Positioning of individual Quantum Dots using a single laser beam photolithography

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The permanent marking of the position of individual quantum emitters, such as Quantum Dots (QDs), is highly desirable for systematic studies and for a construction of advanced optical devices. It is particularly important when emitters are randomly distributed, as in the case of self-organized QDs. One of the methods of QD position marking developed so far relies on a μ-Photoluminescence (μ-PL) spectroscopy combined with a photolithography[1,2]. It requires the use of precisely aligned two laser beams: one serving for a determination of a QD position through μ-PL mapping, and the second one, of higher energy, for photoresist exposure.

We demonstrate here a simplified photolithography method, involving only one laser beam for both: a determination of a spatial position of the QD and for a photoresist exposure. We confirm the utility of the method by systematic μ-PL studies of individual QDs containing a single Mn^{2+} ion.

A sample containing a layer of CdTe/ZnTe QD doped with individual Mn^{2+} ions is grown by Molecular Beam Epitaxy. Prior to any measurement a uniform ~ 1 μm layer of negative photoresist (SU-8 2002) is spin-coated on its surface. The laser emitting at 3.06 eV is used as the light source for both: PL excitation and for photoresist exposure. The power density of tens of mW/cm^2, found to not affect the photoresist, is applied for the μ-PL measurement. The power density of tens of W/cm^2 is applied for the photoresist exposure. The μ-PL mapping and *in situ* photolithography is performed in a cold finger helium cryostat at T = 10 K. The photoresist is wet developed, and as a result, permanent spots above the selected QDs are formed on the sample surface (see Fig. 1). Next, the sample is placed in a pumped helium cryostat at T = 1.5 K for μ-PL measurements in magnetic field up to 10 T. Laser beam is focused to ~ 3 μm spot on the sample surface in both experimental setups.

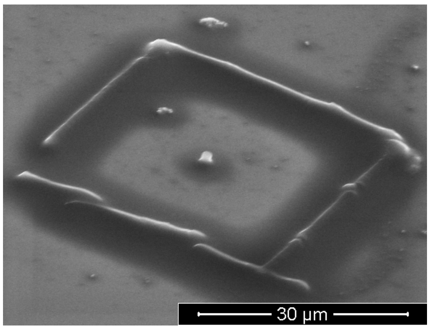

Figure 1: Scanning electron microscopy image of the sample surface. A spot in the center of the square indicates position of a selected CdTe/ZnTe QD with a single Mn^{2+} ion.

Evolution with magnetic field of the sixfold-split QD exciton line coming from the marked QD with a single Mn^{2+} ion is observed in Faraday and, after rotation of the cryostat for 90°, in Voigt configuration. The experimental data is well reproduced with a theoretical model[3] for both configurations of the field.

The ease of application and flexibility of the presented technique allows one to extend its application to other systems. In particular, it is expected to be useful in the case of systems requiring high energy of the PL excitation like NV centers in diamond.

[1] K. H. Lee *et al.* *Appl. Phys. Lett.* **88**, 193106 (2006).
[2] A. Dousse *et al.* *Phys. Rev. Lett.* **101**, 267404 (2008).
[3] J. Kobak *et al.* *Nat. Commun.* **5**, 3191 (2014).