Spectroscopy and Polarization Measurements of the Resonant Excitation of Quantum Dots

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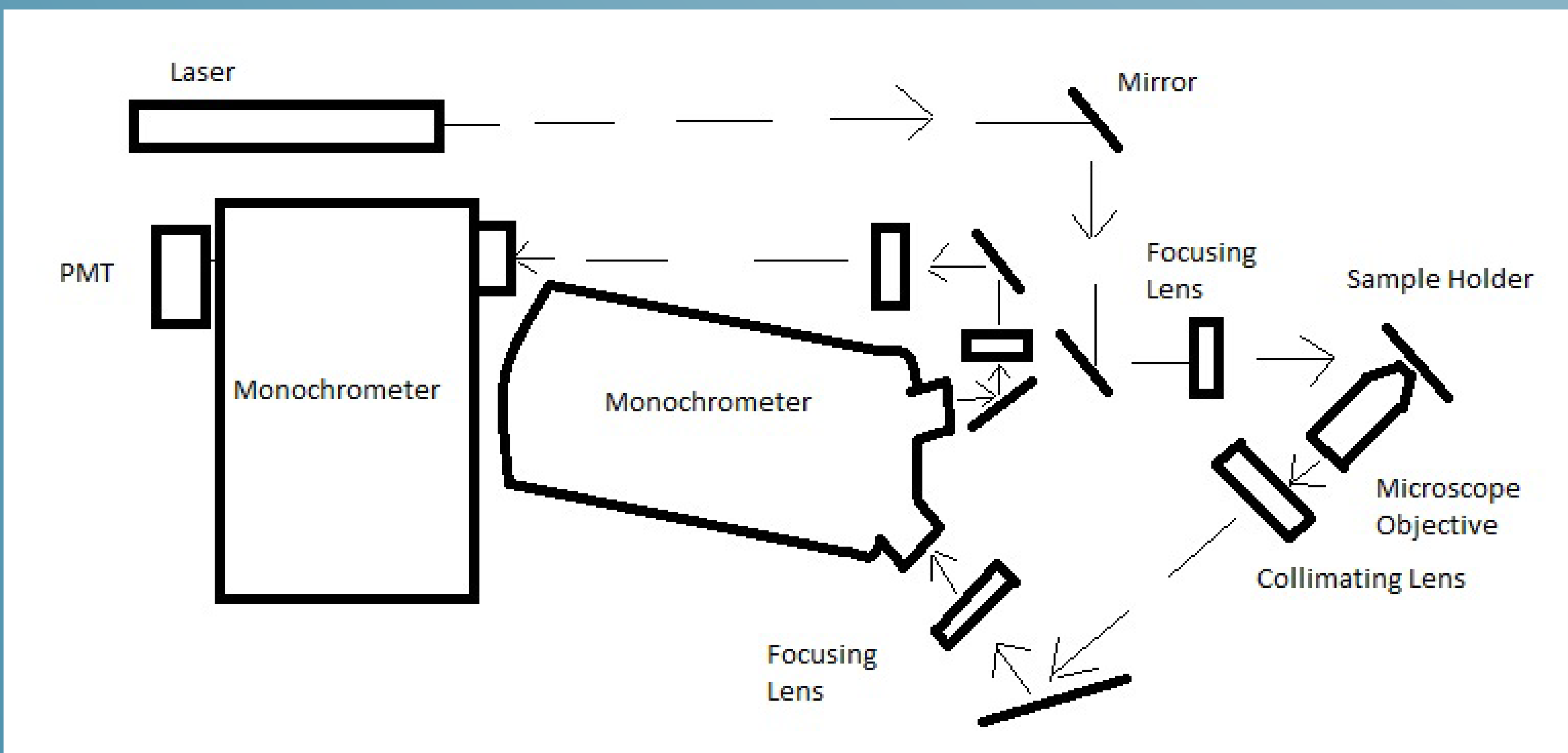
Background

Quantum dots (QDs) are a special type of nanoparticle made of semiconductor materials, which range in size from 2 to 10 nm. QDs are small enough to essentially act as a three dimensional quantum well. When the electron is excited by an incoming photon, it acts like a particle trapped in an infinite potential well. The behavior of QDs can be controlled by changing the size of the QDs. QDs have been unwittingly used for centuries, creating the red color in stained glass windows. QDs have a number of exciting applications in fields from biology through electronics.

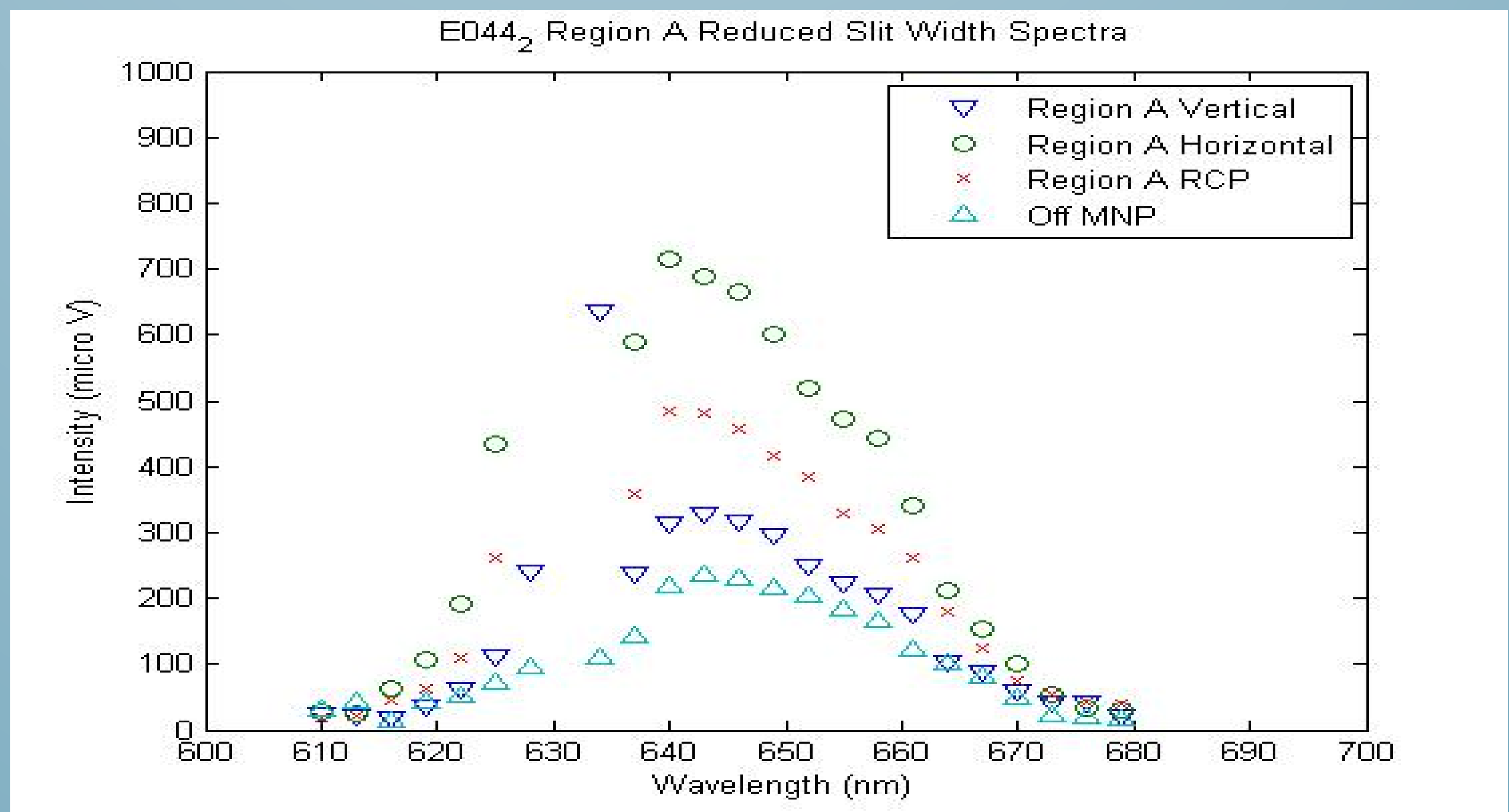
Motivation and Setup

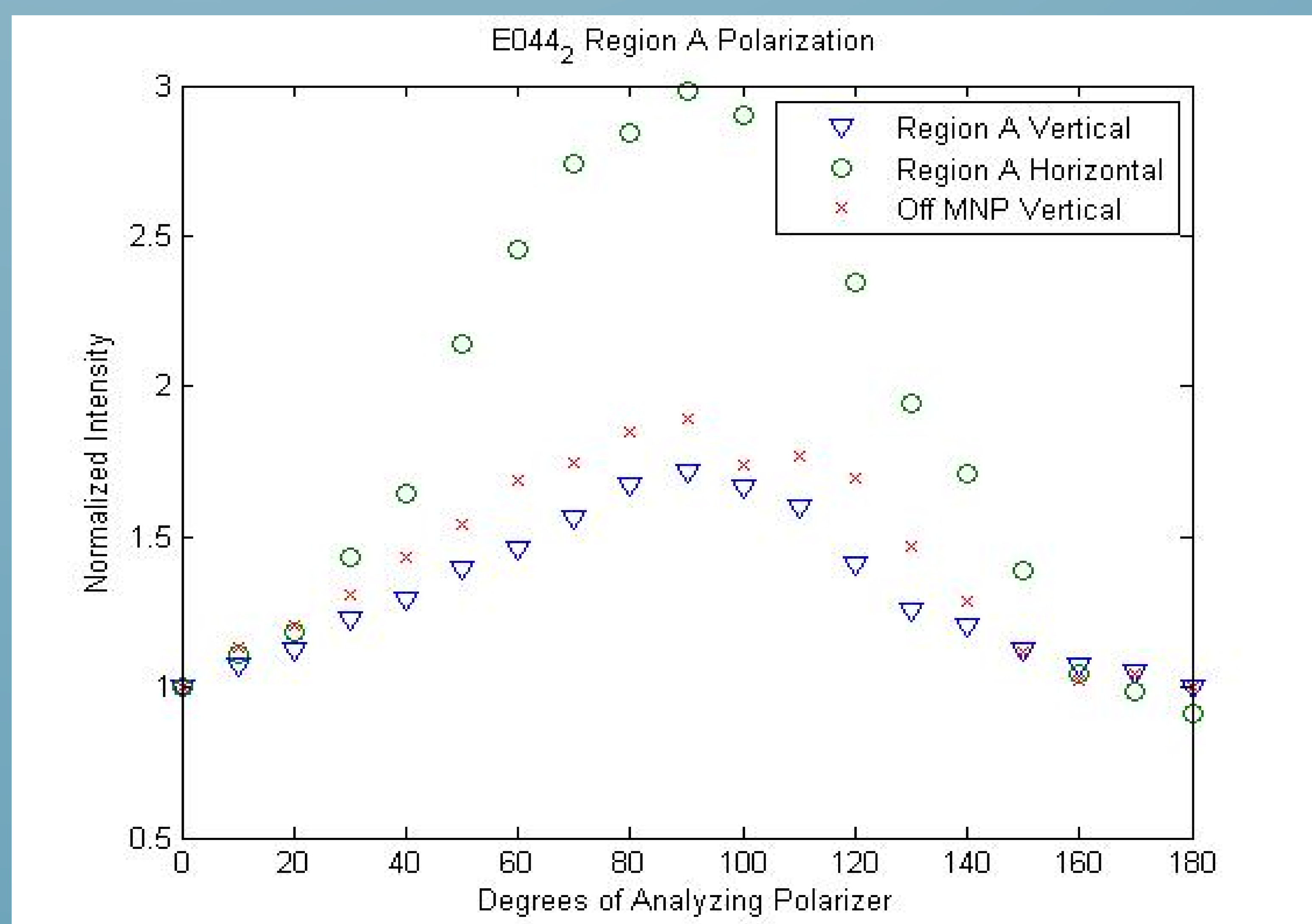
QDs create a sharp spectrum with a peak around 650 nm. Normally, QDs are studied by excitation at a much lower wavelength such as 480 or 514 nm. Exciting the QDs at a source much closer to their peak would potentially create some interesting effects, shedding more light on the exact quantum mechanical make up of the QDs. A resonant setup could not be created using normal methods, however, since the laser light would reflect directly into the spectrometer, ruining it. The double monochrometer setup (pictured below) had to be created to avoid the laser wavelength.



Methods

The QDs were excited using a 633 nm laser in the setup seen below. The scattered light was collected and directed through two monochrometers and into a photo-multiplier tube (PMT). This allowed for sensitive measurements of the scattered light intensity to a specificity of a tenth of a nm. By varying the monochrometers to different wavelengths and recording the PMT's measured intensity (expressed in Volts), a complete spectrum of the QDs could be taken. The light coming from the laser was vertically polarized but could also be varied to be horizontally polarized with a half wave plate. The polarization of the scattered light could be measured by placing a polarizer before the second monochrometer. This analyzing polarizer's angle could then be changed and the resulting recorded intensity measured.





Results

The graphs shown below are typical results presented for one sample in particular. They show the spectrum of the QDs both on and off the metallic nanoparticle (MNP) and with various polarizations of incoming laser light. In general it shows a dramatic enhancement of the emission. This result was consistent across several samples, and is currently being explored in further tests. The sample also shows a significant amount of horizontal polarization no matter the polarization of the incoming light. The horizontal polarization does seem to be pronounced, however, when the incoming light is also polarized.

Conclusion

Resonant Spectroscopy has an interesting effect on the emission of QDs on varying metallic nanoparticle substrates unique from the normally seen emission. In particular, horizontally polarized light seemed to create the greatest enhancement of both the emission and the polarization in the setup shown.

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