Toward resonant spectroscopy of individual quantum dots: development of structures and experimental techniques

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Quantum dots (QDs) are of great interest for number of reasons. Starting from the well known features, such as narrow emission lines and quantum size effect, towards those resulting from interaction of QD excitons with the environment, e.g. due to placing QDs in photonic structures or doping QDs with single magnetic ions. Although many properties of QDs can be accessed through standard photoluminesce experiments with nonresonantly excited single QDs, much better spectral resolution [1] and much higher degree of control over QD excitons can be achieved in experiments with resonant excitation. Such experiments however, require particular design of semiconductor structures and preparation of advance experimental setup. The goal of this work is to present a fabrication and optical study of II-VI semiconductor QDs in various systems, optimized for resonant spectroscopy.

In order to open possibility of single QD absorption experiments we needed almost transparent samples containing QDs. Since II-VI QDs are typically grown on opaque substrates (e.g., GaAs), we have developed new lift-off technique for II-VI compounds [2]. Between a substrate and the relevant ZnTe layer containing CdTe QDs, a layer of hygroscopic magnesium compound (MgTe) was applied. Next, due to a contact with water, MgTe layer was removed and free standing flakes containing QDs were obtained. Microluminescence studies performed at low temperatures indicate that QD in exfoliated layers have similarly good optical properties as QDs in as grown samples. This opens possibility of QDs ensemble absorption measurements, yet micro-structuration, like preparation of masks with nano-apertures, is still required for single QD absorption study.

The second aim of our study is related to the emission wavelength of II-VI quantum dots. II-VI QDs studied so far (CdTe/ZnTe, CdSe/ZnSe, CdTe/(Cd,Mg)Te) exhibit emission wavelength 500 nm $< \lambda <$ 700 nm. Resonant excitation experiments in this range are challenging, especially in comparison with the ease of use of Ti:sapphire lasers (700-1000nm). In order to red-shift the QDs into the desired spectral range, we have grown a series of CdTe QDs in (Cd,Mg)Te barriers with decreasing Mg content. We found that for low Mg content in barrier (below 10%) QD lines are broaden, but for about 14% of Mg in the barrier optical properties of QDs are good and emission is slightly above 700 nm, as required. For higher Mg content in the barrier, emission of QDs is in spectral range not accessible by Ti:sapphire laser.

In our work we combine these two methods in order to achieve the regime of strictly resonant excitation. In particular, we present results of the photoluminescence excitation (PLE) experiments and compare obtained results with the reference spectra measured under non-resonant excitation.

[1] M. Kroner, C. Lux, S. Seidl, A. W. Holleitner, K. Karrai, A. Badolato, P. M. Petroff, R. J. Warburton, *Appl. Phys. Lett.* **92**, 031108 (2008).
[2] B. Seredyński, P. Starzyk, W. Pacuski, to be published in *Materials Today: Proceedings* (2017).