

Towards mapping interactions in hybrid systems with active scanning probes: Probing quantum-confined electrons at room temperature

PI: Jesse Berezovsky with Michael Wolf, Robert Badea, Andrew Blasius
Physics Department, Case Western Reserve University, Cleveland, OH 44106

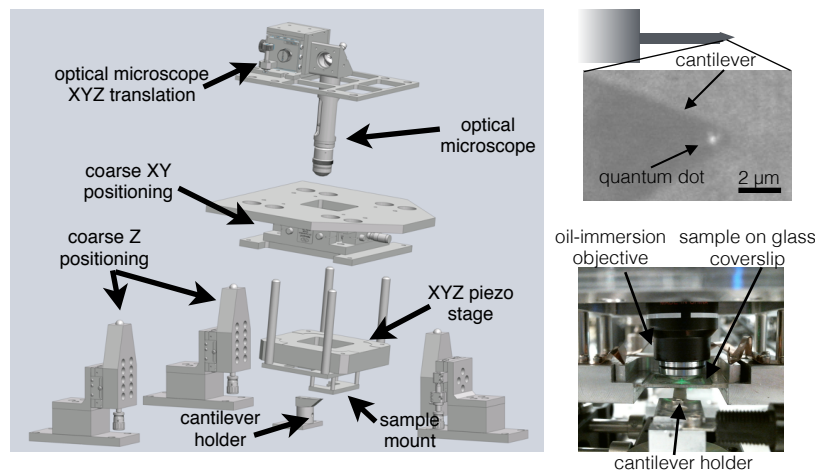


Introduction

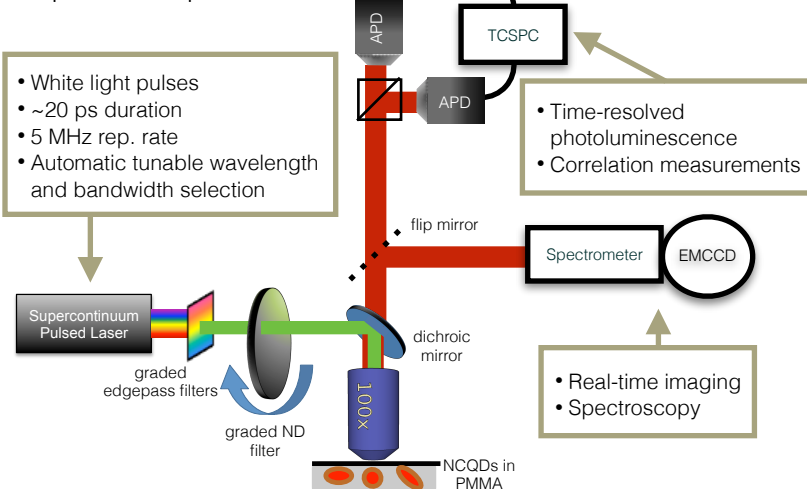
Nanocrystal quantum dots are promising for applications ranging from LEDs, to solar cells, to fluorescent markers. To understand how these structures behave when incorporated into hybrid devices, we aim to study the nanoscale interactions between an individual quantum dot and a device fabricated on a scanned cantilever.

Setup

Combined scanning probe/optical microscope:

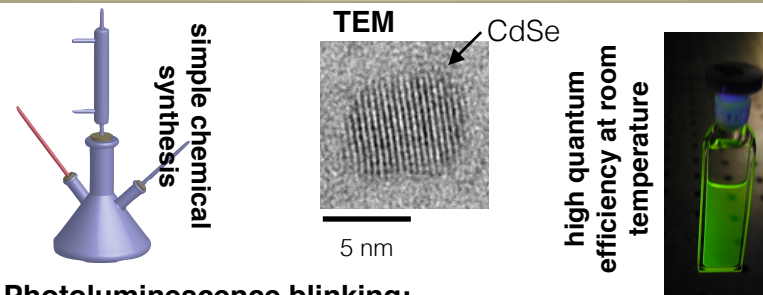


Optical setup:

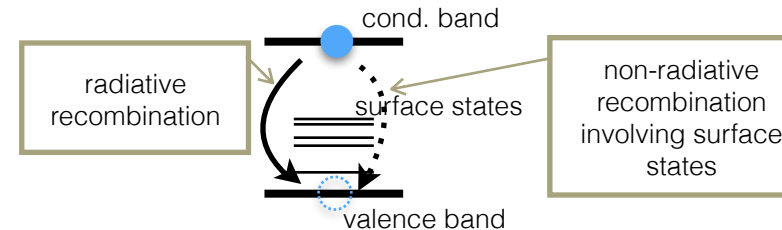


Nanocrystal quantum dots

Platform for engineering electron confinement at room temperature.

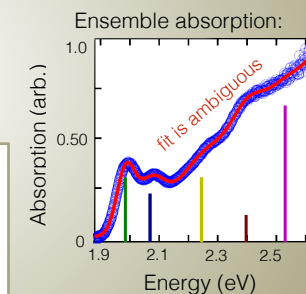


Photoluminescence blinking:

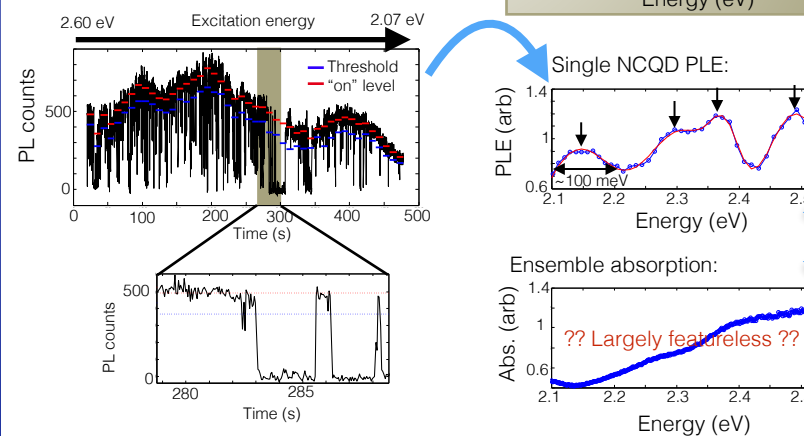


Measuring absorption of a single nanocrystal QD

Discrete optical transitions are obscured by ensemble broadening:



Photoluminescence excitation (PLE) measurement reveals single-QD absorption spectrum:



- Reveals transition energies and room temperature broadening mechanisms.

Wolf, M. & Berezovsky, J., Appl. Phys. Lett. 105, 143105 (2014)

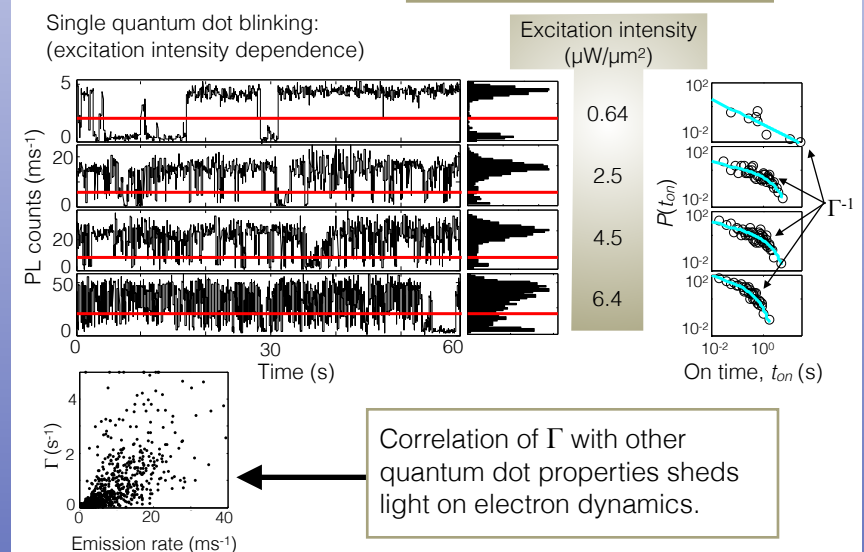
Studying QD physics via blinking statistics

Nanocrystal quantum dot "on" times follow a power-law distribution with an exponential cut-off:

$$P(t_{on}) \propto t_{on}^{-m} \exp(-\Gamma t_{on})$$

"universal" power-law $m=1.5$

Exponential cut-off Γ reveals information about the quantum dot and environment.



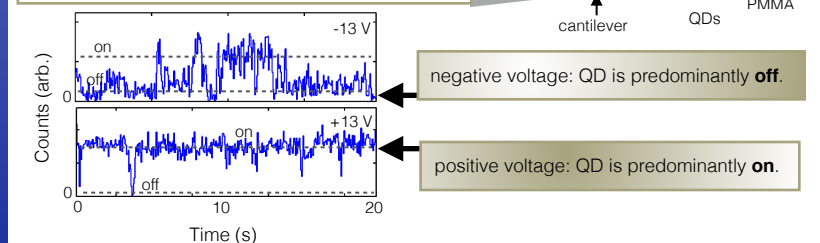
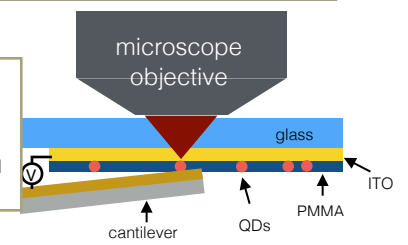
Correlation of Γ with other quantum dot properties sheds light on electron dynamics.

Tuning nanocrystal QDs with a local electric field

First results with combined scanning probe/optical microscopy

Advantages of technique:

- Can measure QDs with and without gate present.
- Tunable air gap included in structure.
- Simple device fabrication.
- Proof-of-concept for next steps - active scanned probes.



Open questions:

- Mechanism: capacitive charging or modification of surface state electron transfer?
- What is the spatial potential profile within PMMA?
- Why do not all QDs show this effect?