**Experiment #3: Building a “Ghetto-Fabulous” Dye Laser**

*Thanks to Chris Reynolds for the title of this lab.*

**Objectives:**

1. Use the 1D “particle-in-a-box” model to find a length for the fluorescent dye molecule using both the UV-Vis absorption and the fluorescent emission of the molecule.

2. Investigate the properties and functioning of a dye laser, including what is required for lasing to occur and how the fluorescent properties of the dye used determine the output of the laser.

**Background:**

In this lab you will first characterize fluorescein, a common fluorescent dye, and then attempt to create a dye laser from fluorescein.

Lasers are commonly used in many instances for physical chemistry and in science generally. In order for lasers to produce the high-intensity, collimated light for which they are known (or in other words, in order for lasers to lase) a number of conditions must be met.

A laser is constructed as illustrated below, with a resonating cavity (rectangular box) filled with a material having a high and a low energy state (short lines on top and bottom of box). A pump of some type (very commonly a bright light or a laser, but electrical energy can also be used as a pump in certain types of laser) excites the electrons in the resonating cavity into the high energy state. Lasing occurs when a photon with the same energy as the energy gap between the high and low energy states travels down the length of the resonating cavity as shown in panel A. If the photon encounters an electron in the excited state, stimulated emission occurs (panel B) and the emitted photon has the same phase and propagation direction as the stimulating photon. On the other hand, if the photon encounters an electron in the ground state it can be absorbed, resulting in a decrease in the number of photons (and thus the intensity of the laser). Because of this, it is crucial that the number of electrons in the excited state be maximized while the number of electrons in the ground state be minimized.



A few things can be done to ensure this takes place. First of all, the pump must be relatively powerful. Indeed, for many lasers (particularly dye lasers) the pump is another laser. Second, the excited state lifetime should be relatively long. The longer the lifetime of the excited state, the more time the excited state can sit before it relaxes by means of spontaneous emission or vibrational/collisional relaxation (in which the energy of the excited state is transferred to another molecule and eventually to heat). The longer the excited state sits, the better chance is has of still being in the excited state when a photon reaches it and is able to cause stimulated emission. Finally, if the energy of the absorption and the emission are different, then photons released via stimulated emission are less likely to be absorbed by neighboring molecules in the ground state and thus the laser intensity is less reduced. Fluorescent molecules provide an easy mechanism for this last condition to occur, as a vibrational relaxation occurs after an electron is excited, ensuring that the energy emitted is different than the energy absorbed. They also typically have relatively long excited state lifetimes (nsecond lifetimes are typical).

The material in the resonating cavity differs between lasers – many use solid crystals (solid-state lasers such as ruby lasers and Nd-YAG lasers), some use gases (He-Ne lasers, with a mix of helium and neon, and Ar lasers) and some use fluorescent dye solutions like the laser you will make. Dye lasers often include wavelength selectors to allow the user to choose specific wavelengths to be amplified. Such lasers are highly useful as they can excite specific transitions with exactly matched energy at high intensities. Your laser, in keeping with the “ghetto-fabulous” theme, will not include an ability to select wavelengths (and because it is kind of expensive and I didn’t want to make you pay for it via lab fees). Finally, most resonating cavities are on both ends with mirrors to bounce light through the resonating cavity multiple times and maximize laser power. One mirror is made partially reflective and partially transmissive (that is, it allow a fraction of the light through and bounces a part of the light off); the laser beam emanates from this mirror.

**Procedure:**

1. Make 10 mL of fluorescein solution with a concentration of ~1 x 10-4 M using methanol as the solvent.

2. Measure the absorbance of the fluorescein solution using the UV-Vis. (Use a methanol blank, don’t forget to log in!)

3. Measure the fluorescence of the fluorescein solution using the spectrofluorimeter. Run an emission scan with the excitation set at 400 nm and the emission scanning from 420 to 600 nm. (Log in!)

4. Now move to the research chemistry lab (SCA 205). Choose a resonating cavity (you have lengths of 10 cm, 16 cm, and 22 cm to choose from, unless someone else broke one before you) and fill the cavity with your fluorescein solution. Cap both ends with PDMS plugs to prevent the dye from leaking out.

5. Choose a light source and excite your laser with the light source. It might help to place mirrors below the resonating cavity to increase the intensity of the light reaching your laser. Point one end of the resonating cavity into the Ocean Optics spectrophotometer and record the spectrum using the SpectaSuite software. (Click on the “save” icon, check before recording that the cap for the light inlet has been removed.) You may need to adjust the cavity carefully before it feeds into the spectrophotometer well. You may also want to record a “blank” spectrum with the pump light(s) running but without having the resonating cavity pointing toward the light inlet. Check to see if you have induced lasing by placing your hand a few inched from one end of the resonating cavity. If you can see a green spot on your hand, you have induced lasing.

6. Now use all of the lights available to you at the same time to pump your laser. Record a spectrum and again check for lasing. If the spectrophotometer maxes out, decrease your exposure time or place a partial mirror between your resonating cavity and the spectrophotometer inlet to allow the spectrum to be recorded. You may want to try a few alternate setups, with different pump light arrangements and with mirrors on one or both sides. (You might want to take a picture of your best setup.) Record your best spectrum.

7. Shut off everything correctly and return the ocean optics spectrophotometer and the laser equipment. Dispose of your fluorescein solution in the waste beaker.

**Report:**

1. Plot all experimental data (Abs, fluorescence, and spectrophotometer intensity) vs wavelength. Normalize the data and plot them on a single chart so that they can be easily compared to one another.

2. Using the particle-in-a-box model, calculate the size of the fluorescein “box” from both your UV-Vis data and your fluorescence data. (I want to see two numbers – one from fluorescence and one from UV-Vis data.) How do your numbers compare to literature values about the size of fluorescein? Be sure to include the structure of fluorescein in your lab report. What assumptions have you made in this calculation? How valid are those assumptions?

3. Compare the fluorescence output measured by the fluorimeter to that measured by the Ocean Optics spectrophotometer. Discuss any differences and their origin in your lab report.

4. What is the origin of the “blank” signal seen in the spectrophotometer?

5. What setup worked the best for you and why? You may include a picture if the picture is helpful.