Experiment 4: Fluorescent Light

Apparatus: Ultraviolet lamps, fluorescent dyes, color filters, pc spectrometer

In this experiment you will use ultraviolet light to produce fluorescent light and you will study the relationship between the two. The ultraviolet lamps can be dangerous and their invisible radiations should never be directed at the unprotected eyes, although ordinary vision-correcting glasses provide a good shield. The UV lamps in use in this lab emit a faint visible blue light when on.

Procedure:
A. Fix the position of the beaker and the UV lamp. The lamp’s radiation should point away from the room toward the wall. Take the following spectra:
   1. UV radiations alone (without the beaker in place).
   2. UV radiation directly transmitted through the empty beaker.
   3. UV radiation directly transmitted through the beaker when it is filled with water.

B. Next, fill the beaker with the liquid dye and place it in position to receive the UV radiation. For each color of dye take the following spectra:
   1. UV radiation directly transmitted through the dye-containing beaker
   2. Visible radiation at 90° to the UV beam.

C. For various color filters study how the fluorescent intensity varies when:
   1. The filter is placed in the path of the UV beam between the beaker and the lamp
   2. The filter is placed between the eye and the illuminated beaker or between the fiber-probe and the illuminated beaker.

Comment on what you think is the source of the fluorescent light.
Fluorescence
Hot objects that emit light because of their high temperature are said to be *incandescent*. All other emitting sources are called *luminescent*. There are many types of luminescence:
- *Electroluminescence* describes the light emitted by a diffuse gas in a discharge tube when an electric current runs through the gas. An electroluminescent bulb is popularly called fluorescent, but we will reserve that term for another use.
- *Radioluminescence* describes the light emitted when radioactive decay products strike a phosphor as in a radium-containing watch dial.
- Various chemical reactions can produce light called *chemiluminescence*, as in the glow-sticks used as party favors. When these reactions occur in living creatures (glow-worms, fire flies, etc.) they are called *bioluminescence*.

There are many other sorts of luminescence. The most important for understanding laser operation is *fluorescence*:
- Fluorescence (as we will use the word) is another name for photoluminescence. It describes the light emitted by an object (a diffuse gas, a liquid solution, or a solid) when the object is illuminated with light from an external source. Fluorescence is distinguished from mere reflection in that it does not occur at a surface but throughout the body of the illuminated object and the spectrum of fluorescent light is often very different from that of the illuminating light.

A typical fluorescence experiment is shown below. Light (often from an ultraviolet source) illuminates a sample. This is called the primary light. This causes the sample to glow and the spectrum of the glow is measured, usually at right angles to the primary beam. The sample will normally glow brightest at the edge where it first meets the primary light. These glows are best studied in an otherwise dim room and are often very beautiful.

![Fluorescence Experiment Diagram](image)

Experiment shows that (except under unusual conditions) the fluorescent light always has a longer wavelength than the primary light. This is called Stokes’s law. This was one of the first facts to be learned about fluorescent light and was first put forward in the mid nineteenth century by George Gabriel Stokes, an English physicist who studied fluorescent phenomena using sunlight and multiple prisms to produce beams of selected wavelengths. It is a testament to Stokes’s skill that this work was done in the days before electric light bulbs and was carried out in England, a country not known for either the quality or quantity of its natural sunlight.
Stokes’s law has a natural explanation in terms of the atomic properties of matter. Consider an atom that has absorbed some light and been excited to a higher energy state. Call the energy of the ground and excited states $E_0$ and $E_1$ respectively. The atom can de-excite back to its ground state, producing light whose frequency is given by $f = (E_1 - E_0) / h$. The excited atom might also de-excite to some state whose energy lies intermediate between $E_0$ and $E_1$, such as the state of energy $E_2$ illustrated in the figure. In this case the atom will radiate light at a frequency $f' = (E_1 - E_2) / h$. Since $E_2 > E_0$ we have $f' < f$, and since $\lambda f = c$ it must be true that $\lambda' > \lambda$. Stokes’s law gives us a physical picture of fluorescence: an atom is first excited by the primary light and then de-excites to an intermediate state. There may even be several intermediate states as the atom progressively loses energy. Each time the atom changes state it radiates and this radiation must be less energetic (longer wavelength) than the primary radiation.

Question: Can you think of a way to modify the standard fluorescence experiment so that the wavelength of the fluorescent light might be shorter than that of the primary light?

Fluorescence is today a diagnostic tool of great utility in analyzing chemical mixtures. Many naturally occurring minerals exhibit fluorescence and every field geologist carries a “black light” (UV lamp) to examine the mineral content of rocks.