Exploring the use of Quantum-Dot Nanocrystals for Particle Detection

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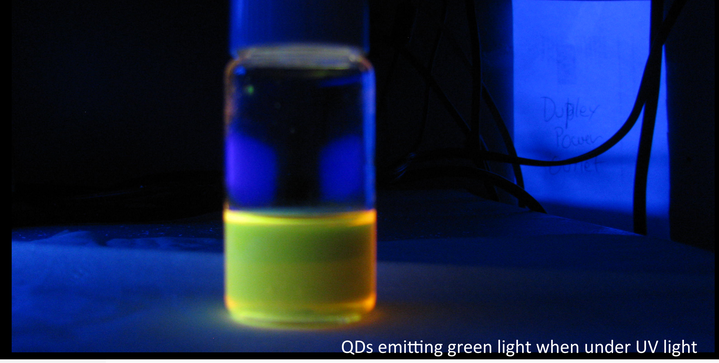
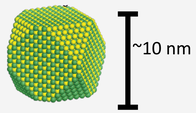


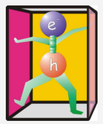
QDs emitting green light when under UV light

What are Quantum-Dot Nanocrystals?

Quantum dot nanocrystals (QDs) are made of ~1-10 nm sized crystals of semi-conductor material.[1,2]



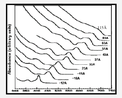
Excitons in the QD are confined in 3D thereby quantizing their center-of-mass motion.[1,2]



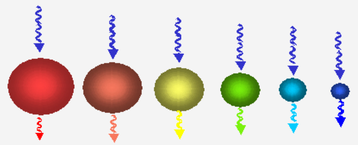
exitons are electron-hole bound states found in semi-conductors.

photon emitted upon electron-hole recombination.

Confinement leads to larger gaps between conductance, valence bands and exciton states. [1]



larger intraband gaps lead to blue shift in absorbance/emission and also more peak structure



Gaps between bands and exiton states depend on the size of the QD, which is controllable during synthesis. Thus, can tune emission spectrum. [1,2,3]

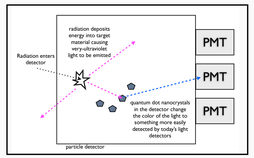
QDs are efficient emitters. Quantum yields of 70-90% have been measured.[4]

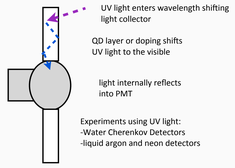
References

[1] L. Brus. *Quantum Crystallites and Nonlinear Optics.* Appl. Phys. A 53, 465-474 (1991)
[2] Nano Reviews 2010, 1:5117
[3] DJ Norris et al. *Size Dependence of Exciton Fine Structure in CdSe Quantum Dots.* Phys. Rev. B 53: 16347-16354 (1996)
[4] I. Mekis et al. *One-Pot Synthesis of Highly Luminescent CdSe/CdS Core-Shell Nanocrystals via Organometallic and "Greener" Chemical Approach.* J Phys. Chem B 107: 7454-7462 (2003)

Potential Particle Physics Applications

One possible application is to use a suspension of QDs as a liquid scintillator.[5]

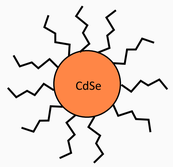




Another is to use a layer of QDs as a wavelength shifting fluor to shift UV to light at peak PMT response

[5] L Winslow and R Simpson. *Characterizing Quantum-dot-doped Liquid Scintillator for Applications to Neutrino Detectors.* JINST 7 (2102)

Our Quantum Dots

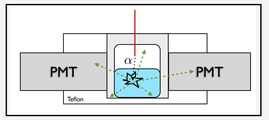


Our QDs were synthesized by students at the North Carolina School of Science and Math (a local high school)

QDs are made of a CdSe core and surrounded by oleic acid surficant. Our solvent is octadecene.

Measuring QD Light Yield in response to radiation

Setup

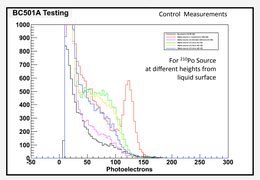


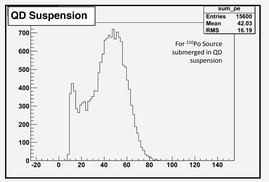
Two pmts face a sample of QDs or scintillator.

PMTs triggered in coincidence to suppress ambient light backgrounds

Preliminary Results

Light yield compared to BC501A, a commonly used organic scintillator.





Light Yield comparable to other scintillators even with unoptimized solution and the use of PMTs with non-optimal peak QE (425 nm)

Scintillator	LY (% anthracene)	Peak Emission
Anthracene	100%	400-450 nm
BC501A	78%	425 nm
NaI(Ti)	230%	415 nm
Our QDs	**29%**	**~550 nm**

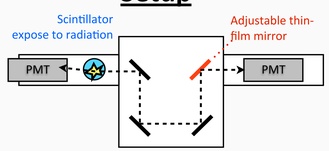
Next Steps

Measure Birks' constant by measuring ratio of light yield for alpha and gamma

Study light yield dependence as a function of concentration.

Measuring QD emission spectra in response to radiation

Setup

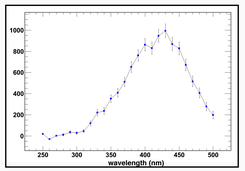


Built spectrometer to measure emission spectra of scintillation light

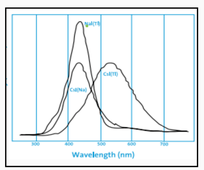
Preliminary Results

So far have measured only control emission spectrum for NaI(Ti) crystal with a ^{57}Co source in order to validate setup.

NaI(Ti) Emission Spectrum (Rates are corrected for PMT QE)



NaI(Ti) Emission Spectrum from Manufacturer



Next Steps

Measure emission spectrum for QDs expose to different types of radiation.