HL 12 Symposium Quantum optics in semiconductors I

Time: Tuesday 11:15–13:15 Room: HSZ 01

Keynote Talk HL 12.1 Tue 11:15 HSZ 01

Single Photon Nanotechnology based on Semiconductor Quantum Dots — •A. J. Shields — Quantum Information Group, Toshiba Research Europe Ltd, 260 Cambridge Science Park, Milton Road, Cambridge CB4 0WE UK

The potential application of quantum optics in areas such as secure optical communications and ultra-fine imaging has stimulated research on novel components for the generation and detection of single photons. We summarise here progress on quantum photonics based on integrating semiconductor quantum dots into conventional semiconductor devices. The electroluminescence of a single quantum dot in a p-i-n junction can be used to realise a light emitting diode (LED) for single photons.[1] We describe here recent work on incorporating cavities to enhance the emission efficiency,[2] control the polarisation of the emission,[3] as well as gating schemes to reduce the jitter in the emission time and exceed GHz repetition rates.[4] Engineering the dot nanostructure allows the emission wavelength to be tuned to the fibre optic transmission band at 1300nm.[5] We show also that quantum dots integrated inside resonant tunnelling diodes make efficient, low noise detectors of single photons.[6]

[1] Yuan et al, Science 295, 102 (2002)
[2] Bennett et al, Appl. Phys. Lett. 86, 181102 (2005)
[3] Unitt et al, Phys. Rev. B 72, 033318 (2005)
[4] Bennett et al, Phys. Rev. B 72, 033316 (2005)
[5] Ward et al, Appl. Phys. Lett. 86, 201111 (2005)
[6] Blakesley et al, Phys. Rev. Lett. 94, 067401 (2005)

Keynote Talk HL 12.2 Tue 11:45 HSZ 01

Size-tunable exchange interaction in InAs/GaAs quantum dots — •U. W. Pohl, A. Schliwa, R. Seguin, S. Rodt, K. Pötschke, and D. Bimberg — Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin

A systematic variation of the exciton fine-structure splitting ranging from above 500 μeV to -80 μeV was found in self-organized InAs/GaAs quantum dots of decreasing, well-defined sizes [1]. This finding is of basic interest for novel applications in e.g. quantum cryptography and logics. The assignment of the dependency was enabled by the recently reported multi-modal size distribution of equally shaped dots in our ensembles [2], providing a major step towards controlling the exchange interaction of confined excitons and resulting properties. We will discuss the origin of such intriguing dot ensembles and show how the comprehensive knowledge of structural dot properties advances understanding and control of excitonic properties. Comparison with model calculations allow statements on the main effects governing the electronic states, yielding the degree of correlation and piezoelectricity as key parameters being responsible for exciton binding energy and fine-structure splitting, respectively.

[1] R. Seguin et al., Size-dependent fine-structure splitting in self-organized InAs/GaAs quantum dots, Phys. Rev. Lett., in print.
[2] U. W. Pohl et al., Evolution of a multimodal distribution of self-organized InAs/GaAs quantum dots, Phys. Rev. B, in print.

Keynote Talk HL 12.3 Tue 12:15 HSZ 01

Quantum Optics of Excitons in Semiconductors — •Heinrich Stolz — Institut für Physik, Universität Rostock,

The quantum optical properties of excitons,the bound states of the electron hole system at low and moderate densities in semiconductors are determined by the interplay between the fermionic nature of their constituents and the interaction with the bosonic photon field. In semiconductors with reduced dimensionality we have in addition to take the breakdown of the k-selection rule due to the modified symmetry and due to the always present disorder into account. This leads to a large variety of effects, which go beyond those in normal atomic quantum optics.

In this talk, the properties connected with the spontaneous radiative decay of excitons will be considered in more detail. In a coherently driven state this leads to the phenomena of resonance fluorescence (RF), which in a 2d quantum well shows up as the driven specularly reflected light and the spontaneous radiation in arbitrary directions. In a real quantum well, the latter is superimposed by the disorder induced Rayleigh scattering. By doing optical homodyning of the resoannce fluorescence under quasi-monochromtic resonant excitation, the reflected light shows strong phase-dependend noise, in contrast to what is expected from the usual semiclassical picture. In the same range of excitation powers, the spectral shape of the RF changes dramatically by developing side wings similiar to the well known Mollow triplet in atomic RF. Both effects can be explained by the simple picture of an ensemble of two-level system. Applying in addition high spatial resolution, we are able to resolve RF from single exciton states and clarifiy their dependence on the disorder.

Keynote Talk HL 12.4 Tue 12:45 HSZ 01

Microscopic Theory of Semiconductor Quantum Optics — •Mackillo Kira and Stephan W. Koch — Philipps-University Marburg

Quantum optical properties of semiconductors are investigated on the basis of a microscopic theory that includes the quantized light field, Coulomb interacting fermionic electrons and holes, as well as phonons at the same consistent level. The theory is evaluated for a wide range of phenomena including excitonic photoluminescence, entanglement in incoherent emission, and squeezing in resonance fluorescence. The results provide the microscopic foundation of quantum-optical spectroscopy where one generates and detects quasi-particle states in semiconductors whose quantum-statistical properties are governed by that of the exciting light.

References:

[1] S. Chatterjee et al., Phys. Rev. Lett. 92, 067402 (2004).
[2] W. Hoyer et al., Phys. Rev. Lett. 93, 067401(2004).
[3] M. Kira and S.W. Koch, Phys. Rev. Lett. 93, 076402 (2004).
[4] M. Kira and S.W. Koch, E. Phys. J. D 36, 143 (2005).