Absorption and Photoluminescence of Upconverter and Downconverter with USB Spectrometer

Overview:

Students will explore a number of materials using a USB spectrometer to investigate the nature of absorption and emission of light. Using spectra data, they will also learn about energy transfer from a host lattice to impurities or dopants.

Essential Question:

How to measure the absorption and emission of light?

What confirms energy transfer from one material to another?

How do absorption and emission look different?

What are the differences between conventional photoluminescence and upconversion and downconverson?

Background:

As light particles called photons travel, they hit different materials. During this process, some those traveling photons will get absorbed into the material and some will be reflected, and some will transmit through. A portion of those absorbed photons will be emitted from the material, called emission or photoluminescence. Ultimately, this process is the cause of colors around us, including red/orange sunrise and purple clouds during sunset. Different colors have different wavelengths like you see in figure 1.

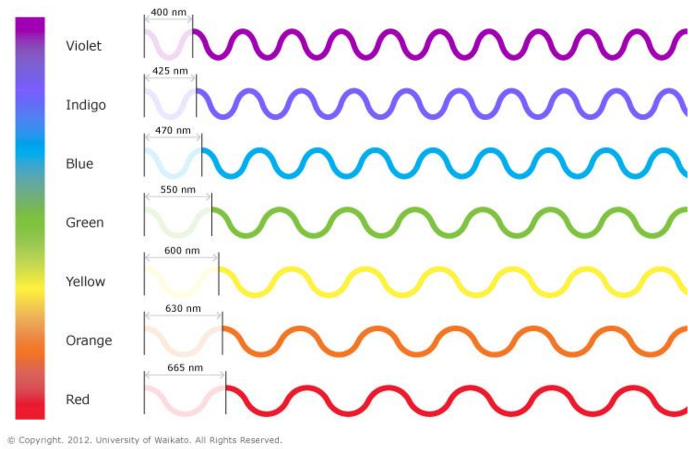

Figure 1 Different wavelengths of visible light

In detail, once photons get absorbed into a material, some of them will be emitted at a longer wavelength. These numbers are the results of absorption and photoluminescence measurements, providing valuable information about the material. You have been using devices such as TVs and phones that utilize photoluminescence.

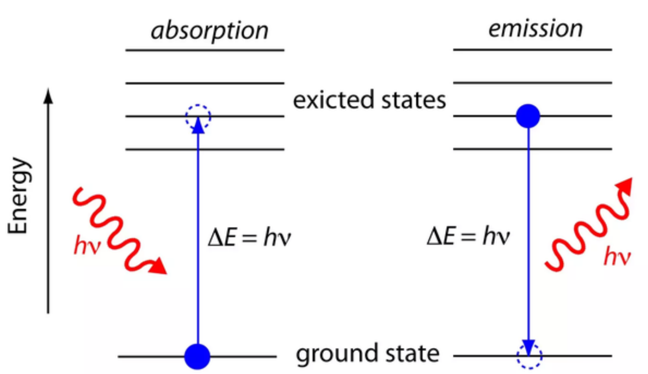

Figure 2 Conventional absorption and emission processes

In order to enhance these devices, scientists have been adding impurities certain materials for decades. These impurities or dopants will add more spectral properties to be harvested for further applications. You can also see the effects of these dopants using absorption and photoluminescence. Unlike conventional emission process like figure 2, doped materials show slightly different emission process. Once the photons are absorbed, the energy will be transferred to impurities in the system like in figure 3. Using what we just learned, we will explore various emission processes in this lab.

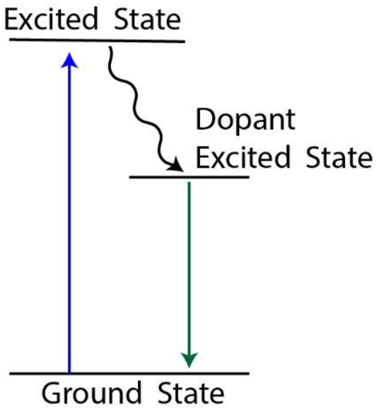

Figure 3 Blue arrow indicates absorption. Green arrow shows emission from the excited state of a dopant, and the black arrow shows energy transfer from the excited state of the host material to the excited state of the dopant.

Research Connection:

For many of CEI fellows and MEMC groups work with spectral data and doped nano materials for solar and display applications. Particularly, perovskites have demonstrated a number of advantages such as high photoluminescence quantum yields, narrow emission bandwidths, broadband absorption, and band gap tunability. Doping this material ytterbium ions have shown significant advantages in solar applications. Through this lesson, students will be able experience aspects involved in developing a device from a research scientist's perspective.

NGSS Standards:

Standard Number	Standard text
MS-PS4-2	Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials
HS-PS4-4	Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter

Materials:

- USB spectrometer
- Tonic water (optional for demo)
- Food coloring
- Rare earth doped upconversion nanoparticles from Sigma Aldrich

Procedure:

1. Make a range of colored solutions using food coloring. Make sure not to make your solutions too concentrated. Record what wavelengths you expect your solutions will be based on your observation.
2. Connect the USB spectrometer to a computer and open the spectrometer software.
3. Measure absorption and photoluminescence of your solutions with food coloring and record their wavelengths.
    a. Where are the absorption and photoluminescence peaks?
    b. How far apart are they?
    c. Do they match your expected wavelengths?
4. Now, construct energy schemes for your solutions with food coloring and discuss with your lab partner.
5. Construct a hypothesis of how upconversion works prior to taking its measurements.
6. Measure absorption and photoluminescence of rare earth doped upconversion nanoparticles and save. Be sure to handle this sample with care.
7. Again construct energy scheme of the upconverter and the upconversion process.
8. Now construct an energy scheme for upconversion and discuss with your lab partner.
9. For your lab report, construct a hypothesis and an energy scheme of how downconversion may work.

Resources:

- http://sciencenetlinks.com/lessons/light-2-the-lighter-side-of-color/.

Sources:

- https://www.sigmaaldrich.com/catalog/product/aldrich/900544?lang=en&region=US
- https://www.pasco.com/prodCatalog/PS/PS-2600_wireless-spectrometer/index.cfm