Cadmium-free $CuInS_2$ quantum dots – candidate for bio-imaging applications

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Outline

I. Ternary $CuInS_2$ quantum dots - motivations

II. Synthesis and structure analysis

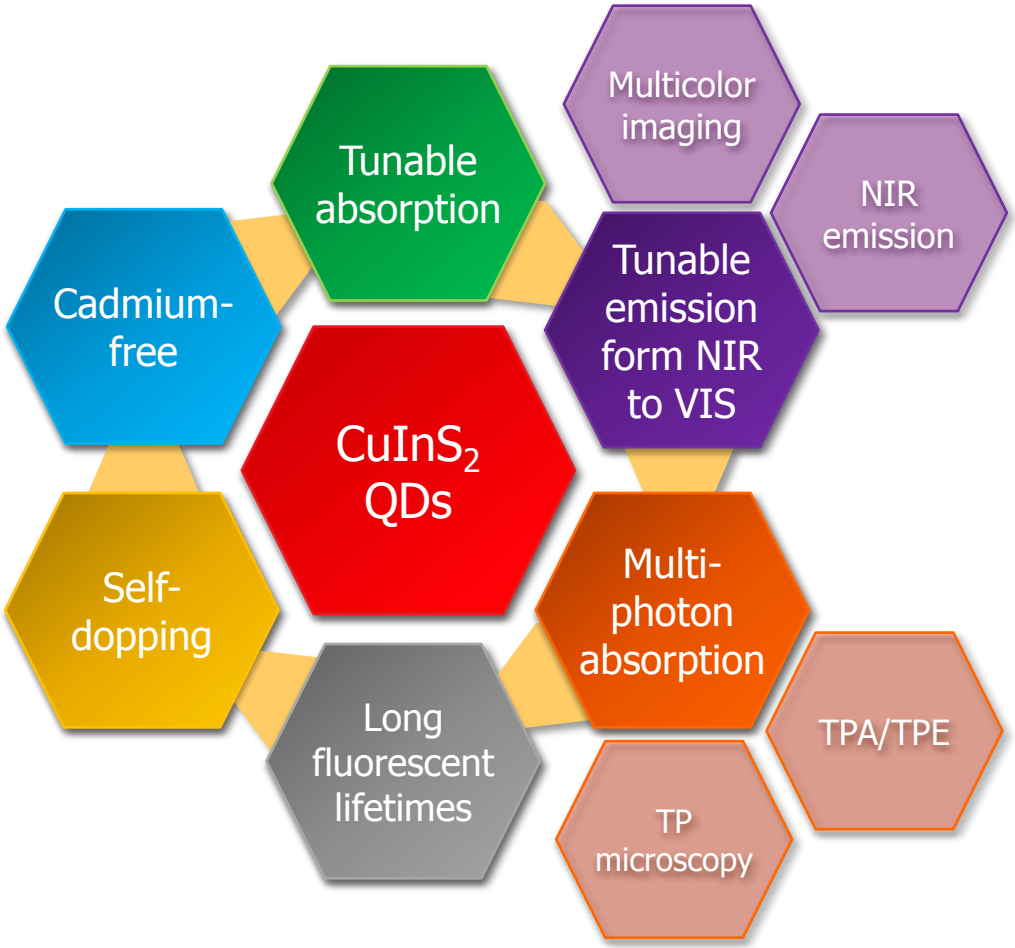
III. Optical properties

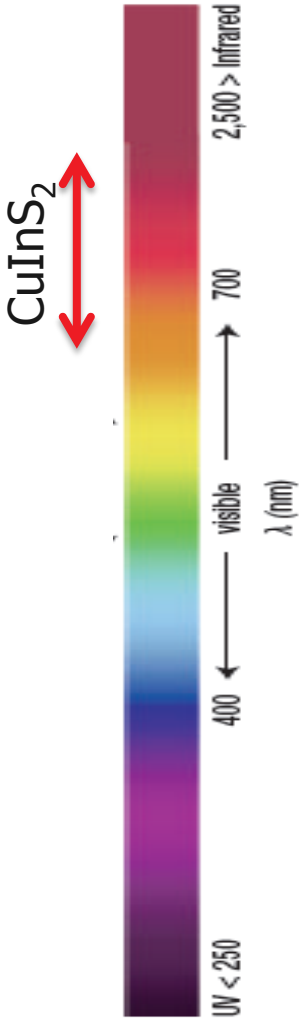
- Absorbance, Time-resolved fluorescence spectroscopy
- Time-resolved two-photon fluorescence spectroscopy

IV. Conclusions

Ternary $CuInS_2$ quantum dots

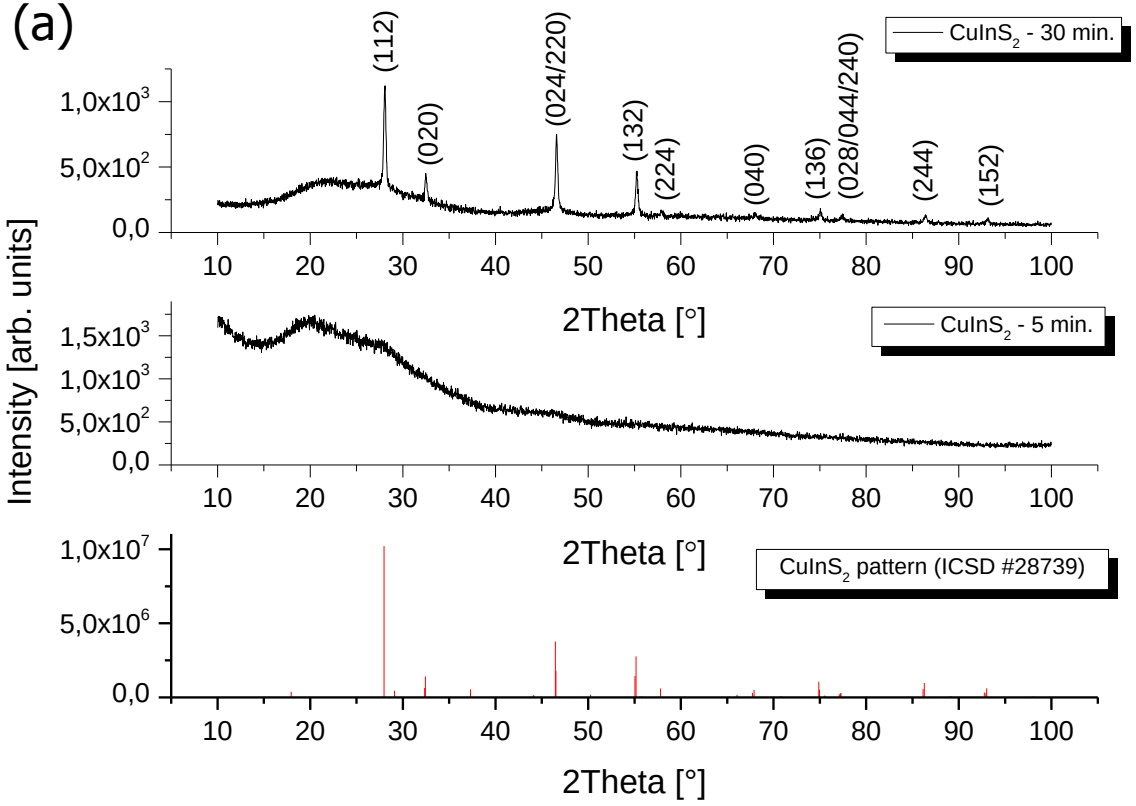
Motivation





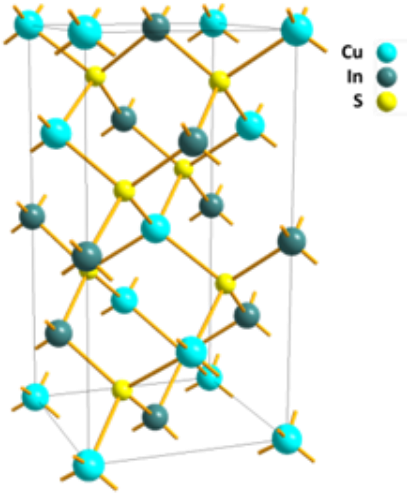
Crystallographic structure analysis

(a)



X-ray diffraction patterns of CIS_5 and CIS_{30} $CuInS_2$ quantum dots.

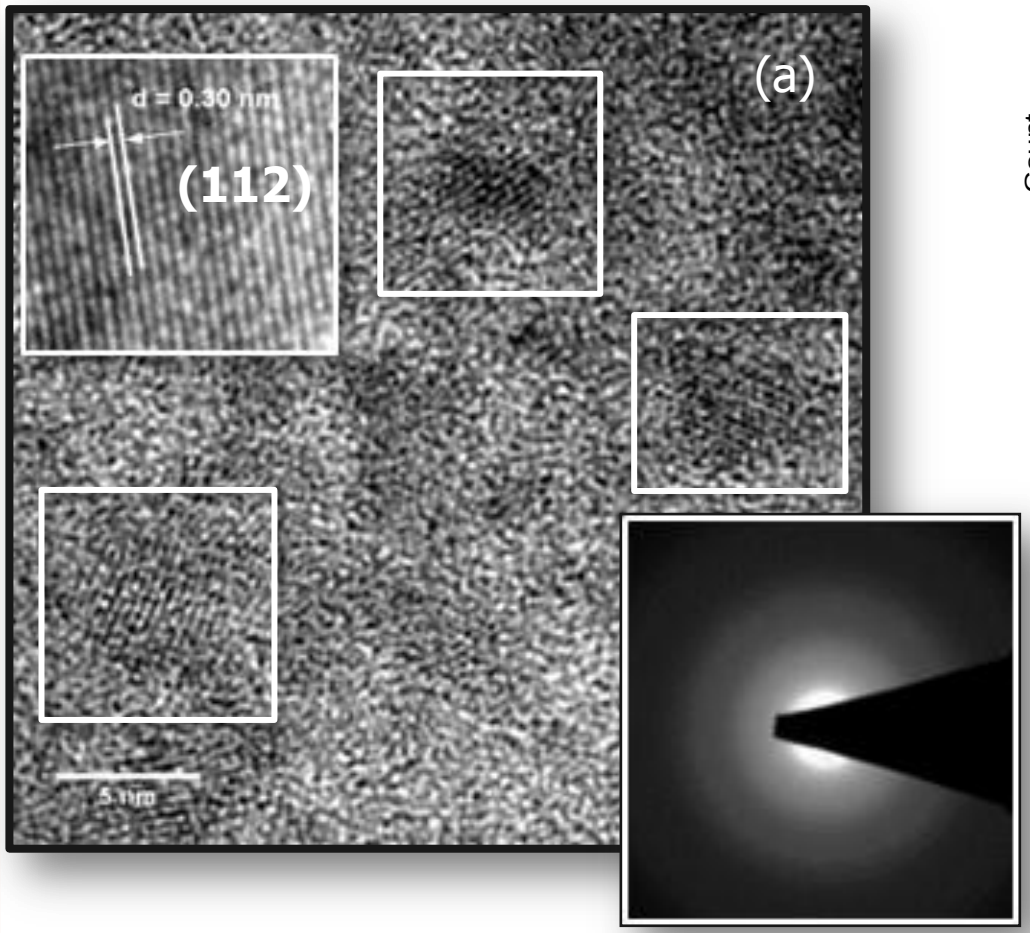
(b)

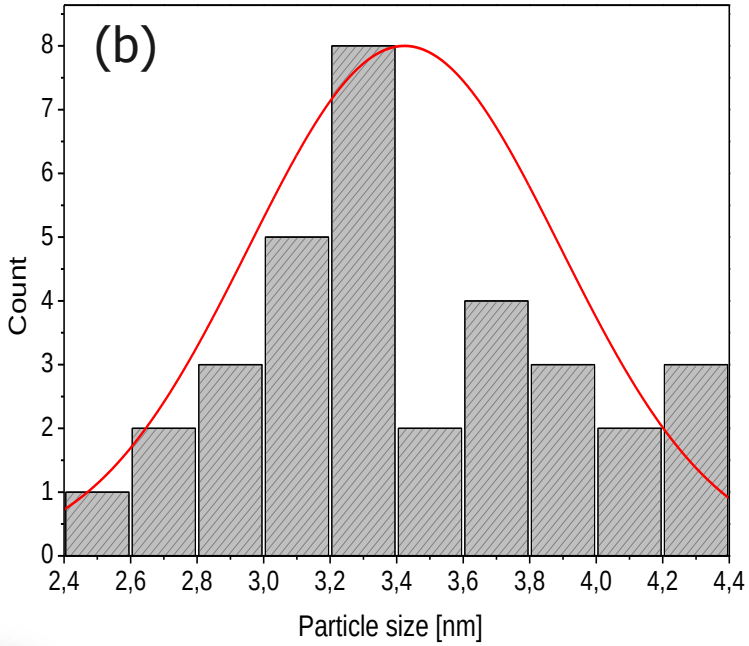


CIS_{30} cell parameters:
a = b = 5.514 Å
c = 10.994 Å
V = 334.26 Å

c/a = 1.99

TEM morphology analysis



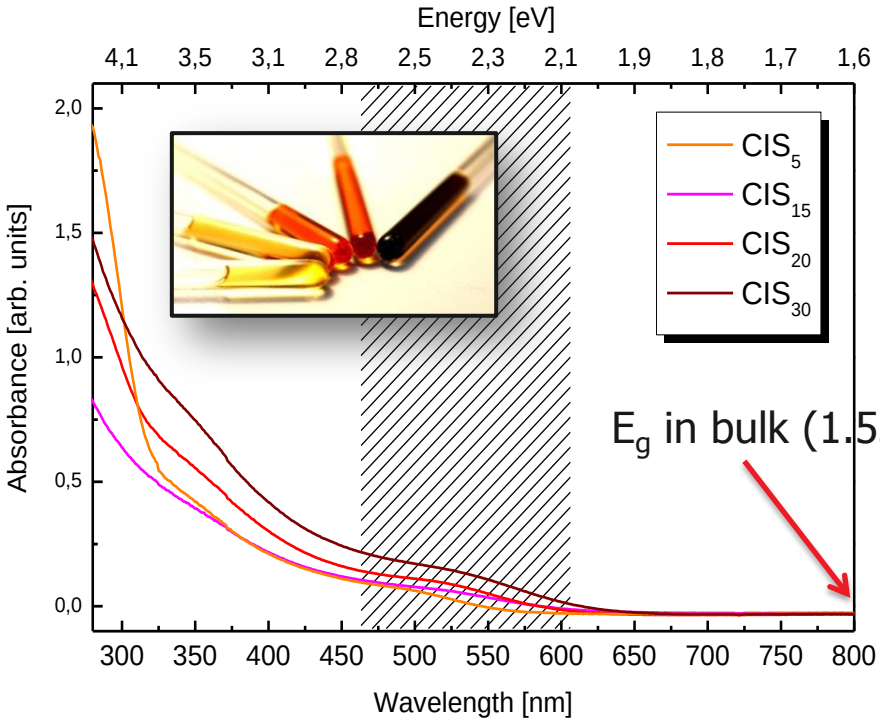


Size distribution of $CuInS_2$ QDs synthesized for 30 minutes at 200°C

Mean size: μ = 3.4 nm
Standard deviation: σ = 0.46 nm

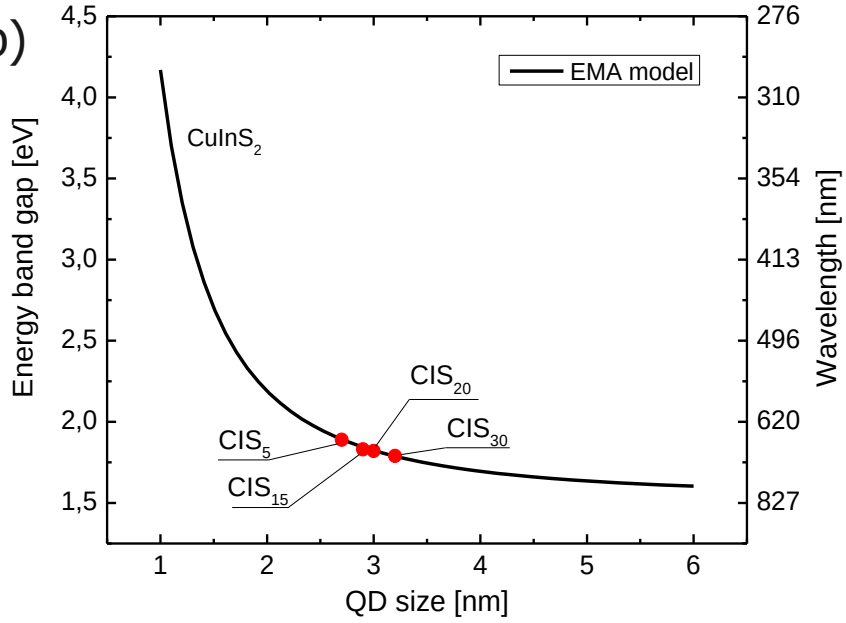
Optical absorption

(a)



Effective mass approximation model

(b)



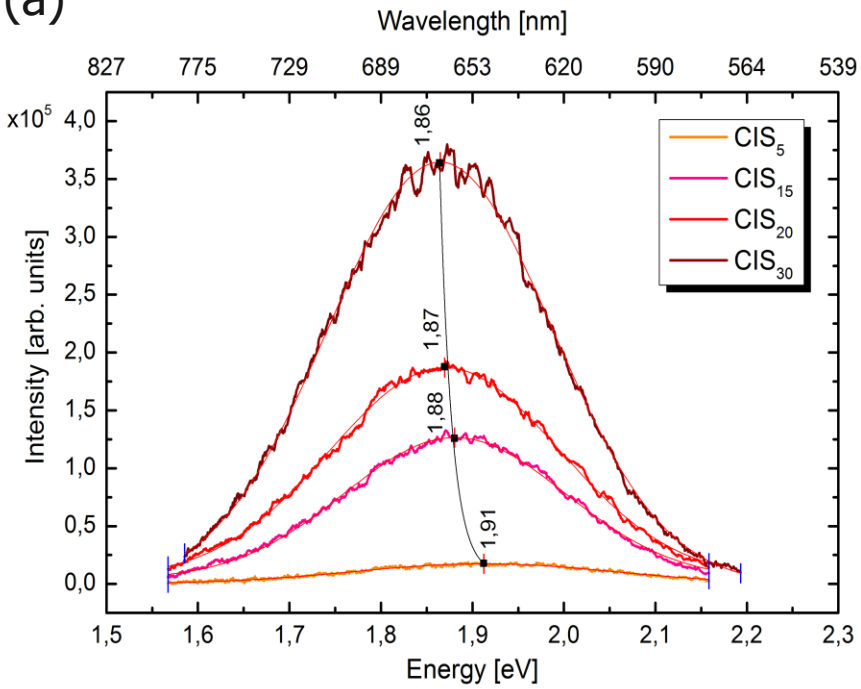
Exciton Bohr radius:

$$a_B^A = (a_B^H m_0 \varepsilon/\mu) = 3.8\,nm$$

$$\mu = m_e m_h / m_e + m_h$$

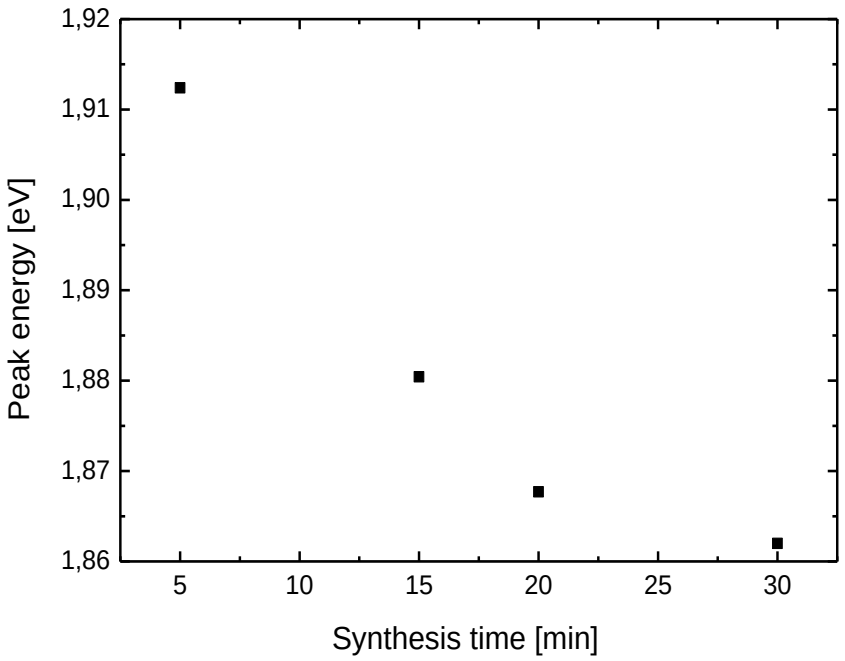
Time-resolved photoluminescence spectroscopy

(a)



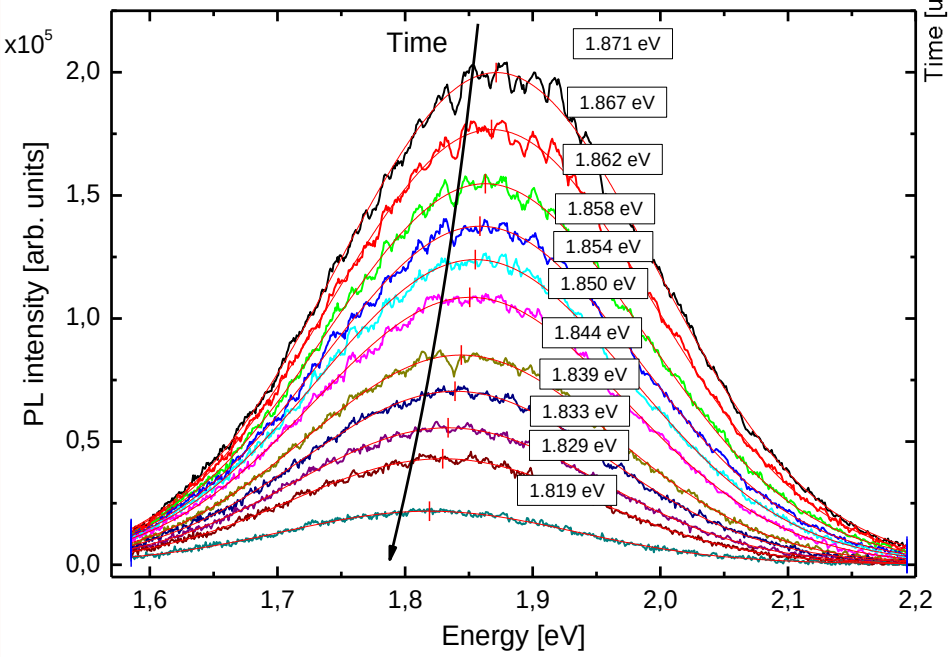
Photoluminescence spectra of CIS QDs with different size.

(b)

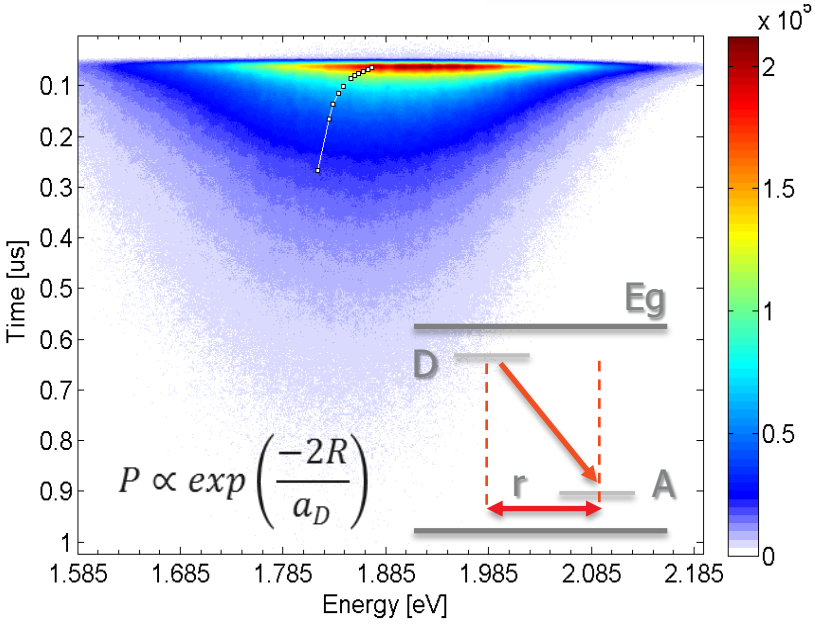


PL peak energy shift for CIS QDs synthesized at 5, 15, 20 and 30 min.

(a)

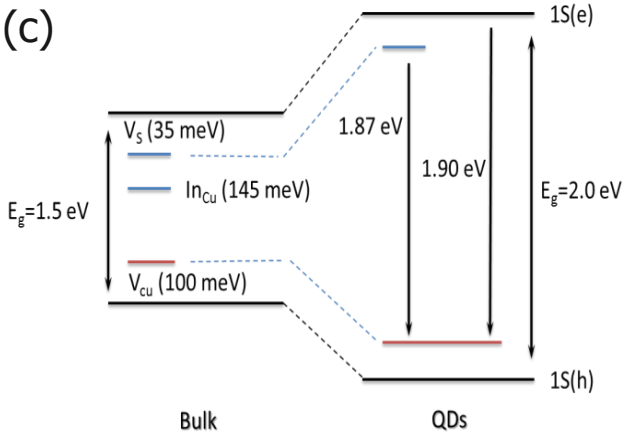


(b)

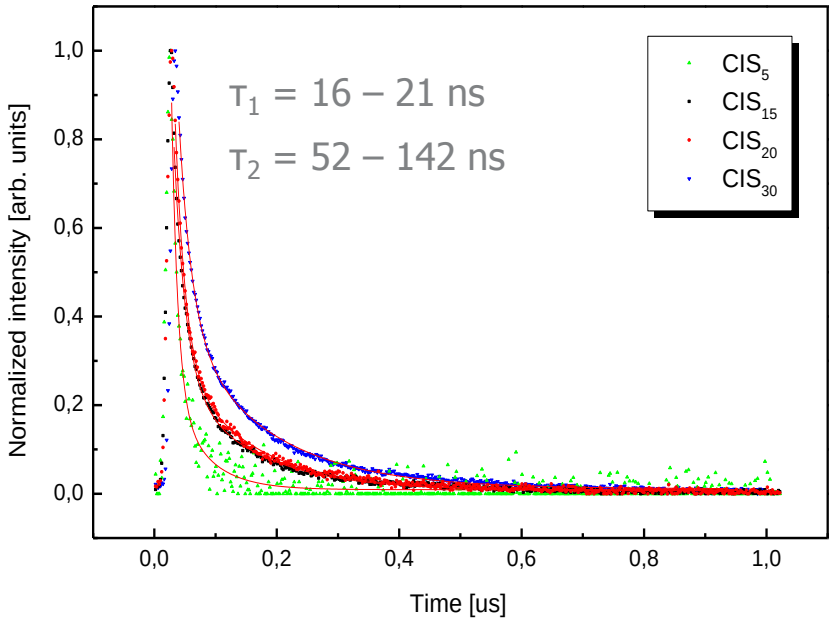


$$h\nu = E_g - E_A - E_D + \frac{e^2}{\varepsilon \cdot r}$$

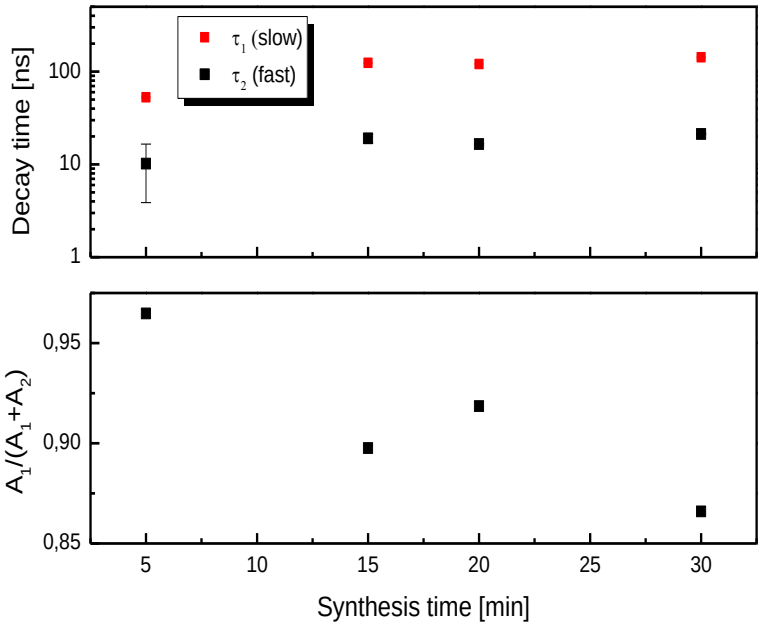
(c)



(a)



(b)

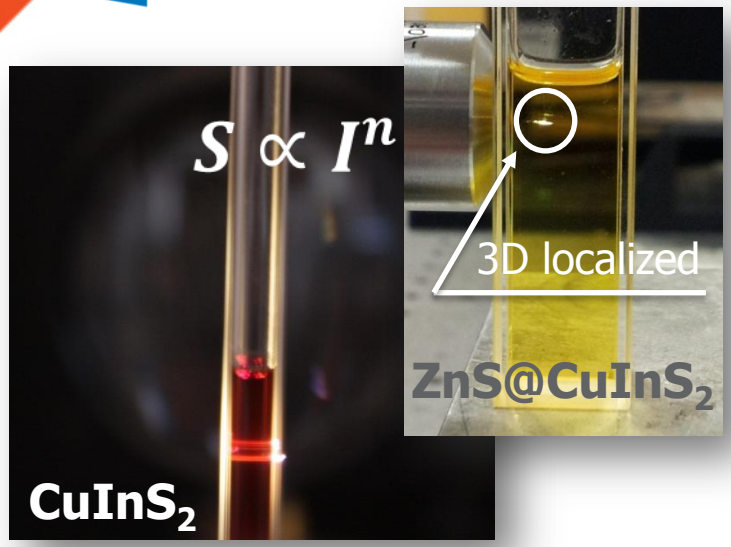


$$I(t) = I_0 e^{-\lambda_1 t} = I_0 e^{-(\lambda_{R1}+\lambda_{NR2})t}$$

$$\lambda_1 = \frac{1}{\tau_1} = \lambda_{R1} + \lambda_{NR1} = \frac{1}{\tau_{R1}} + \frac{1}{\tau_{NR1}}$$

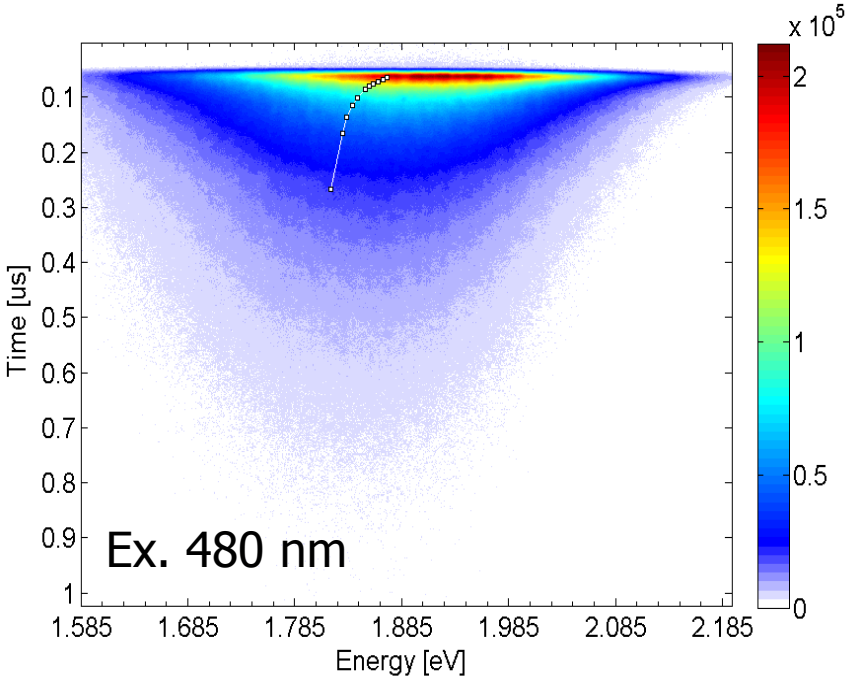
$$I(t) = A_1 e^{-\lambda_1 t} + A_2 e^{-\lambda_2 t} = A_1 e^{-(\lambda_{R1}+\lambda_{NR1})t} + A_2 e^{-(\lambda_{R2}+\lambda_{NR2})t}$$

Two-photon excited fluorescence

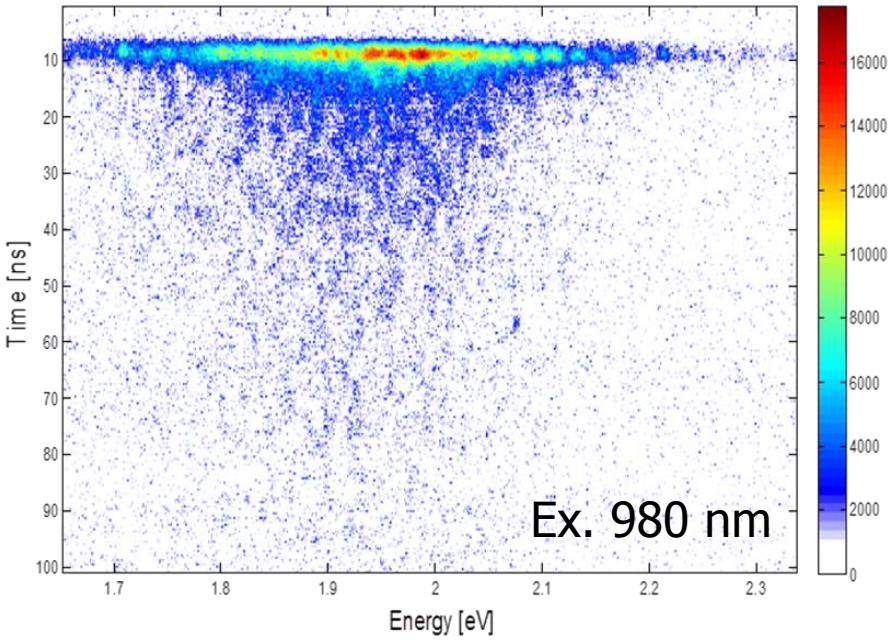


Time-resolved two-photon excited fluorescence

(a)



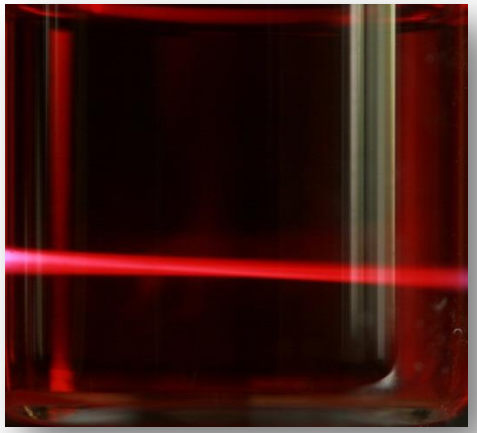
(b)



Conclusions

- Colloidal cadmium free, ternary I-III-VI_2 QDs with well control of size can be synthesized in one pot synthesis.
- Tunable absorption edge significantly blue-shifted from that of bulk material (E_g = 1.53 eV), with high absorption over 2.0 eV is seen.
- Donor-acceptor pair (DPA) recombination mechanism is observed in the $CuInS_2$ QDs.
- Bi-exponential decay with fast and slow components is seen in each sample.
- To components of the bi-exponential decay curve should be identified as two objects with different radiative lifetimes.
- $CuInS_2$ QDs exhibit two-photon absorption mechanism in the range of 800 – 1400 nm.

Thank you for attention



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