Piezoelectric effect in ZnTe quantum dots inserted in (Zn,Mg)Te nanowire

P. Baranowski[1], P. Wojnar[1], M. Szymura[1], N. Zawadzka[2], R. Pasławska[2], M. Wójcik[1], S. Chusnutdinow[1], G. Karczewski[1], and T. Wojtowicz[3]

[1]*Institute of Physics, Polish Academy of Sciences, 02-668 Warsaw, Poland*

[2] *Faculty of Physics, University of Warsaw, ul. Pasteura 5, PL-02-093 Warsaw, Poland*

[3]*International Research Centre MagTop, Institute of Physics, Polish Academy of Sciences, 02-668 Warsaw, Poland*

Introduction

Semiconductor nanowires belong to the most intensively studied nanostructures in the last decade due to their emerging applications in the field of nanoelectronics and nanophotonics. In strained (111)-oriented core/shell nanowires the piezoelectric effect is expected due to lack of inversion symmetry of the system. We investigate the influence of the latter effect on the optical spectrum from individual nanowire quantum dots (NWQDs).

We present optical properties of ZnTe/(Zn,Mg)Te NWQDs grown by molecular beam epitaxy by employing the vapor liquid solid growth mechanism assisted with gold catalysts. ZnTe NWQDs with three different average lengths, estimated to 6, 12 and 40 nm, are fabricated. A clear dependence of the biexciton binding energy on NWQD length on is found and interpreted in terms of the presence of piezoelectric field.

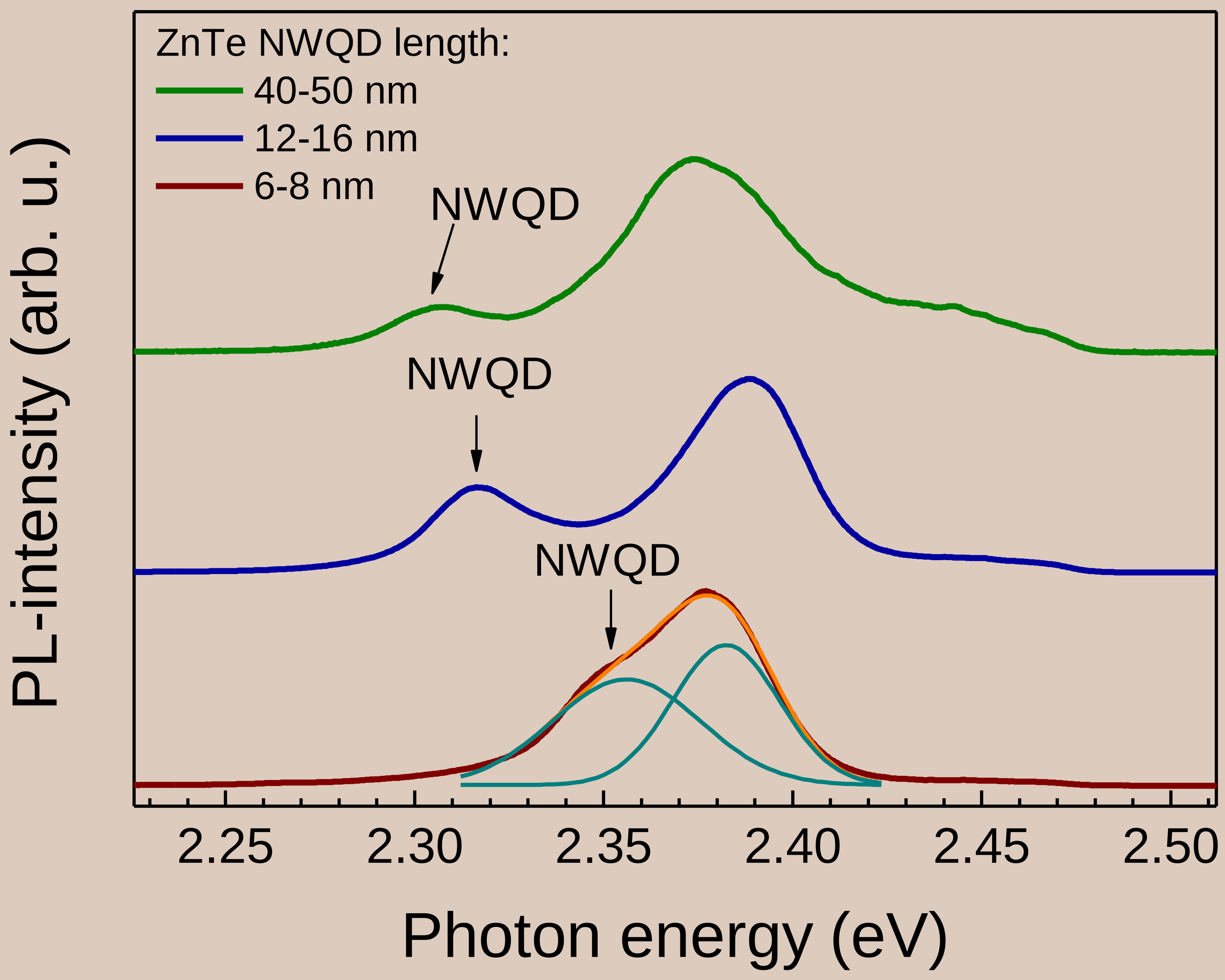

Fig. 1 Photoluminescence from (Zn,Mg)Te nanowires with ZnTe axial insertion with various lengths. Emission lines with lower energy come from ZnTe nanowire quantum dots (NWQDs). We observe their significant redshift with increasing length of the NWQD. Excitation is performed with 405 nm laser line and the temperature of the measurement is 7 K.

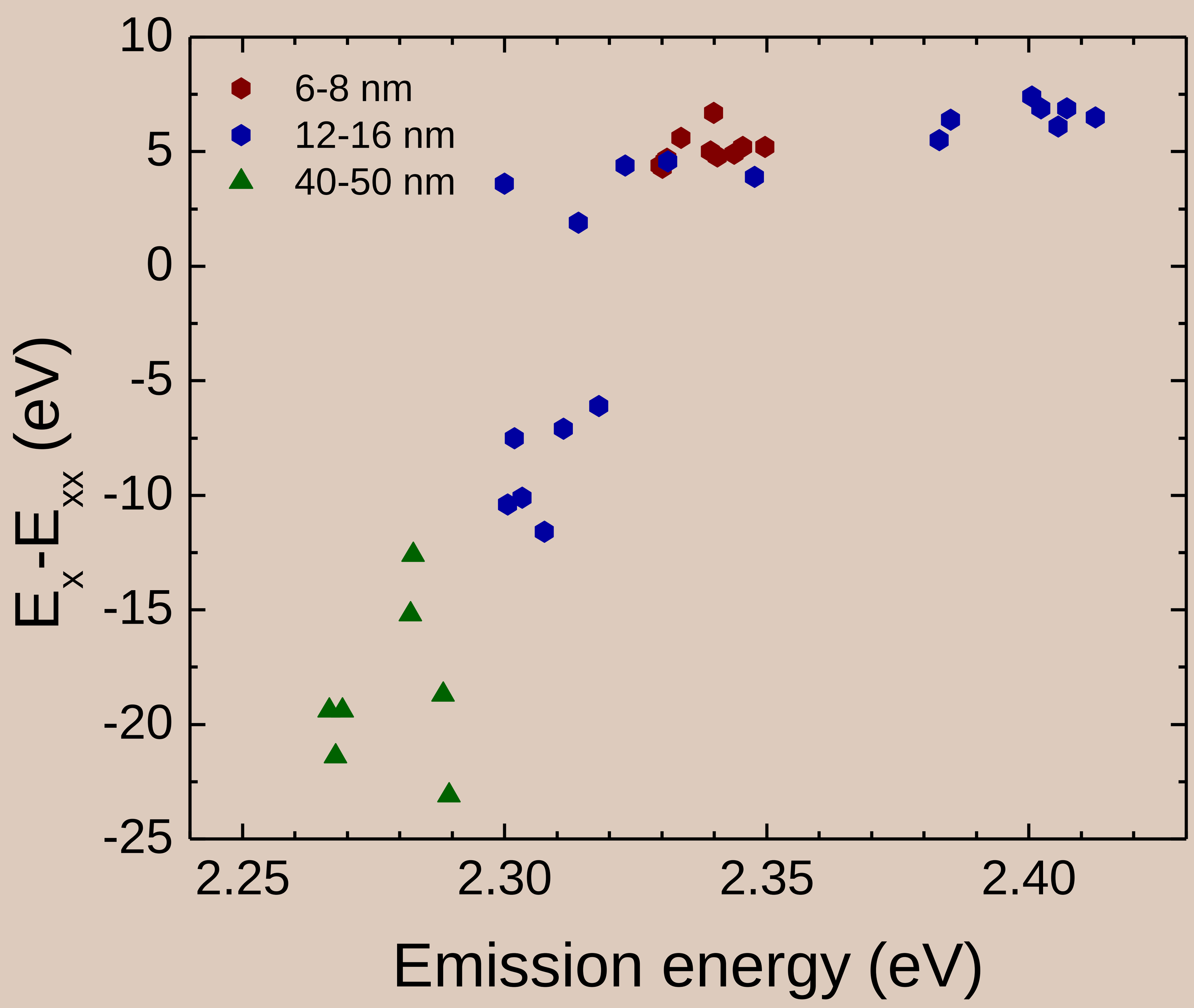

Fig. 3 The biexciton binding energy defined as X - XX spectral distance versus the X emission energy plotted for several individual quantum dots revealing a gradual change from binding to antibinding character of biexcitons. The temperature of the measurement is always 7 K, and the excitation performed with 405 nm laser line.

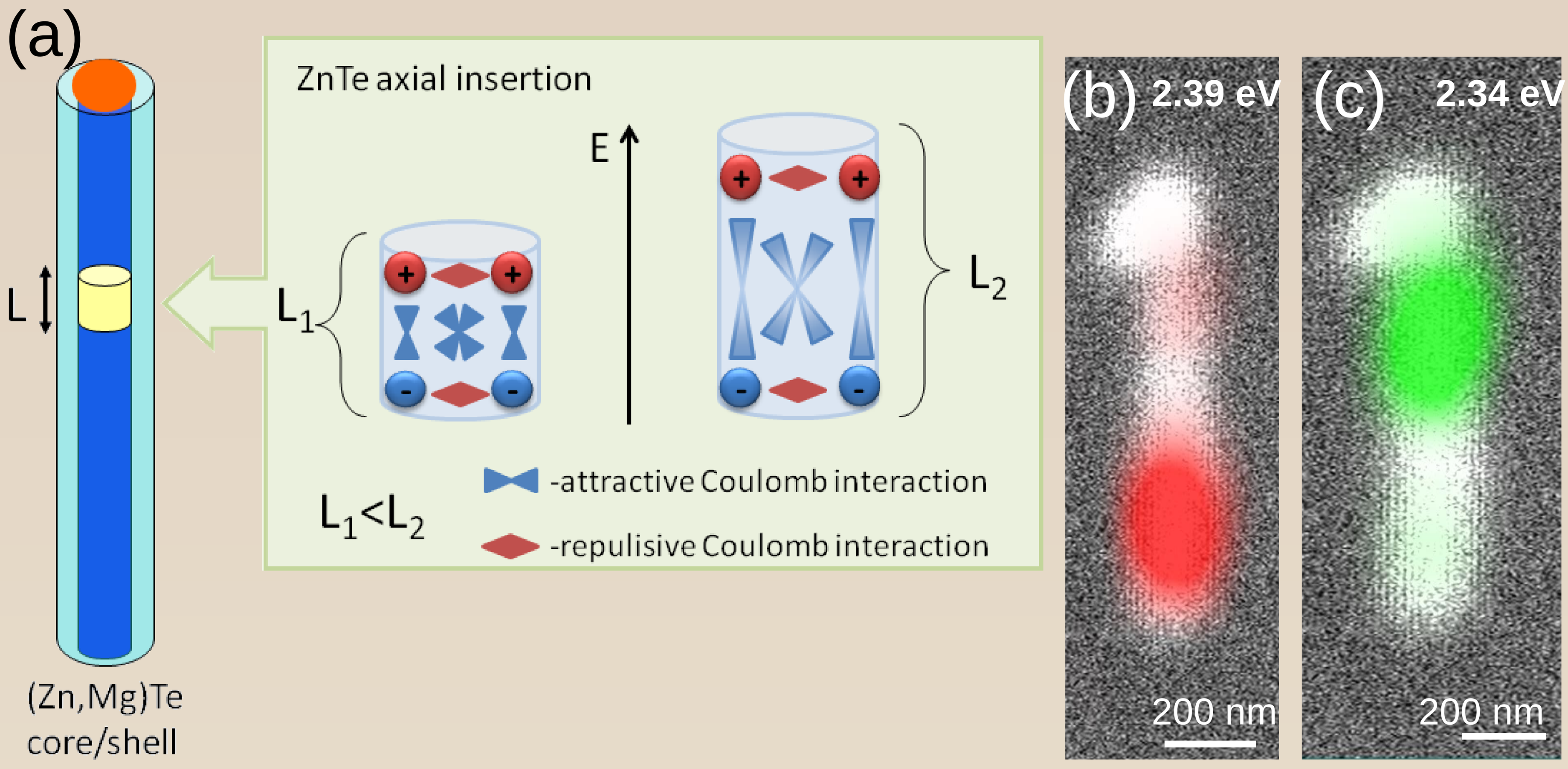

Fig. 2 (a) Scheme of investigated nanowire heterostructure along with schematic arrangement of electrons and holes inside ZnTe nanowire quantum dot and corresponding attractive (blue) and repulsive (red) interactions within biexciton complexes. In longer NWQDs the attractive Coulomb interaction is reduced. (b)(c) Cathodoluminescence map performed at 2.39 eV – nanowire core (b) and 2.34 eV – NWQD (c) combined with SEM image. Probe current is set to 500 pA, acceleration voltage is set to 15 kV and temperature is stabilized at 7 K.

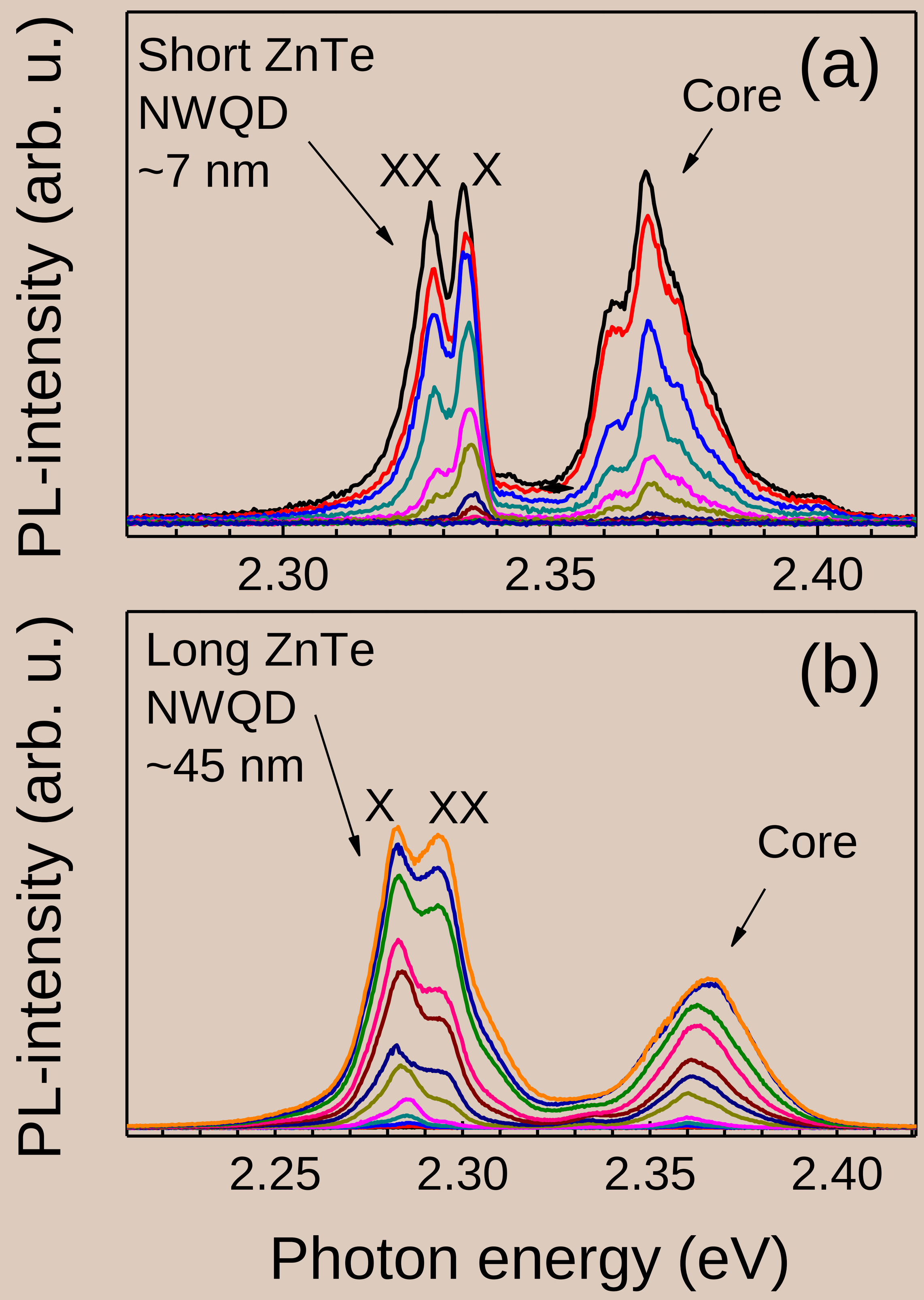

Fig. 4 μ-PL spectra with increasing excitation fluence from relatively short (7nm) individual ZnTe/ZnMgTe NWQDs (a) and relatively long (45 nm) NWQDs (b). Biexciton binding energy exhibits either binding or antibinding character respectively. Temperature of measurements- 7 K, excitation- 405 nm.

Summary

- Emission energy from NWQD shifts from 2.35 eV to 2.30 eV with increasing lengths of ZnTe insertions from 7 to 50 nm.
- In photoluminescence spectra from individual NWQDs we observe the appearance of biexcitonic emission with increasing excitation fluence. Depending on the NWQD-length the **biexcitonic emission** exhibits either **binding or antibinding** character.
- The interpretation of this results relies on **piezoelectric effect** which appears in our NW hetero-structures. Strain in (111) oriented core/shell nanowire result in the appearance of an **internal electric field**. This results in spatial carrier separation within the dot. Increase of length of ZnTe NWQD result in the increase of the distance between opposite charge carriers. Consequently biexciton binding energy (defined as X-XX spectral distance) is significantly affected.

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