Terahertz Spectroscopy of CdSe Quantum Dots

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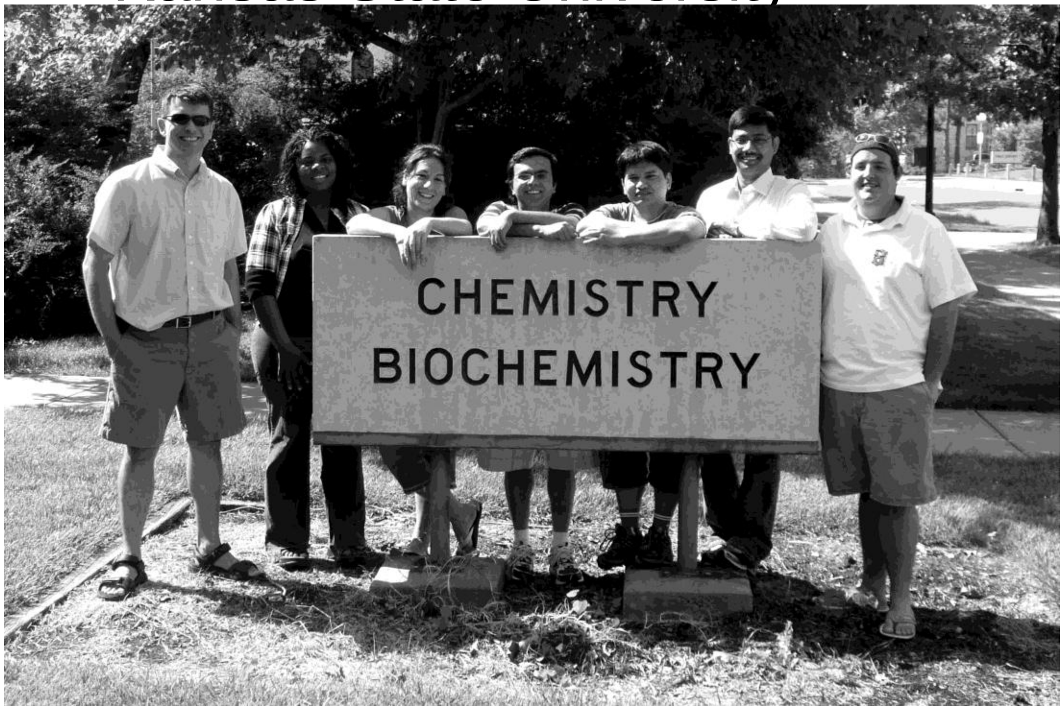
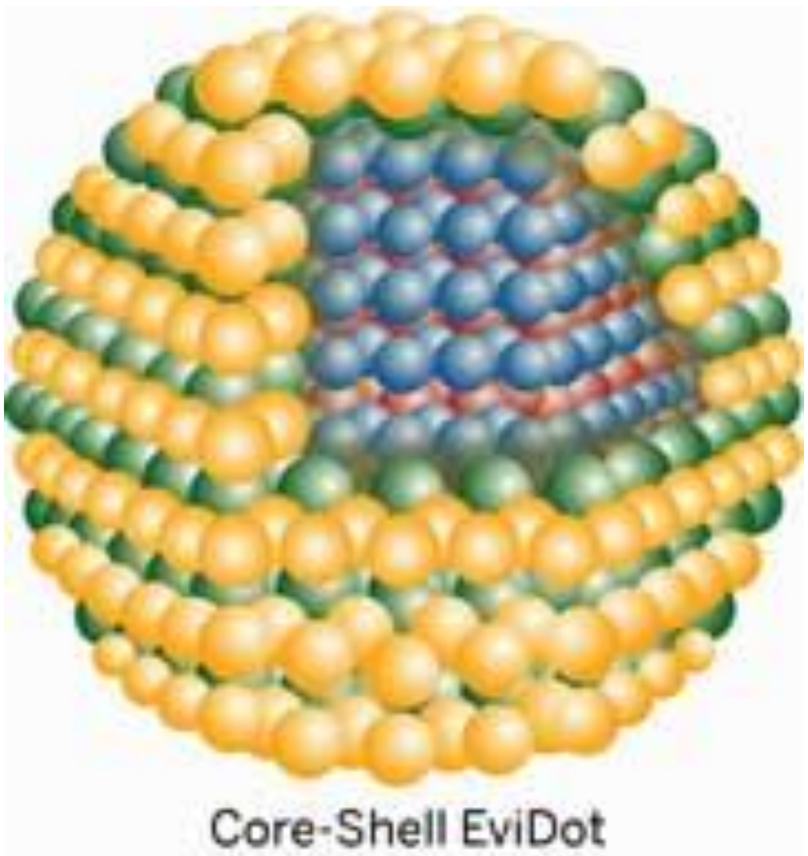
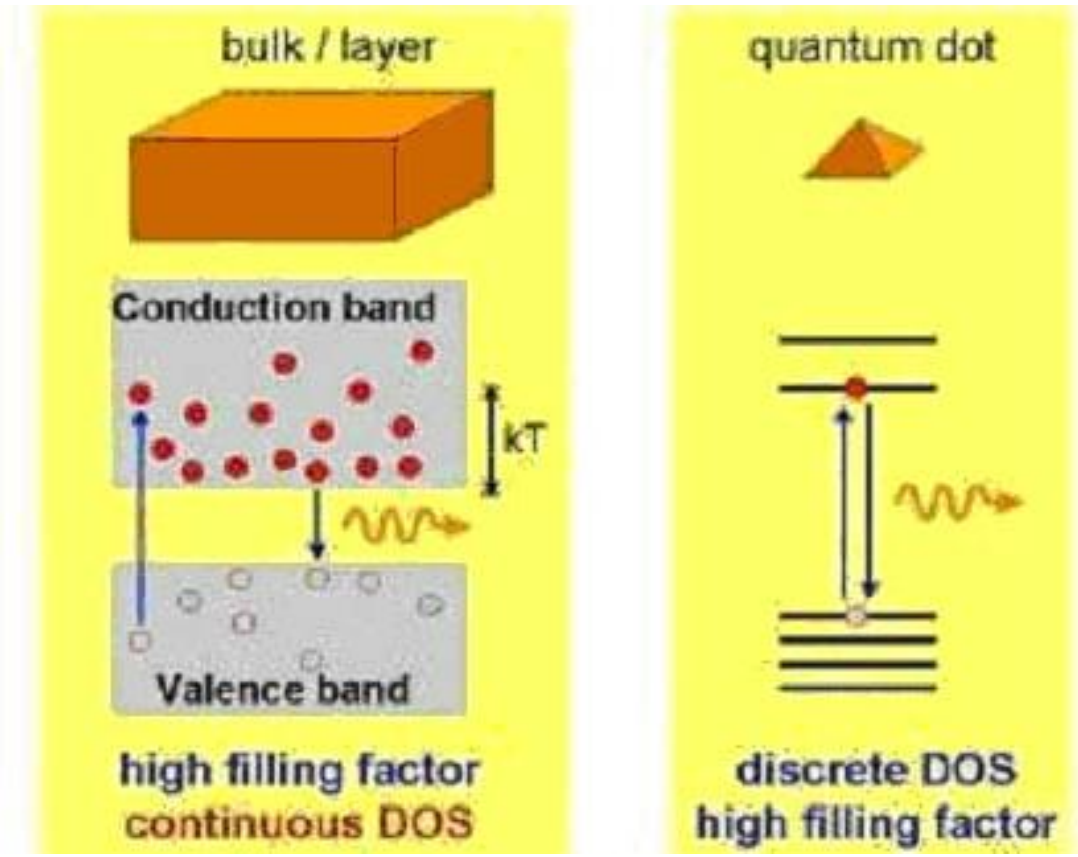


What is a quantum dot?



- Nanocrystals
- 2-10 nm diameter
- semiconductors

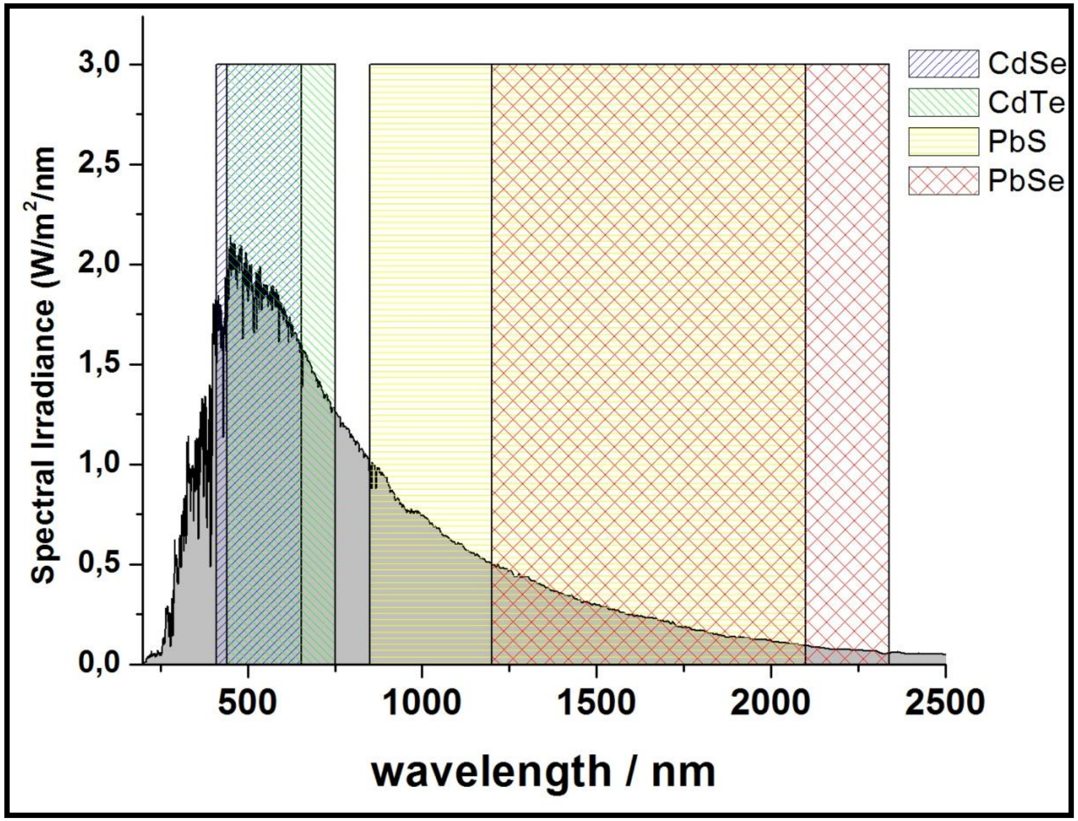
What is a quantum dot?



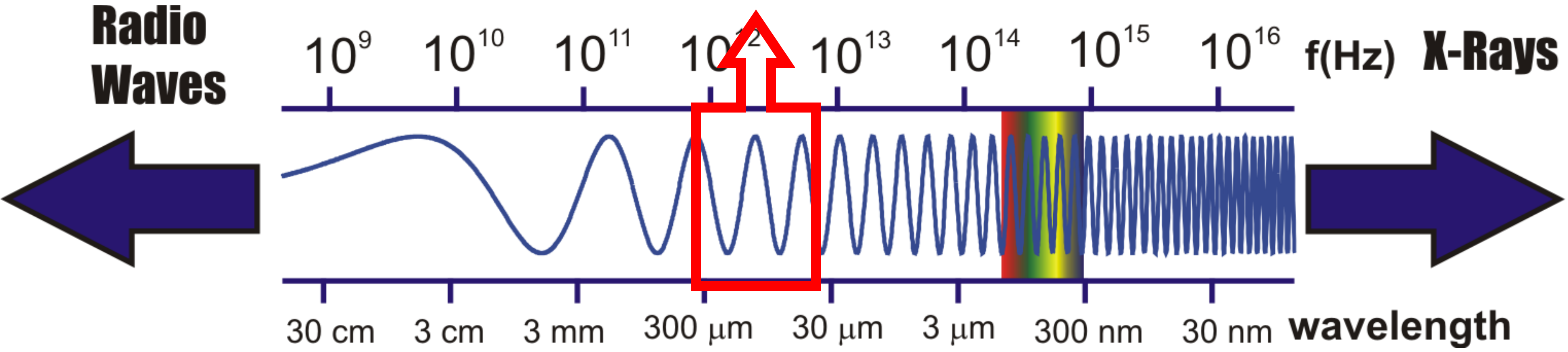
- Exciton Bohr Radius
- Discrete electron energy levels
- Quantum confinement

Motivation

- Semiconducting nanocrystals are significant due to; strong size dependent optical properties (quantum confinement)
- applications solar cells

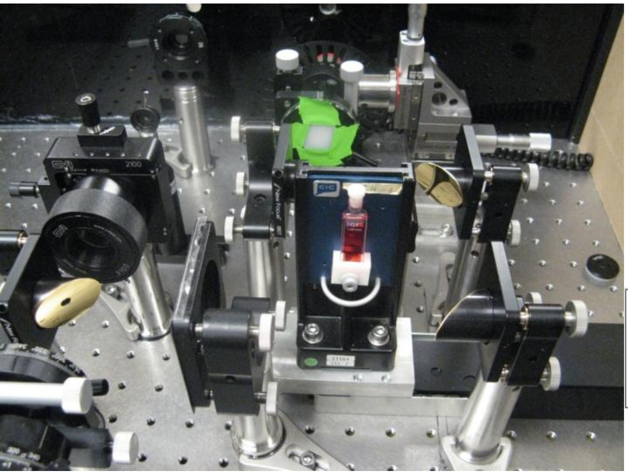


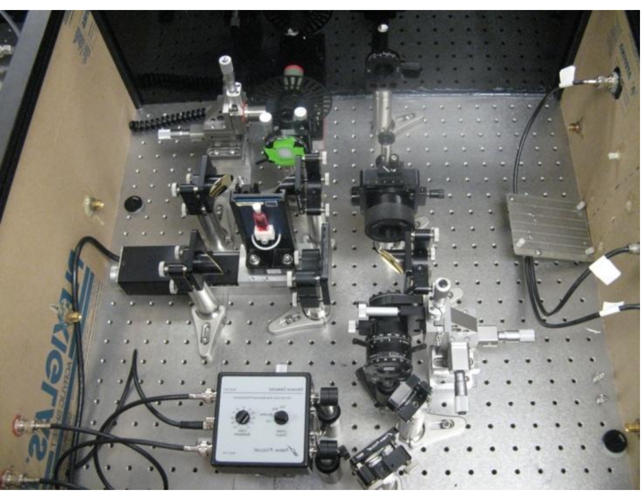
Terahertz gap

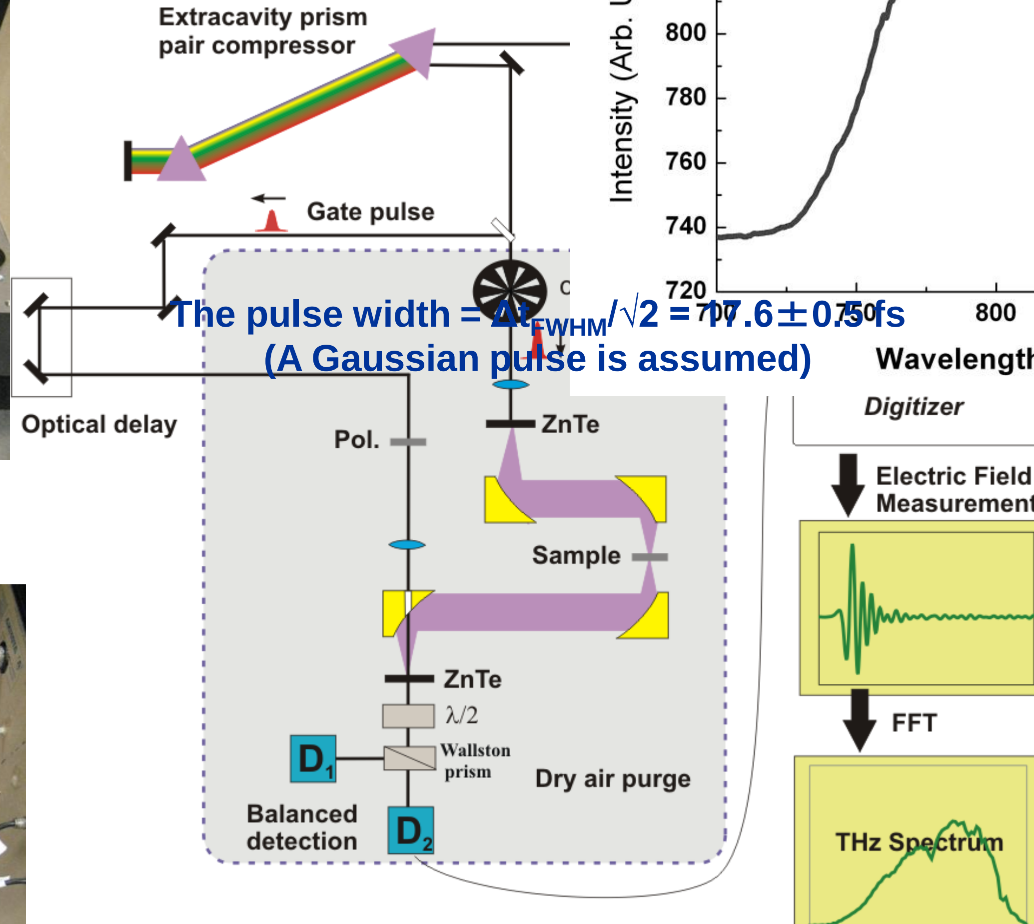


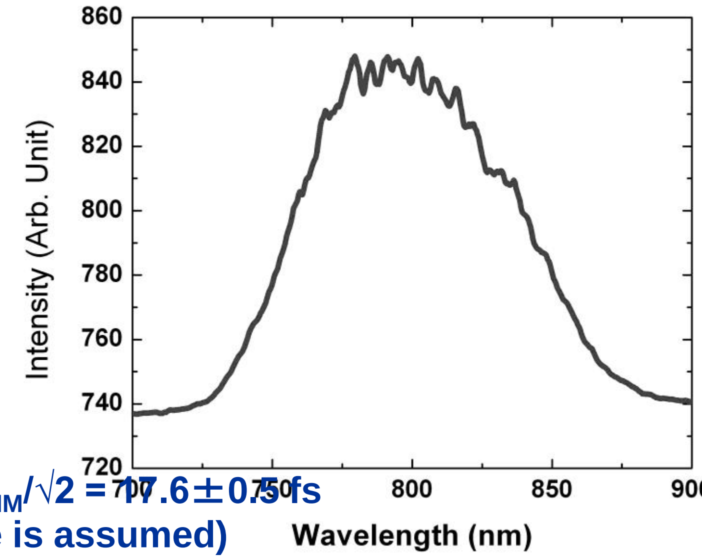
1 THz = 300 μm = 33 cm^{-1} = 4.1 meV

Time domain terahertz S



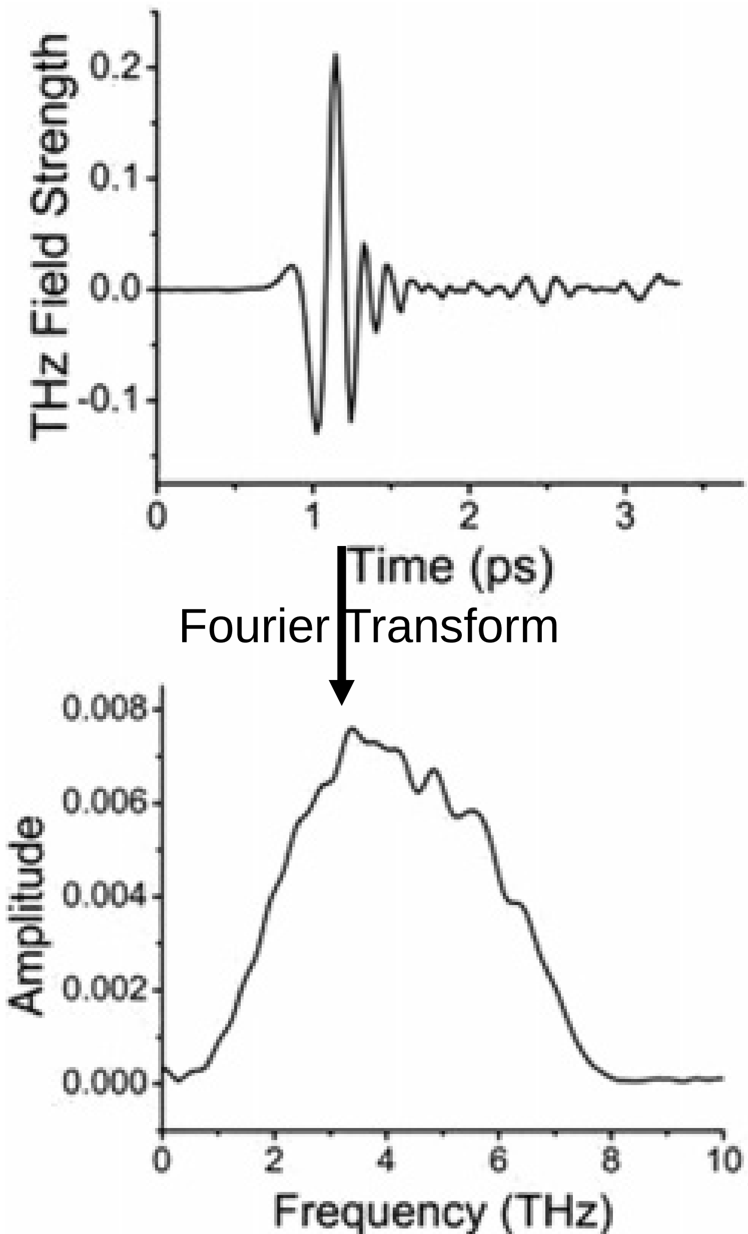






The pulse width = $\Delta t_{FWHM}/\sqrt{2}$ = 17.6±0.5fs
(A Gaussian pulse is assumed)

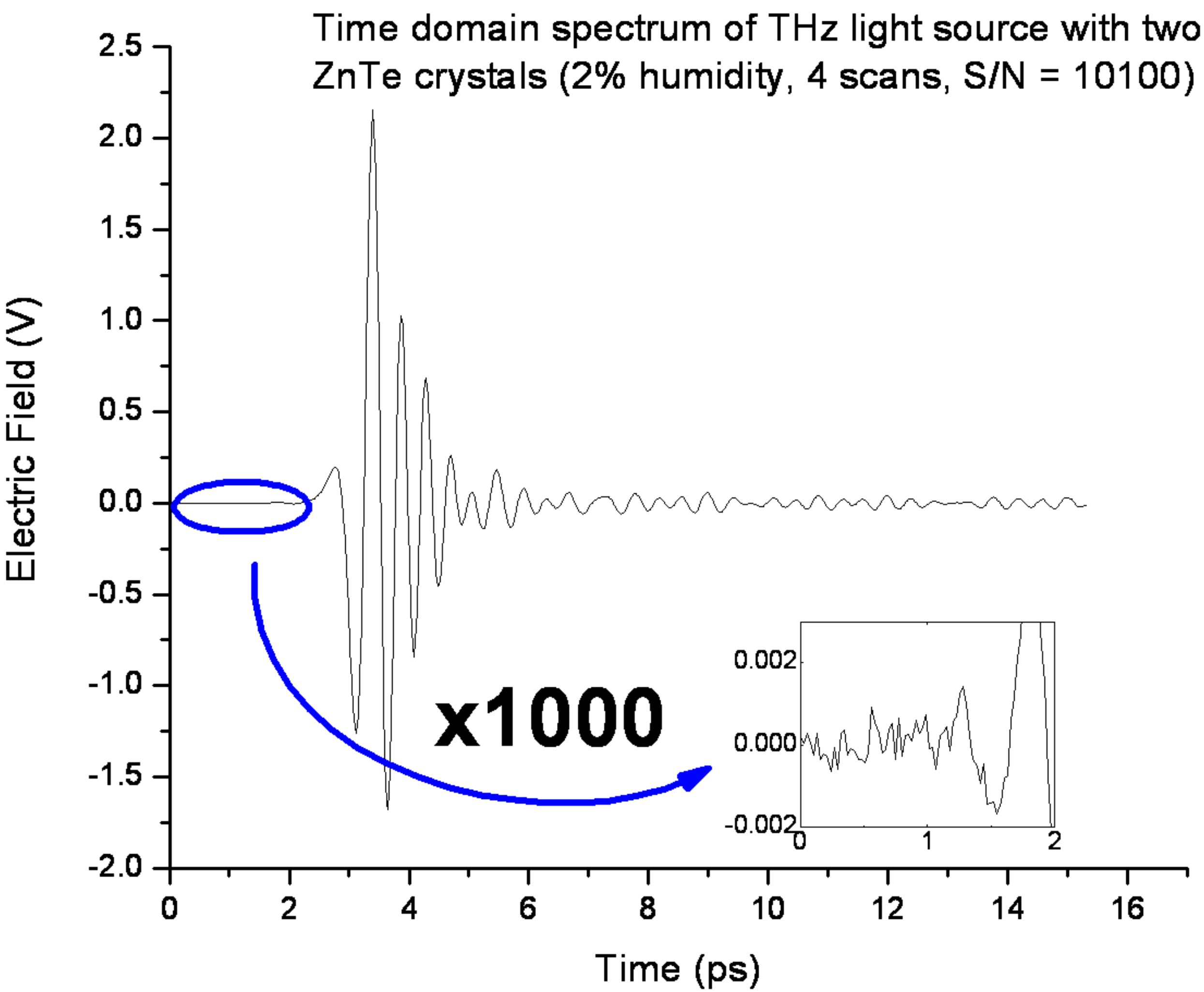
Terahertz Signal



To obtain the response of the sample to the THz radiation 2 measurements are made

- THz electric field transmitted through the empty cell
- THz electric field transmitted through the sample cell

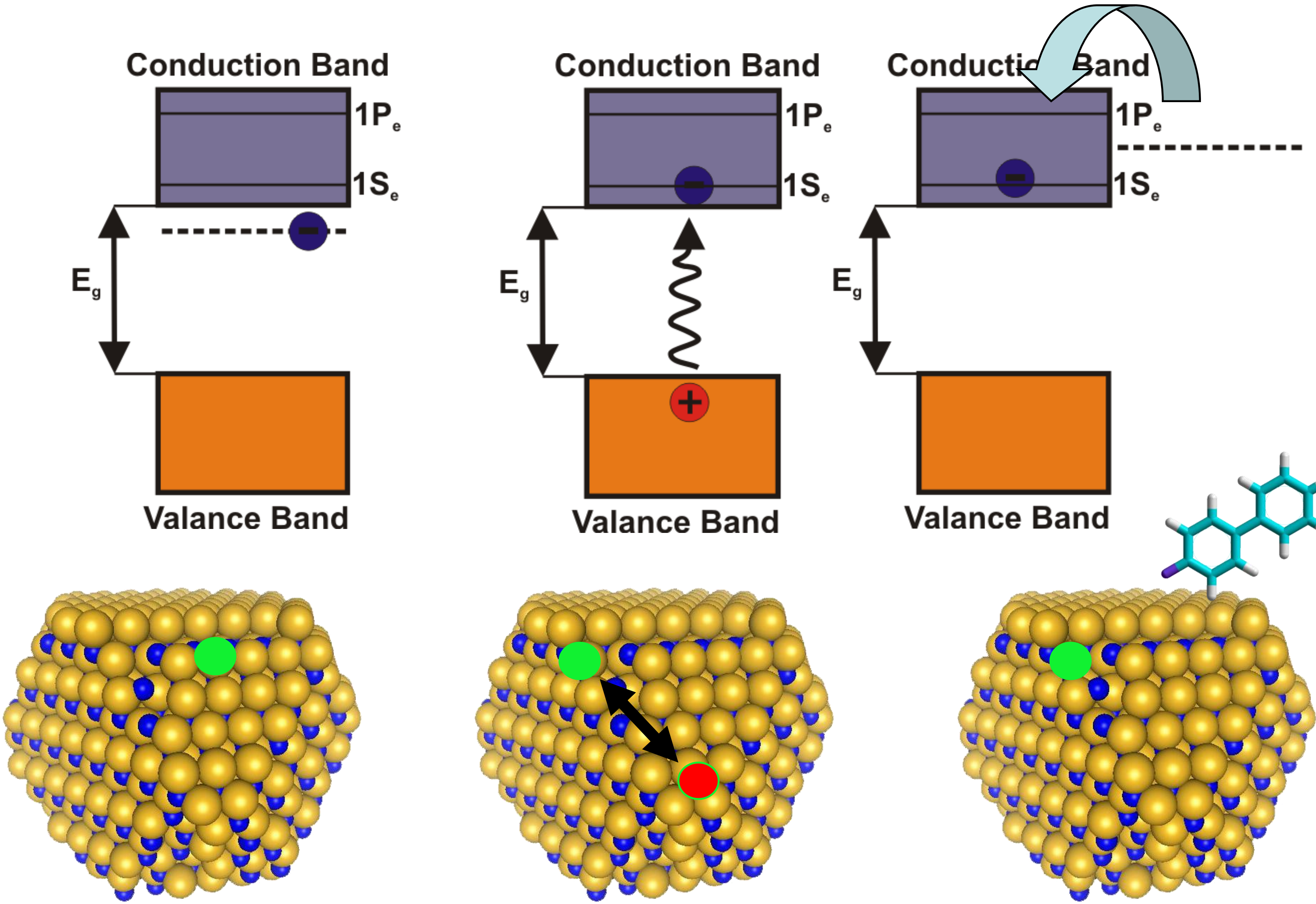
Terahertz signal



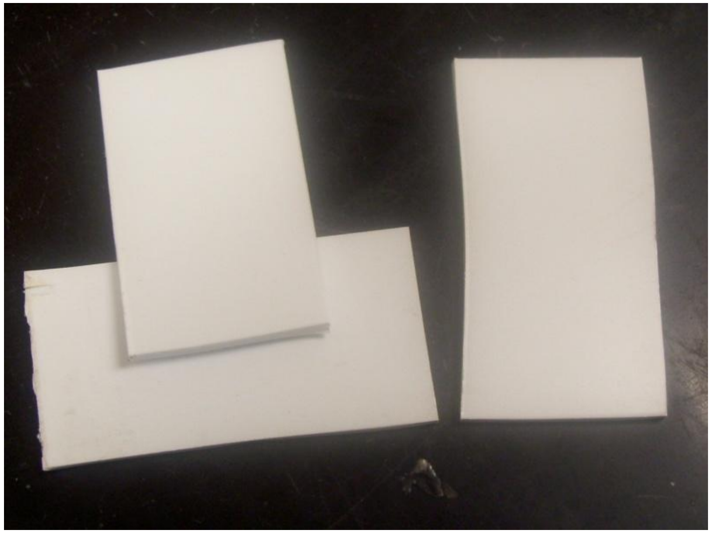
Doping

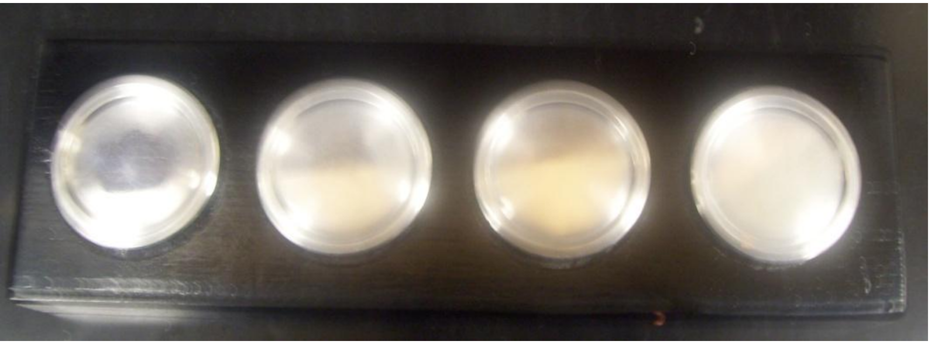
- Intentionally adding impurities to change electrical and optical properties
- Add free electrons to conduction band or free holes in valence band
- Tin and Indium dopants

Free carrier Absorption in Quantum Dots

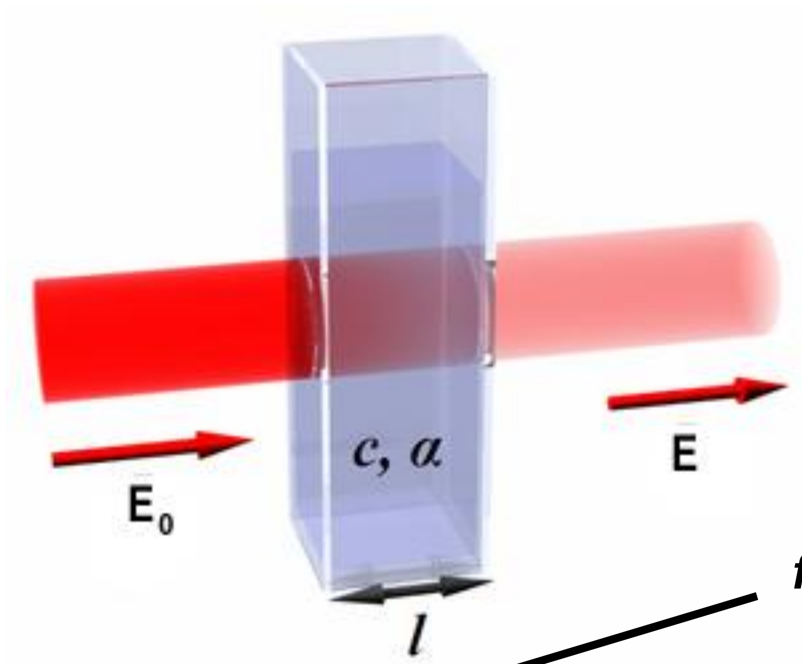


Purification and sample preparation of quantum dots





Experimental procedure & Data analysis



time domain:

frequency domain:

$$\frac{\Im E(t)}{\Im E_0(t)} = \frac{E(\omega)}{\tilde{E}_0(\omega)} = \sqrt{T(\omega)}\,\exp(i\phi(\omega))$$

Power transmittance

Relative phase

$\sqrt{T(\omega)}$, $\Phi(\omega)$ ⇨ Complex refractive index ($n_r(\omega) + i.n_{im}(\omega)$)

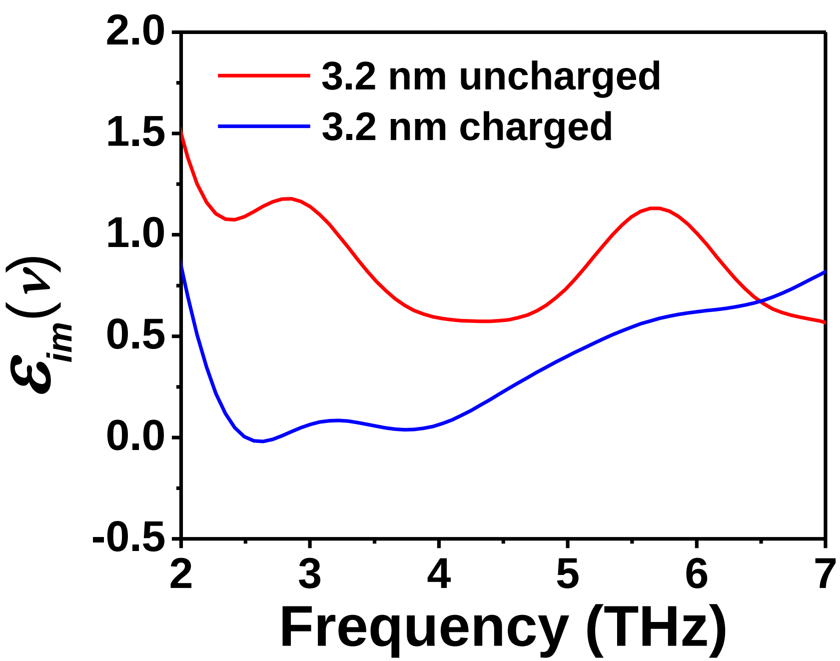
No Kramer-Kronig analysis!!!

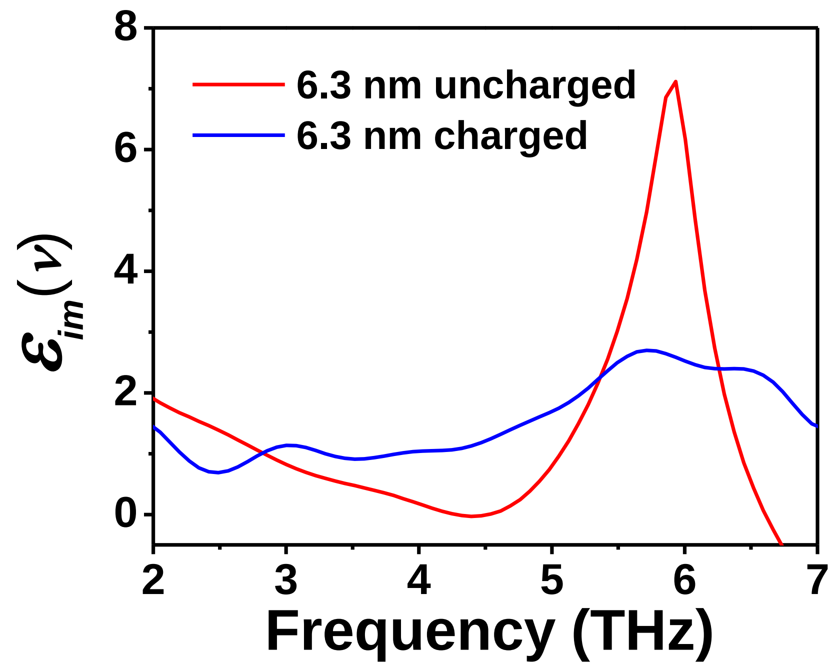
Changes upon charging large quantum dot: Intrinsic Imaginary Dielectric constant

The frequency dependent complex dielectric constants determined by experimentally obtained

- Frequency dependent absorbance and refractive index.

The complex dielectric constant = $(n_r(\hat{\imath}) + in_i(\hat{\imath}))^2$





- **For the charged samples Frohlich Band diminishes: A broader and weaker band appears**
- **The reason of this is the presence of coupled plasmon-phonon modes**

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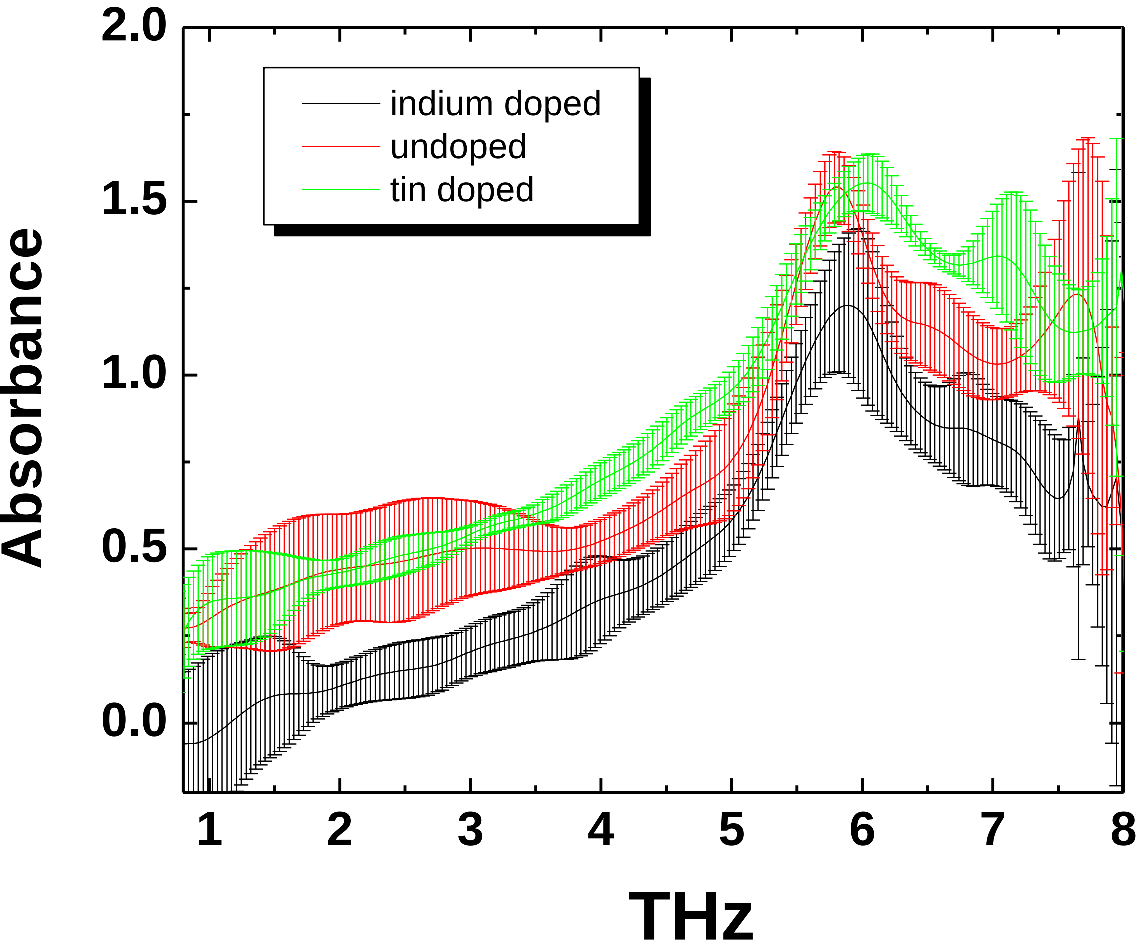
Results



- Surface phonon
- Shift of resonance of tin doped
- Agreement with charged QDs

Results