FM 81: Enabling Technologies: Quantum Materials

Time: Thursday 14:00–16:00 Location: 3042

Invited Talk FM 81.1 Thu 14:00 3042

Electrostatically defined quantum devices in bilayer graphene
— •Christoph Stampfer — JARA-FIT and 2nd Institute of Physics, RWTH Aachen University, 52074 Aachen Germany — Peter Grünberg Institute (PGI-9), Forschungszentrum Jülich, 52425 Jülich, Germany, E

Graphene and bilayer graphene (BLG) are attractive platforms for quantum circuits. This has motivated substantial efforts in studying quantum dot (QD) devices based on graphene and BLG. The major challenge in this context is the missing band-gap in graphene, which does not allow confining electrons by means of electrostatics. A widely used approach to tackle this problem was to introduce a hard-wall confinement by etching the graphene sheet. However, the influence of edge disorder, turned out to be a road block for obtaining clean QDs. The problem of edge disorder can be circumvented in clean BLG, thanks to the fact that this material offers a tuneable band-gap in the presence of a perpendicularly applied electric field, a feature that allows introducing electrostatic soft confinement in BLG. Here we present gate-controlled single, double, and triple dot operation in electrostatically gaped BLG. We show a remarkable degree of control of our device, which allows the implementation of two different gate-defined electron-hole double-dot systems with very similar energy scales. In the single dot regime, we reach the very few hole regime, extract excited state energies and investigate their evolution in a parallel and perpendicular magnetic field.

FM 81.2 Thu 14:30 3042

Quantized conductance in topological insulators revealed by the Shockley-Ramo theorem
— Paul Seifert[1,2,3], Marinus Kundinger[1,2], Gang Shi[4], Xiaoyue He[4], Kehui Wu[4], Yongqing Li[4], Alexander Holleitner[1,2], and •Christoph Kastl[1,2] — [1]Walter Schottky Institut and Physics Department, Technical University of Munich, Am Coulombwall 4a, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, 80799 Munich, Germany — [3]ICFO-Institut de Ciencies Fotoniques, Castelldefels, Barcelona, 08860, Spain — [4]Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China

Materials with topological order promise coherent transport phenomena even in the presence of disorder and potentially at room temperature. Here, we image the local conductance of helical surface modes in the prototypical topological insulators Bi_2Se_3 and $BiSbTe_3$. We apply the Shockley-Ramo theorem to design an optoelectronic probe circuit for the surface states, and find a conductance quantization at e^2/h without any external magnetic field. The unprecedented response is a signature of local spin-polarized transport, and it can be switched on and off via an electrostatic field effect. The read-out does not require coherent transport between electrodes, in contrast to the Landauer-Büttiker description. It provides a generalizable platform for non-trivial gapless systems, such as Weyl-semimetals and quantum spin-Hall insulators. [1] P. Seifert et al. Quantized Conductance in Topological Insulators Revealed by the Shockley-Ramo Theorem. Phys. Rev. Lett. 122, 146804 (2019).

FM 81.3 Thu 14:45 3042

Scalable production of optical elements for photonics with quantum emitters
— •Fiammetta Sardi, Thomas Kornher, Roman Kolesov, Ferdinand Schiller, and Jörg Wrachtrup — 3rd Physics Institute, University of Stuttgart, Stuttgart, Germany

We show different methods to enhance the emission of quantum emitters, such as V_{Si} in SiC and rare-earth ions in $LiNbO_3$. We demonstrate a scalable way of manufacturing solid-immersion lenses (SILs) on 4H-silicon carbide (SiC) to enhance collection efficiency of fluorescence of silicon vacancy defect centers. The fabrication process is based on thermal reflow of a lithographically defined photoresist mask followed by high selectivity reactive ion etching. The procedure results in SILs with high effective NA. The fluorescence collection efficiency enhancement of 3.4 times is confirmed by confocal microscopy of individual V_{Si} centers. We show optical measurements of thin-film $LiNbO_3$ based optical microdisk resonators. Structured with scalable fabrication techniques, we achieved Q-factors of 10^5 with mode volume of $25 \cdot (\lambda/n)^3$, providing the possibility of $\sim$ 300 Purcell enhancement of resonant emitters within these structures. Owing to electro-optic properties of lithium niobate, the resonators are electrically tunable over the range of 300 GHz. Once activated with rare-earth ions, lithium niobate resonators present a flexible and scalable platform for cavity QED with single rare-earth emitters.

FM 81.4 Thu 15:00 3042

Anisotropic CVD growth of diamond pillars for Scanning-NV-Magnetometry
— •Arne Götze[1,2], Christian Giese[1], Volker Cimalla[1], and Oliver Ambacher[1,2] — [1]Fraunhofer IAF, Freiburg, Germany — [2]Chair for Power Electronics, INATECH, Uni Freiburg, Germany

The technique of Scanning-NV-Magnetometry promises to be a valuable tool for sciences and the industry. By fitting a diamond nanopillar containing single or multiple NV centers to an atomic force microscope, magnetic fields can be measured with high spatial resolution and sensitivity. The current method to produce these diamond tips is to perform lithography and use an oxygen plasma etch process. NV centers are created by nitrogen-ion implantation and annealing. Both of these process steps damage the diamond lattice around the NV center, whose spin coherence time and magnetic sensitivity deteriorate in consequence. By utilising anisotropic diamond growth in CVD (chemical vapour deposition) reactors we show that it is possible to create diamond pillars without introducing crystalline damage in the vicinity of the NV centers in the tip of the pillars. The properties of the resulting diamond tips, as well as limitations and opportunities of this process are discussed.

FM 81.5 Thu 15:15 3042

Parametric instabilities in a 2D periodically-driven bosonic system
— •Thomas Boulier[1], James Maslek[1], Marin Bukov[2], Carlos Bracamontes[1], Eric Magnan[1], Samuel Lellouch[3], Eugene Demler[4], Nathan Goldman[5], and James V. Porto[1] — [1]JQI, NNIST and UMD, College Park, Maryland 20742 USA — [2]Univ. of California Berkeley, CA 94720, USA — [3]LPLAM, Universite Lille 1, CNRS; F-59655 Villeneuve d'Ascq, France — [4]Harvard University, Cambridge, MA 02138, USA — [5]CNPCS, Universite Libre de Bruxelles, CP 231, Campus Plaine, B-1050 Brussels, Belgium

A promising approach to engineer new states of matter is to rapidly oscillate some parameters, so-called Floquet engineering, where new properties can emerge that are not present in the static system. Such oscillations carry energy which can be absorbed, and one might expect heating. Energy absorption in interacting many-body systems is an interesting open question with practical implications for quantum engineering. Recently, theoretical work predicted that for interacting bosons, Floquet systems can be inherently unstable. We experimentally confirm this prediction with a Bose-Einstein condensate in a periodically shaken 2D optical lattice. At large shaking amplitude, circular drives heat faster than linear drives, which illustrates the non-trivial dependence on the drive geometry. In all cases, we demonstrate that the BEC decay is dominated by the emergence of unstable Bogoliubov modes, rather than scattering in higher Floquet bands. We also report an unexpected additional heating, pointing to effects beyond current theories.

FM 81.6 Thu 15:30 3042

Large and tunable valley splitting in a ^{28}Si/SiGe quantum dot
— •Tom Struck[1], Arne Hollmann[1], Veit Langrock[1], Andreas Schmidbauer[2], Floyd Schauer[2], Helge Riemann[3], Nikolay V. Abrosimov[3], Dominique Bougeard[2], and Lars R. Schreiber[1] — [1]JARA-FIT Institute Quantum Information, Forschungszentrum Jülich GmbH and RWTH Aachen University, Germany — [2]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Regensburg, Germany — [3]Leibniz-Institut für Kristallzüchtung (IKZ), Berlin, Germany

^{28}Si has proven to be the host material of choice for electron spin qubits trapped in electrostatically defined quantum dots (QDs) [1,2]. A major challenge for Si/SiGe is the low valley splitting E_{VS} hampering qubit control. Here we investigate E_{VS} of a ^{28}Si/SiGe QD in a molecular-beam epitaxy-grown heterostructure with a residual ^{29}Si concentration of less than 60 ppm. We extract E_{VS} from the T_1 spin relaxation time as a function of magnetic field. We measure a large $E_{VS} > 200\,\mu$eV, which we can reproducibly tune by voltages applied to the depletion-gates. Investigating several mechanisms, we identify displacement of the QD with respect to atomistic details at the Si/SiGe interface as the dominant tuning mechanism.

[1]Yoneda, J. et al. A > 99.9%-fidelity quantum-dot spin qubit with coherence limited by charge noise. Nature Nanotechnology 13,102-106(2017).
[2]Veldhorst, M. et al. A two-qubit logic gate in silicon. Nature 526, 410-414 (2015).

FM 81.7 Thu 15:45 3042

Towards high-temperature coherence-enhanced transport in few-atomic layers heterostructures — •Chahan Kropf[1], Angelo Valli[2], Paolo Franceschini[4], Luca Celardo[3], Massimo Capone[2], Claudio Giannetti[4], and Fausto Borgonovi[1] — [1]Istituto Nazionale di Fisica Nucleare, Sezione di Pavia, via Bassi 6, I-27100 Pavia, Italy — [2]Scuola Internazionale Superiore di Studi Avanzati (SISSA), and CNR-IOM DEMOCRITOS, Istituto Officina dei Materiali, Consiglio Nazionale delle Ricerche, Via Bonomea 265, I-34136 Trieste, Italy — [3]Benemérita Universidad Autónoma de Puebla, Apartado Postal J-48, Instituto de Física, 72570, Mexico — [4]ILAMP (Interdisciplinary Laboratories for Advanced Materials Physics), Università Cattolica del Sacro Cuore, Brescia I-25121, Italy

The possibility to exploit quantum coherence to enhance the efficiency of charge transport in solid state devices working at ambient conditions would pave the way to disruptive technological applications. We tackled the problem of the quantum transport of photogenerated electronic excitations subject to dephasing, on-site Coulomb interactions, and an intrinsic electric potential in one-dimensional wires. Using quantum master equations and density-mean-field-theory we show that the transport to a continuum of states representing metallic collectors can be optimized by exploiting the "superradiance" phenomena. This is a coherent effect which we estimate to be robust against dephasing and electron-electron interactions in a parameters range that is compatible with actual implementation in few monolayers transition-metal-oxide (TMO) heterostructures.