FRI 12: Quantum Phenomena in Solid-State Devices

Time: Friday 10:45–12:30 Location: ZHG105

FRI 12.1 Fri 10:45 ZHG105

Probing many-body correlations using quantum-cascade correlation spectroscopy — •Thomas Volz — School of Mathematical and Physical Sciences, Macquarie University, Sydney, Australia

In quantum optics, the radiative quantum cascade is of fundamental importance. Two-photon cascaded emission has been instrumental for example to test Bell inequalities and generate entangled photon pairs. These experiments rely on the nonlinear nature of the underlying energy ladder, which enables the direct excitation and probing of specific single-photon transitions. Here we use exciton-polaritons to explore the cascaded emission of photons in the regime where individual transitions are not resolved. We excite a polariton quantum cascade by off-resonant laser excitation and probe the emitted luminescence using a combination of a narrow spectral filter and a Hanbury-Brown and Twiss setup for measuring the second-order autocorrelation function of the photons. The measured photon-photon correlations exhibit a strong dependence on the polariton energy and therefore on the underlying polaritonic interaction strength, with clear signatures of Feshbach resonances due to two- and three-body excitonic complexes, shedding new light on earlier observations of photon autocorrelations in resonant transmission. We not only establish photon cascade correlation spectroscopy as a highly sensitive tool to study the underlying quantum properties of novel semiconductor materials and many-body quantum phenomena. Our findings also highlight the potential of semiconductor exciton-polariton systems for generating single-photon non-linearities.

FRI 12.2 Fri 11:00 ZHG105

X-ray parametric down-conversion reveals EUV-polariton — •Christina Bömer — Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

Spontaneous parametric down-conversion (PDC) of photons is a gateway into the quantum realm. On the occasion of 100 years of Quantum Physics, we present a study of the effect in the x-ray regime and report the observation of a novel hybrid-state of light and matter that emerges from this fundamental nonlinear process. In our experiment, single x-ray photons are spontaneously converted by a diamond crystal into photon pairs. Of each pair, one photon is tuned to the extreme-ultraviolet (EUV) spectral range, where its coupling to the surrounding diamond is so strong that photonic and electronic properties hybridize: This forms the EUV-polariton. Remarkably, the hybridization occurs without an enhancement cavity, which marks a stark contrast to the prevalent paradigm of strong-coupling in cavities. The EUV-polariton links quantum hybridization in the microscopic domain to meso- and macroscopic length scales via its cavity-free propagation. This offers enticing prospects for studying buried interfaces and nanostructures using the polariton itself as a probe.

FRI 12.3 Fri 11:15 ZHG105

Single polycyclic aromatic molecular emitters embedded in a hexagonal boron nitride stack — •Tianyu Fang, Ricardo Gioia Alvarez, and Daqing Wang — Institut für Angewandte Physik, Universität Bonn, Wegelerstraße 8, 53115 Bonn, Germany

Single polycyclic aromatic hydrocarbon molecules embedded in solid-state matrices have been proven an excellent platform for narrow-linewidth single-photon emission. We extend this host-guest setting to van der Waals materials to leverage the advantages of flexible hybrid integration. By encapsulating perylene molecules between hexagonal boron nitride stacks, we observe spectrally narrow single-photon emission at cryogenic temperatures. We determine the exact emission origins through vibronic spectra assignment and resolve 0-0 zero-phonon-line linewidths down to the GHz scale.

FRI 12.4 Fri 11:30 ZHG105

Electron-hole quantum dots in bilayer graphene — •Christoph Stampfer[1,2], Katrin Hecker[1], Lars Mester[1], Hubert Dulisch[1], Konstantinos Kontogeorgiou[3], Simone Sotgiu[1], Fabian Hassler[3], and Christian Volk[1,2] — [1]JARA-FIT and 2nd Institute of Physics A, RWTH Aachen University, Aachen, Germany, EU — [2]Peter Grünberg Institute (PGI-9), Forschungszentrum Jülich, Jülich, Germany, EU — [3]JARA-Institute for Quantum Information, RWTH Aachen University, 52056 Aachen, Germany, EU

Here we show that bilayer graphene allows the realization of electron-hole double quantum dots that exhibit near-perfect particle-hole symmetry, in which transport occurs via the creation and annihilation of single electron-hole pairs with opposite quantum numbers. We demonstrate that particle-hole symmetric spin and valley textures lead to a protected single-particle spin-valley blockade. The latter will allow robust spin-to-charge and valley-to-charge conversion, which are essential for the operation of spin and valley qubits. By time-resolved measurements where we apply a dual pulse between the (0e, 0h) to (1e, 1h) charge configurations we study unconventional higher order tunneling processes which are able to lift the blockade. Extracting the timescales of blockade lifting and investigating the main mechanisms in the strong lead-quantum dot coupled system, allows us to confirm the state degeneracies. Combined with microwave control, the presented spin-valley blockade will enable the study of spin and valley coherence times by electron spin-resonance or electron dipole spin-resonance techniques, and open the door for spin and valley qubit operation.

FRI 12.5 Fri 11:45 ZHG105

Interplay between Hund's rule and Kondo effect in the third shell of a quantum dot — •Olfa Dani[1], Johannes C. Bayer[1,2], Timo Wagner[1], Gertrud Zwicknagl[3], and Rolf J. Haug[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Hannover, Germany — [2]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [3]Institut für Mathematische Physik, Technische Universität Braunschweig, Braunschweig, Germany

We study electron transport in the third shell [1] of a gate-defined quantum dot in a GaAs/AlGaAs two-dimensional electron gas. The device structure allows the precise determination and controlled variation of the number of electrons (N) occupying the quantum dot [2]. We observe zero-bias anomalies (ZBAs) with unexpected large widths for successive filling of the shell of the quantum dot. The ZBAs display a characteristic particle-hole symmetry for the three spin-degenerate orbital states. The broad widths of the ZBAs are attributed not only to the contribution of a Kondo resonance but also to the presence of excited Hund multiplets [3]. The role of Hund's rule exchange is further supported by the triangular trend of the charging energy as function of N in the third shell. The quantum dot is viewed as a multi-orbital Kondo impurity with Hund's interaction and serves as a model system for a Hund's coupled impurity.

[1] L. P. Kouwenhoven, et. al., Rep. Prog. Phys. 64, 701-736 (2001).
[2] T. Wagner, et. al., Nat. Phys.15, 330-334 (2019).
[3] O. Dani, et. al., arXiv: 2505.21675 (2025).

FRI 12.6 Fri 12:00 ZHG105

Hybrid optomechanics with double quantum dots — •Victor Ceban — Institute of Applied Physics, Moldova State University, Chisinau, Moldova

The quantum dynamics of a hybrid optomechanical device made of a double quantum dot (DQD) interacting with phonons and photons had been investigated. The system dynamics is solved for the cases when one bosonic field is multi-mode and the other is single-mode. The contribution of the multi-mode field is treated via the reservoir theory, within the Born and Markov approximations, and a set of corresponding damping terms are introduced into the master equation which describes the system dynamics. The behaviour of different optomechanical devices can be described via the proposed model where the single-mode field describes either photons in an optical cavity or phonons in a nanomechanical resonator, while the contribution of the multi-mode field is given by the electromagnetic vacuum or a thermal phonon bath. Here we present the effect of the environmental (phonon/photon) reservoir on the single-mode (photon/phonon) field due to the interaction with the DQD.

FRI 12.7 Fri 12:15 ZHG105

Atomic-size contacts obtained from lithographically fabricated electrodes using electromigration at room temperature in ambient condition and under vacuum — •Samanwita Biswas[1], Werner Wirges[1], Thomas Hultzsch[1], Marcel Strohmeier[2], Annika Zuschlag[2], Sarah Loebner[1], Dieter Neher[1], Elke Scheer[2], and Regina Hoffmann-Vogel[1] — [1]University of Potsdam — [2]University of Konstanz

Developing tunable yet stable atomic junctions for molecular electronics has always been challenging. The standard electrode material for molecular electronics is Au because of its electronic simplicity and resistance to chemical reaction making it easy to use. Pd, with its d-bands contributing to the charge transport and its relatively low Fermi energy is interesting for establishing good electrical contact to low-dimensional materials. In our study we explore the charge transport of electron beam lithography patterned Pd nanocontacts with a width of about 100nm.Via electromigration (EM) we have further narrowed them down to a cross section of few atoms and eventually reaching also the one atomic contact limit. We have conducted EM in nitrogen atmosphere in a glove box and under vacuum. The experiments under vacuum have been performed using a mechanically controlled break junction setup in combination. Atomic force microscope and scanning electron microscope measurements indicate successful EM. The conductance histograms from both experiments show comparable results.