# Determination of strain-related spin Hamiltonian parameters by angle-dependent optically detected magnetic resonance

**A. Bogucki, M. Goryca, W. Pacuski and P. Kossacki**

*Faculty of Physics, Institute of Experimental Physics, University of Warsaw, ul. Pasteura 5, 02-093 Warszawa, Poland*

Full coherent control of single magnetic transition-metal impurities in semiconductor system has not been achieved so far. To perform such experiments one has to know as much as possible about spin Hamiltonian of particular ion. For example manganese ion $Mn^{2+}$, which has electron spin equal to S=5/2, in the first approximation is considered as isotropic. However in more advanced studies it is crucial to take into account the influence of the surrounding crystal environment - in particular effect of strain. For bulk crystals detailed studies of spin Hamiltonian were performed, e.g., with electron paramagnetic resonance (EPR) technique [1,2]. Although EPR method is sensitive enough for bulk crystals and large superlattices, it is impractical for single nanostructures. Great improvement of sensitivity can be achieved by combining the EPR with optical spectroscopy. In this work we use optically detected magnetic resonance (ODMR) which is based on coupling between the spins and photo generated carriers [3,4]. Such an approach allows for extremely precise determination of spin Hamiltonian of manganese ion in single (Cd,Mn)Te/(Cd,Mg)Te quantum well (QW). Moreover, by varying the orientation of the magnetic field we were able to obtain full information about strain Hamiltonian parameters in studied QWs, including its in-plane anisotropy.

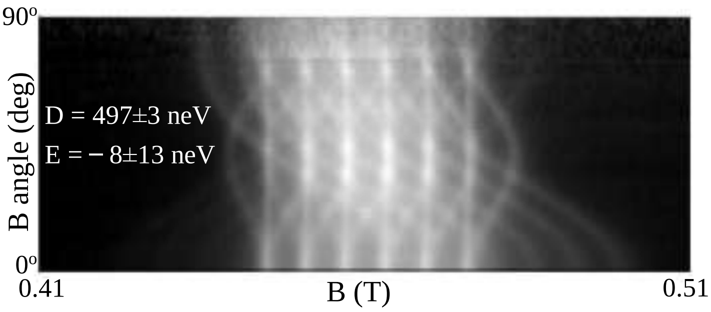


Fig. 1. ODMR angular map of (Cd,Mn)Te/(Cd,Mg)Te QW. Intensity of map is proportional to microwave absorption. Vertical axis corresponds to the direction between the magnetic field and samples' growth axis.

The sample used in the experiment contains a single (Cd,Mn)Te quantum well with Mn content equal to about 0.2%. The sample is excited by microwave radiation produced inside a planar waveguide short-circuited at the end. The sample is kept at pumped helium temperature in a cryostat placed inside a superconductive magnets providing magnetic field up to 3 T. Two perpendicular pairs of superconductive coils enable rotation of magnetic field in one plane. The waveguide is driven with a microwave current at frequencies of about 13 GHz. The heating of the magnetic ions system occurs for the magnetic fields and microwave frequencies corresponding to the paramagnetic resonance. This results in a decrease of the giant Zeeman shift of the photoluminescence lines related to charged and neutral exciton recombination. ODMR measurements for different angles in Voigt geometry as well as rotation of magnetic field from Faraday to Voigt geometry enable extremely accurate determination of zero-field interaction parameters related to the strain of the investigated quantum well with resolution as good as few nano electron volts.

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[3] A.V. Komarov, *et al., JETP* **46**, 318 (1977)
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