PROCEEDINGS OF SPIE

SPIEDigitalLibrary.org/conference-proceedings-of-spie

Plasmonically enhanced photobrightening using quantum dots

Magee, Meredith, French, David, Furr, Miles, Herzog, Joseph

Meredith Magee, David French, Miles Furr, Joseph Herzog, "Plasmonically enhanced photobrightening using quantum dots," Proc. SPIE 11462, Plasmonics: Design, Materials, Fabrication, Characterization, and Applications XVIII, 114622B (20 August 2020); doi: 10.1117/12.2568160

SPIE.

Event: SPIE Nanoscience + Engineering, 2020, Online Only

Downloaded From: https://www.spiedigitallibrary.org/conference-proceedings-of-spie on 24 Aug 2020 Terms of Use: https://www.spiedigitallibrary.org/terms-of-use

Plasmonically enhanced photobrightening using quantum dots

Meredith Magee[*a], David French[b], Miles Furr[a], Joseph Herzog[a]
[a]R. B. Annis School of Engineering, University of Indianapolis, Indianapolis, IN 46227, USA;
[b]Department of Physics, University of Arkansas, Fayetteville, AR, 72701, USA

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 has 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 imaging[1], sensors[2], solar technology[3], and tv displays[4]. 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 composition[5]. 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 shell[6]. 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 photobrightening[7]. The emission spectrum of quantum dots is known to be highly tunable based on size, material, and structure of the quantum dots[5]. 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.

[*] mageem@uindy.edu; www.jbherzog.com

Plasmonics: Design, Materials, Fabrication, Characterization, and Applications XVIII,
edited by Din Ping Tsai, Takuo Tanaka, Proc. of SPIE Vol. 11462, 114622B
© 2020 SPIE · CCC code: 0277-786X/20/$21 · doi: 10.1117/12.2568160

Downloaded From: https://www.spiedigitallibrary.org/conference-proceedings-of-spie on 24 Aug 2020
Terms of Use: https://www.spiedigitallibrary.org/terms-of-use

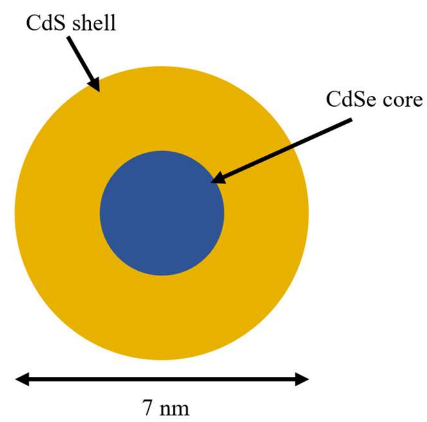

Figure 1. The cross section of a quantum dot. The core is a 3nm Cadmium Selenide sphere, and the outer layer is a 2nm Cadmium Sulfide shell. The overall diameter is approximately 7nm.

2.2 Set up

The optical setup up 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 1.07×10^{-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].

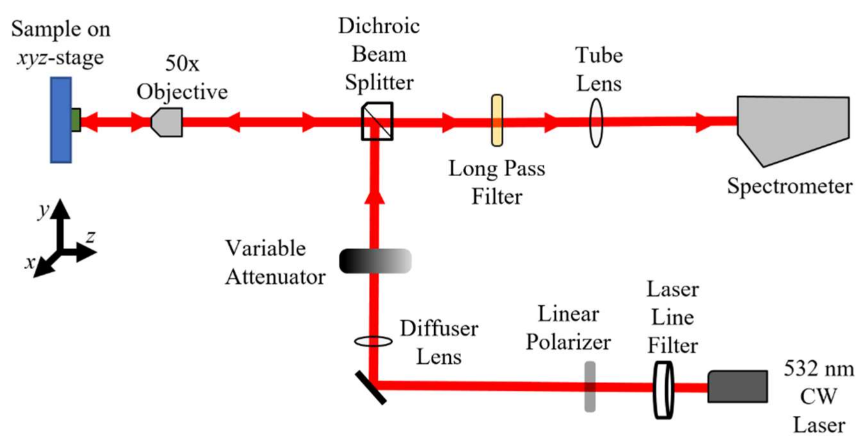

Figure 2. The optical path and setup for testing photoluminescence of our quantum dots in our sample. The excitation light from the 532 nm laser passes through a line filter to restrict the laser to one wavelength; then it is polarized. The diffuser focuses the laser on the back of the objective, which increases the beam spot size on the sample. The variable attenuator is used to adjust laser power. When the excitation light hits the sample, emitted light, as well as some scattered excitation light, goes back through the objective, passing through the dichroic beam splitter and long pass filter, which filter out most of the excitation light. The tube lens focuses the emitted light onto the spectrometer for measuring.

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.

Downloaded From: https://www.spiedigitallibrary.org/conference-proceedings-of-spie on 24 Aug 2020
Terms of Use: https://www.spiedigitallibrary.org/terms-of-use

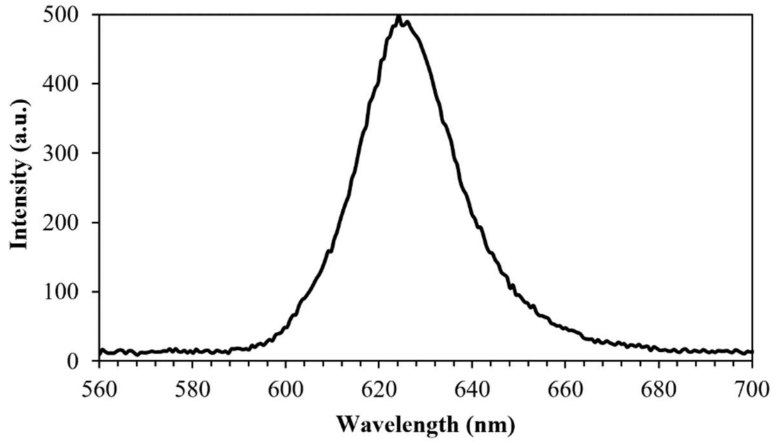

Figure 3. The photoluminescence emission spectrum of quantum dots emitted light intensity as a function of wavelength. The peak is around 627 nm.

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

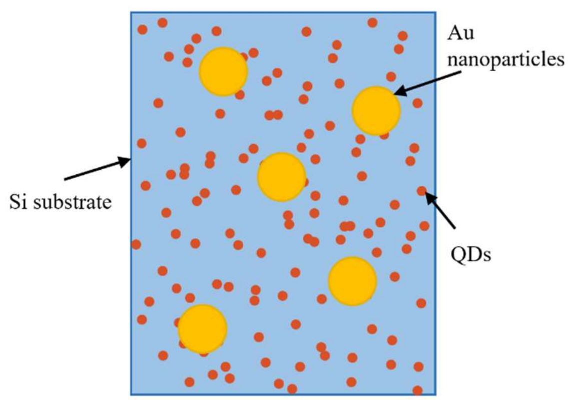

Figure 4. The sample preparation method for testing plasmonic effects on quantum dot photoluminescence. Quantum dots are deposited on a silicon substrate, then the gold nanoparticles are deposited on top of the quantum dots.

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.

Downloaded From: https://www.spiedigitallibrary.org/conference-proceedings-of-spie on 24 Aug 2020
Terms of Use: https://www.spiedigitallibrary.org/terms-of-use

5. ACKNOWLEDGEMENTS

MM, MF, and JBH have been supported by the 2020 Faculty Scholarship Grant through the Office of Grants & Sponsored Programs at the University of Indianapolis. We would also like to thank Lisa Battiato in the R.B. Annis School of Engineering for all of her administrative support. DF and JBH would like to acknowledge funding provided by the University of Arkansas through the Department of Physics, the Fulbright College of Arts and Sciences, and the Office of Research & Innovation.

REFERENCES

[1] Somers, R. C., Bawendi, M. G.., Nocera, D. G., "CdSe nanocrystal based chem-/bio- sensors," Chem. Soc. Rev. 36(4), 579–591 (2007).

[2] Posani, K. T., et al. "Nanoscale quantum dot infrared sensors with photonic crystal cavity." Applied Physics Letters 88.15 (2006).

[3] Abraham, G., French, D. A, Bajwa, P., Heyes, C. D., Herzog, J. B., "Optical Enhancement of Photoluminescence with Colloidal Quantum Dots," Proc. SPIE, 9556 1C, (2015).

[4] Zhang, Min, et al. "Ultrasmooth quantum dot micropatterns by a facile controllable liquid-transfer approach: low-cost fabrication of high-performance QLED." Journal of the American Chemical Society 140.28, 8690-8695 (2018).

[5] Lee, S. F., Osborne, M. A., "Brightening, blinking, bluing and bleaching in the life of a quantum dot: friend or foe?" Eur. J. Chem. Phys. Phys. Chem. 10(13), 2174–2191 (2009).

[6] French, D., "Plasmonic Enhancement of Photoluminescence and Photobrightening in CdSe Quantum Dots," PhD Dissertation. University of Arkansas. (2018).

[7] Jones, M., Nedeljkovic, J., Ellingson, R. J., Nozik, A. J., Rumbles, G., "Photoenhancement of Luminescence in Colloidal CdSe Quantum Dot Solutions," J. Phys. Chem. B, vol. 107, no. 41, (2003).

Downloaded From: https://www.spiedigitallibrary.org/conference-proceedings-of-spie on 24 Aug 2020
Terms of Use: https://www.spiedigitallibrary.org/terms-of-use