Spin-dependent Coupling of Charged Quantum Dot Excitons with Continuum States

Bernhard Urbaszek[1,2], Richard J. Warburton[1], Khaled Karrai[3], Christian Schulhauser[3], Alexander Högele[3], Ewan J. McGhee[1], Alexander O. Govorov[4], Brian D. Gerardot[5], X. Marie[2], T. Amand[2] and Pierre M. Petroff[5]

[1] School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh EH14 4AS, UK
[2] Laboratoire de Nanophysique, Magnétisme et Optoélectronique, INSA, 135 avenue de Rangueil, 31077 Toulouse Cedex 4, France
[3] Center for NanoScience and Sektion Physik, Ludwig-Maximilians-Universität,Geschwister-Scholl-Platz 1, 80539 München, Germany
[4] Department of Physics and Astronomy, Ohio University, Athens, Ohio USA
[5] Materials Department, University of California, Santa Barbara, California 93106, USA

The discrete nature of optical transitions in individual semiconductor quantum dots can be described by an artificial atom model and has stimulated proposals for using dots in quantum information devices. Whereas interactions of discrete quantum dot states and continuum states from the wetting layer are usually regarded as a source of incoherence [1] they can also give rise to a new type of coherent interaction [2].

Here we report magnetic field (0 to 9T) temperature dependent (4 to 30K) photoluminescence (PL) on neutral and charged excitons in individual InAs quantum dots. By placing dots in a MISFET structure we are able to create neutral, singly, doubly and triply (X3-) charged excitons by applying a small bias [3]. This approach allows us to uncover different mechanisms by which the discrete quantum dot states are allowed to couple to delocalised continuum states [4].

We focus on the X3- exciton. For a symmetric dot, the S=1 initial state (two parallel spins, one in the px, the other in the py-state) is favoured and the emission consisting of a narrow line and a lifetime broadened peak at lower energy can be described by taking only discrete states into account [3].

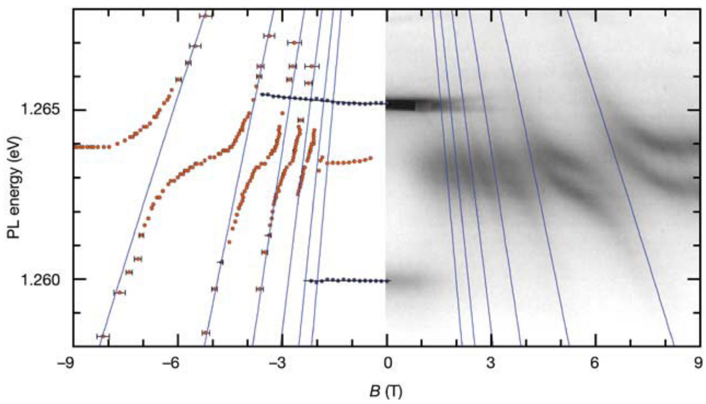

Fig. 1. Photoluminescence from the triply charged exciton versus magnetic field at 4K.

In a magnetic field above about 1 T, the S=0 initial state of the X3- is favoured (two anti-parallel spins in the px-state). In this case, the emission has a very large linewidth. We argue that the final state of the S = 0 X3- is responsible for the broadening as it couples efficiently to the energetically higher lying continuum states. For weakly confined p-states, this coupling initially introduces incoherence. At high magnetic fields Landau levels form in the continuum of wetting layer states. The discrete quantum dot states can couple coherently to these Landau levels [2] giving rise to a series of anti-crossings (see Fig.1).

Occupation of the wetting layer is found to promote the S=0 X3- over the S=1, analogous to a magnetic field. In this case, the X3- emission becomes broad with dot- and energy-dependent features. On increasing the temperature, a sharp, well defined line emerges despite the complexity of the S=1 spectrum and despite the presence of the electrons in the wetting layer. We assign this sharp line to emission from the thermally occupied S=1 initial state into the S = 3/2 final state both from its energy and from the emergence of the singlet (S = 1/2 final state) at lower energy [3]

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[2] K.Karrai *et al*, Nature 427, 135 (2004)
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