Plasmonically enhanced photobrightening using quantum dots

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ABSTRACT
This study explores optical characteristics in quantum dots. CdSe quantum dots samples have been prepared and an optical photoluminescence experimental setup has been created to measure the light emission from the quantum dots as a function of time and laser intensity. Initial baseline measurements and photoluminescence spectrum have been measured. This preliminary work sets up future studies of quantum dot photobrightening, which is when the emitted light from a CdSe quantum dots gradually increases with time while under constant laser illumination. Future work will investigate photobrightening as a function of laser intensity and with the presence of plasmonic nanoparticles to give insight into plasmonic enhancement and light interaction between plasmonic particles, quantum dots, and photobrightening effects. Results of this study can add value to future quantum dot technologies.

1. INTRODUCTION
Quantum dots have shown a variety of applications, and are being used in medical imaging1, sensors2, solar technology3, and tv displays4. By studying the behavior of quantum dots, we can improve these technologies. In this study, we focus on quantum dots and their behavior in regard to emitting light. We focus on the wavelength and intensity of the emitted light. Quantum dots emit a different wavelength of light based on their size, shape, and composition5. By exciting a sample of quantum dots with a laser, we can measure the emission spectrum and determine the wavelength of emitted light for our sample of quantum dots.

2. METHODS

2.1 Quantum Dots
The quantum dots used in this study are semiconductor nanostructures that are only a few nanometers in diameter, with a three-nanometer cadmium selenide sphere core, and a two-nanometer cadmium sulfide outer shell6. When these structures are excited by incoming energy, an electron is excited into a higher energy level. When that electron returns to its original state, the quantum dot emits light. When a quantum dot is subject to constant excitation energy, the emitted light gradually increases over time, a behavior of quantum dots known as photobrightening7. The emission spectrum of quantum dots is known to be highly tunable based on size, material, and structure of the quantum dots5. The quantum dots are suspended in hexane and stored in a dark environment to prevent unwanted excitation. This is important to ensure that the initial intensity of the quantum dots remains constant, and to improve their lifetime. The quantum dots are then sonicated in a heated bath to distribute the particles evenly across the solution and deposited on a silicon substrate. The sample is left to dry before testing.
2.2 Set up

The optical setup for the experiment is shown in Figure 2. The excitation light is a 532 nm laser passes through a laser line filter to restrict the light to a single wavelength, then polarized via a linear polarizer. The laser gets focused onto the 50x objective, causing the light to diverge in the objective, making the area of the beam spot about $1.07 \times 10^{-5}$ cm$^2$. When the light hits the sample, it emits light, which passes back through the objective toward the spectrometer. The dichroic beam splitter and long pass filter work to remove excitation light, and the tube lens focuses the emitted light onto the spectrometer. The spectrometer measured the emission spectrum of the quantum dots. Full details for this experimental setup can be found in Ref. [6].

3. PRELIMINARY RESULTS

The setup described above allowed us to measure the emission spectra of a sample of quantum dots. Figure 3 shows the emission spectrum measured by the spectrometer as a small region of quantum dots is exposed to a laser. The photoluminescence peak is around 627 nm.
4. CONCLUSION AND FUTURE WORK

4.1 Conclusion

In this work, we were able to study the behavior of quantum dots and the light they emit when they are exposed to an excitation laser. Quantum dot technologies are currently relevant and also have more up and coming applications, so gaining insight into their behavior and possible applications is important. The wavelength and intensity of the emitted light is the focus of our studies, and we start by looking at the emission spectrum of our sample of quantum dots.

4.2 Future Work

The next step for this research is investigating photobrightening as a function of laser intensity. This will give us insight into the baseline photobrightening of our quantum dots and confirm the idea that the intensity of the emitted light of the quantum dots increases with increased excitation energy. Following that, we will be focusing on plasmonic enhancement and its effects on our quantum dots. Adding a layer of gold nanoparticles over a layer of quantum dots as seen in Figure 4 can be used to plasmonically enhance the excitation light in a very small area, increasing the excitation energy. By increasing the energy of the excitation light through plasmonic enhancement, the photobrightening of quantum dots should increase.

Figure 3. The photoluminescence emission spectrum of quantum dots emitted light intensity as a function of wavelength. The peak is around 627 nm.

Figure 4. The sample preparation method for testing plasmonic effects on quantum dot photoluminescence. Quantum dots are deposited on a silicon substrate, then the gold nanoparticles are deposited on top of the quantum dots.
5. ACKNOWLEDGEMENTS

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