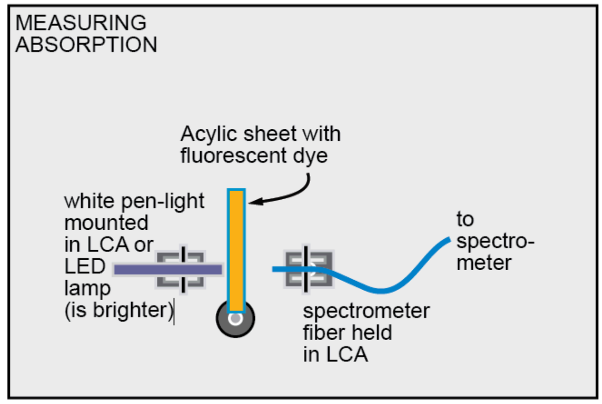
(1) Measure emission! Obtain the smooth red and green acrylic sheets that contain fluorescent dyes. Store the dark reading in the spectrometer, then turn on the UV flash lights or the white PEN light or lamp light as shown in the diagram at right and measure the emission spectrum using the spectrometer in 'intensity mode'. Measure each of the 2 colors this way, recording data from 400 nm to 700 nm. The acrylic can be mounted as shown at right using a binder clip from the blue bins, and a post with a long screw on top of it.



(2) Measure absorption!

You will need to choose which light sources (white LEDs, the halogen lamps, etc.) will give you satisfactory results. It is expected that a much better source might be the high quality light sources on our equipment shelves (LS-1, LS-2, we have two of them), which connect to the blue optical fiber for their output. You can adjust their output intensity using the bronze knob. These light sources are more stable and have a broader emission spectrum, and therefore are preferred over the white LEDs.

In this experiment, you will notice that there is a strong absorption peak that is several 10's of nm BELOW the emission peak you measured in part 1. This is how all fluorescent and phosphor materials work. They absorb a higher energy photon, and re-emit it as a lower energy photon. Using the steps listed below, record absorbance from 400 nm to 700 nm.



- Store the dark reading with the white light OFF.
- Store the reference reading with the white light ON and with a glass slide in front of the white light (not the acrylic sheet). Comment on why we must at least put a glass slide for a reference reading instead of no slide at all (air). Hint, glass has similar refractive index as the acrylic does.
- Now use the spectrometer in absorbance mode to measure the absorbance for the red and green acrylic sheets.

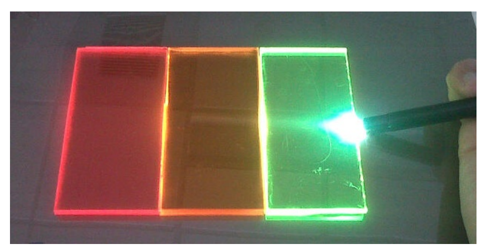
The spectrometer can directly give absorbance, or you can collect the raw data and calculate it using:

$A = -\log[(S_\lambda - D_\lambda) / (R_\lambda - D_\lambda)]$.

S_λ = Sample intensity at wavelength λ
D_λ = Dark intensity at wavelength λ
R_λ = Reference intensity at wavelength λ

(3) Calculate the approximate % energy lost in the energy conversion from the peak absorption peak to the peak emission peak (hint, this is just a Stokes shift calculation). Regarding white light sources, comment on why CCFLs, which use 200-400 nm UV light to excite phosphors, could never even in theory be as energy efficient as using a blue LED with a yellow phosphor.

(4) Stokes shift in action! Obtain the red, amber, and green smooth fluorescent sheets, lay them down side-by-side in the order you see in the photo shown at right (red/amber/green). Excite them with the white LED or white lamp coupled to the edge on the green side, and then on the red side (taking a photo each time). You should see the effects of both stokes shift and absorption in action. Explain why the two experiments give dramatically different results.



3. A Big Challenge for Light Emitters – Light Out-coupling – Goal: quickly explore the issue of light-outcoupling from light emitters. This issue effects LEDs for lighting, and also displays such as OLEDs.

(1) Obtain a smooth green fluorescent sheet, and a roughened green fluorescent sheet.

(2) Do a theoretical calculation, based on surface-areas of the smooth sheet (measure it with the ruler) of how much higher the irradiance (W/m^2) coming out the edges of the sheet should be vs. the irradiance coming out from the larger faces. This is a simple calculation. Explain your answer (which also explains why the edges of the sheet seem appear brighter and seem to glow). Provide a photograph that demonstrates brighter edges than the faces of the sheet.

(3) Calculate theoretically what % of light should escape any surface for the smooth sample, assuming acrylic has a refractive index of 1.5. See this lecture and the previous weeks lecture for the formulas that you need.

(4) Now, perform the same observation done for part (2) on the rough sheet (brightness of edges vs. larger faces), and explain the why the results are so different.

4. Setup Dismantle and Storage **–** Proper care of optical components is just as important to achieving reliable results as is careful experimental setup. Improper handling, setup, dismantling, and storage will detract from your final grade in this course. Unsure about any component? Just ask. The next group should find all parts neatly stored in the optics kit. There is a card with each kit that shows where each component goes.

5. Theory/Calculation Problems (Organic light emitting panels and organic light collecting panels) **–** Goal – improve understanding on how organic (polymer) materials are used for light emission in displays, and how they could be used for solar power collection.

(1) **OLED displays suffer from poor light out-coupling**. You cannot simply roughen the surface to improve out-coupling, because it will cause the display to look poor in bright lighting (especially in sunlight, why? Please answer this.). Find online ONE technique to improve light out-coupling in OLEDs, place in your lab report an image of how it works, and briefly explain how it works.

(2) In the early days of solar panels (photovoltaics) the silicon solar cells were VERY expensive. They were so expensive, that some products used large **red fluorescent acrylic sheet, and placed an array of small silicon solar cells at the edge of the sheet**. Questions: (a) how does this work and what is the benefit? (b) in terms of energy conversion loss, how much does this fluorescent sheet approach compare to a large sheet of silicon solar cells that receive sunlight directly (no fluorescent sheet)? Do some simple calculations to support your answer. If you understand how responsivity changes with wavelength for both approaches, then this is easy to answer.

(3) Calculate maximum possible optical efficiency in the visible spectrum assuming simple TIR and zero loss for **Cascade solar detector technology** (see the extra files folder, and file "Cascade Photovoltaic.pdf"). Just calculate the optical power efficiency at getting light to the photovoltatic cells (the solar cells have their own inefficiency, but again, only calculate the efficiency loss before the light gets to the detectors). This is a simple calculation based on looking at Fig. 5 and the data in Fig. 3, and looking at energy conversion. *You may ignore light outcoupling issues, (assume they optically 'glue' all the pieces together and that all the light is internally waveguided, which obviously is not the real case).*