FM 38: Enabling Technologies: Quantum Dots, Quantum Wires, Point Contacts and Excitonic Systems

Time: Tuesday 14:00–16:00 Location: 3043

FM 38.1 Tue 14:00 3043

Real-time detection of Auger recombination in a self-assembled quantum dot — •Pia Lochner[1], Annika Kurzmann[1], Jens Kerski[1], Philipp Stegmann[1], Jürgen König[1], Rüdiger Schott[2], Andreas D. Wieck[2], Arne Ludwig[2], Axel Lorke[1], and Martin Geller[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany

Auger recombination is a non-radiative process, where the recombination energy of an electron hole pair is transferred to a third charge carrier. In colloidal quantum dots (QDs), this is a common effect, which quenches the radiative emission with recombination times in the order of ps [R. Vaxenburg, et al., Nano Lett. **15**, 2092 (2015).]. In self-assembled QDs it has become possible to observe Auger recombination only recently, with recombination times in the order of μs [A. Kurzmann, et al., Nano Lett. **16**, 3367 (2016).].

In this contribution, we use real-time measurements of the random telegraph signal [A. Kurzmann, et al., PRL, accepted (2019).] to investigate Auger recombination in a single self-assembled QD. This is coupled to a charge reservoir with a small tunneling rate in the order of ms^{-1}. We are able to detect every single Auger recombination, as well as the "resetting" of the quantum dot to the singly charged state by single electron tunneling. By changing the laser power for resonant trion excitation, we can precisely tune the Auger rate while the tunneling rate remains constant and can thus determine the corresponding statistics of the processes.

FM 38.2 Tue 14:15 3043

The development of the optically active gate-defined quantum dots — •Thomas Descamps[1], Feng Liu[1], Chao Zhao[1], Arne Ludwig[2], and Hendrik Bluhm[1] — [1]JARA-FIT Insitute Quantum Information, Forschungzentrum Jülich GmbH and RWTH Aachen Universit, 52074 Aachen, Germany — [2]Lehrstuhl für Angewandte Festkörperphysik, Rhur-Universität Bochum, D-44780 Bochum, Germany

GaAs gate defined quantum dots (GDQD) have been extensively studied as a platform for spin qubits. To improve the scalability, one method to transfer the information relies on the coupling of the electron spin to a photon. In this work, we pursue the coupling of the spin qubit to excitons in a new type of optically active gate-defined quantum dots.

FM 38.3 Tue 14:30 3043

LO-phonon emission by electrons from single-electron sources — •Clarissa Barratt, Lewis Clark, and Clive Emary — Joint Quantum Centre Durham-Newcastle, School of Mathematics, Statistics and Physics, Newcastle University, Newcastle Upon Tyne, NE1 7RU, UK

There is substantial interest in the use of dynamic quantum dots as sources of single electrons, both to explore fundamental issues off solid-state physics as well as pursue quantum-technology applications. This is due to their high accuracy and speed, and the high energy of injection [1].

In this contribution we consider the effect of longitudinal-optical-phonon emission on the relaxation of electrons from a single electron source. Previous approaches to modelling such systems have been semiclassical, using the classical probability distribution only [2].

We derive the complete quantum master equation for this system which takes into account the coherence terms of the density matrix as well as the population previously considered. Our aim is to have a full quantum mechanical description of the electron transport process. These results will be used to calculate arrival times of the electrons, as well as for input into potential future experiments.

[1] Giblin, S. P. et al., An accurate high-speed single-electron quantum dot pump, NJP 12, 073013 (2010)

[2] Emary, C. et al., Phonon emission and arrival times of electrons from a single-electron source, PRB 93, 035436 (2016)

FM 38.4 Tue 14:45 3043

Probing Formation of Conductive Mesocrystalline Superlattice of Nanocrystals on Liquid/Air Interface by in-situ X-ray Scattering — •Santanu Maiti[1,2], Sonam Maiti[2], Andrey Chumakov[3], Marcus Scheele[1], and Frank Schreiber[1] — [1]Forschungszentrum Jülich, Jülich, Germany — [2]University of Tuebingen, Tuebingen, Germany — [3]European Synchrotron Radiation Facility (ESRF), Grenoble, France

Directional cross-linking of organic semiconductors (OSC) with nanocrystals (NC) produces superlattices exhibiting novel structural and electronic properties [1,2]. We will present the result of a study on the in-situ formation of conductive, iso-oriented mesocrystalline superstructures with cubic PbS NCs at the acetonitrile/air interface, investigated simultaneously by grazing incidence small angle X-ray scattering (GISAXS) and grazing incidence X-ray diffraction (GIXD) in real-time [3]. We observe a continuous contraction of superlattices with elapsed time, preserving their superlattice symmetries and attribute these contractions to the complete replacement of native oleic acid ligands with small OSC cross-linker cobalt/copper tetraaminophthalocyanine [4]. Such investigations provide crucial visualizations into the formation mechanism of such nanostructures, which already find applications. [1] M. Scheele et al., Phys. Chem. Chem. Phys. 17, 97 (2015) [2] S. Maiti et al., J. Phys. Chem. Lett. 9, 739 (2018) [3] S. Maiti et al., J. Phys.: Condens. Matter 29, 095101 (2017) [4] S. Maiti et al, J. Phys. Chem. C 123, 1519 (2019)

FM 38.5 Tue 15:00 3043

Tracking wavepacket dynamics through a conical intersection in an organic photovoltaic oligomer aggregate — Ephraim Sommer[1], Xuan Trung Nguyen[1], Lynn Gross[2], Thomas Frauenheim[2], Elena Mena-Osteritz[3], Peter Bäuerle[3], Christoph Lienau[1], and •Antonietta De Sio[1] — [1]Institut für Physik, Universität Oldenburg — [2]BCCMS, Universität Bremen — [3]Institut für organische Chemie II und neue Materialien, Universität Ulm

Conical intersections(CoIns) of potential energy surfaces may profoundly influence the dynamics and yield of energy and charge transfer processes. So far, however, their importance for the dynamics in organic photovoltaics (OPV) materials has not yet been discussed. Here we use two-dimensional electronic spectroscopy, with sub-10-fs time resolution, to probe the light-induced dynamics in an acceptor-donor-acceptor oligomer aggregate used in efficient OPV devices. Upon impulsive optical excitation, we detect a grid-like peak pattern suggesting coherent wavepacket motion in the excited state. After <50 fs, this pattern completely transforms into a broader and nearly featureless single peak. Concurrently, we observe an increase of oscillation period and an abrupt vanishing of the optically excited wavepacket, followed by the emergence of a new one with different oscillatory components. Our experimental results, supported by nonadiabatic excited state molecular dynamics simulations, show that ultrafast energy transfer in stacked dimers of this oligomer thin film involves passage of the optically excited wavepacket through an intermolecular CoIn within <50 fs.

FM 38.6 Tue 15:15 3043

Charge Reconfiguration in Isolated Quantum Dot Arrays — •Johannes C. Bayer, Timo Wagner, Eddy P. Rugeramigabo, and Rolf J. Haug — Institut für Festkörperphysik, Leibniz Universität Hannover, Hanover, Germany

The quantum dot device is based on a GaAs/ALGaAs heterostructure. Up to four lateral quantum dots in series are defined by potentials applied to metallic Schottky gates. Two quantum point contacts in the vicinity are used as charge detectors, allowing real-time detection of electrons tunneling through the array [1, 2].

In the isolated regime, charge detectors are utilized to observe charges tunneling inside the quantum dot array. Our highly tunable device allowed the investigation of isolated double, triple and quadruple quantum dot configurations. Experimental results are complemented by simulations, which enable the identification of the different transitions occurring in these systems. Tunable higher order tunneling transitions between non-neighboring quantum dots are observed for triple and quadruple quantum dot arrays [3, 4].

References

[1] T. Wagner, *et. al.*, Nat. Nanotechnol. **12**, 218-222 (2017).
[2] T. Wagner, *et. al.*, Nat. Phys. **15**, 330-334 (2019).

[3] J. C. Bayer, *et. al.*, Phys. Rev. B **96**, 235305 (2017).
[4] J. C. Bayer, *et. al.*, Ann, Phys (Berlin), **531**, 1800393 (2019).

FM 38.7 Tue 15:30 3043

Quantum State Transfer in Quantum Dot Arrays — Jordi Picó-Cortés, Yue Ban, Sigmund Kohler, and •Gloria Platero — Instituto de Ciencia de Madrid, CSIC

The effect of ac electric fields on the transport properties of low dimensional systems has been a topic of intense research in the last years. Applying ac electric fields to coupled quantum dots allows to transfer charge between them by means of photo-assisted transitions. Experiments in triple quantum dots unambiguously show direct electron transfer between the outer dots, without the participation of the intermediate region other than virtual, thus minimizing the effect of decoherence and relaxation . In the presence of ac driving the direct transfer of electrons between distant dots takes place by means of photo-assisted virtual transitions. I will focus on a protocol for preparing a quantum state at the left edge of a triple quantum dot and directly transferring it to the right edge by means of ac gate voltages. I will show that by the controlled generation of dark states it is possible to increase the fidelity of the transfer protocol . I will discuss as well other protocols which allow for long range charge transfer in quantum dot arrays, as coherent transfer by adiabatic passage (CTAP). I will show how these protocols can be speeded up by shortcuts of adiabaticity. Furthermore, it allows for long range transfer of two electron entangled states in quantum dot arrays with high fidelity. The proposed protocols offer an alternative and robust mechanism for quantum information processing.

FM 38.8 Tue 15:45 3043

Dephasing of Andreev bound states revealed by iterative summation of path integrals — •Stephan Weiss and Jürgen König — Theoretische Physik, Universität Duisburg-Essen, Lotharstr. 1, 47048 Duisburg & CENIDE

Multiple coherent reflections of electrons at superconductor/normal conductor interfaces lead to Andreev bound states (ABS), which have an energy that is smaller than the superconducting gap. As Andreev bound states are current-carrying, they may be probed within quantum-transport measurements. Coupling to a normal metal induces dephasing. We investigate a minimal model, which exhibit a tuneable ABS spectrum, i.e. an interacting quantum dot with a single spin-degenerate level that is brought into proximity to a superconductor. Iterative path-integral summations [1-3] are carried out to obtain the tunnelling current. Our method is numerically exact and treats spin-dependent resonant-tunnelling processes in a natural manner [2,3]. It furthermore allows to take into account small to intermediate Coulomb interactions. A tunnel-coupled normal metal is used to monitor the spectrum of the quantum dot together with the induced dephasing of the Andreev bound states over a wide range of gate- and bias voltages at finite temperatures [3].

[1] S. Weiss, et. al, Phys. Stat. Sol. B, 250, 2298 (2013).
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