HL 70: Spin phenomena in semiconductors

Time: Thursday 15:00–16:45 Location: POT 251

HL 70.1 Thu 15:00 POT 251

Spin noise spectroscopy for nuclear relaxation dynamics in InGaAs epilayer — •Clara Rittmann, Aleksandr Kamenskii, Alex Greilich, and Manfred Bayer — Experimentelle Physik II, Technische Universität Dortmund, 44221 Dortmund, Germany

We study the dynamic nuclear spin polarization in Indium Gallium Arsenide (InGaAs) epilayer under the circular excitation using a spin noise spectroscopy. The sample consists of a 10μm thick epitaxial layer of n-doped InGaAs with 3% of Indium, grown on a GaAs substrate. First, we characterize the unperturbed spin dynamics of resident electrons using the spin noise technique. It allows us to determine the spin relaxation time and the g-factor of the electron system. Further, we discover that an additional off-resonant circular excitation has a strong effect on the Larmor precession of the electron spins, without affecting the spin noise amplitude. This is related to the dynamic nuclear polarization by the optically oriented spins, which in their turn are affected by the induced Overhauser field, produced by the nuclear system. Finally, we study the common time evolution of the electron-nuclear system detecting the spin noise of the residual electrons.

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High-throughput computational discovery of $In_2Mn_2O_7$ as a high Curie temperature ferromagnetic semiconductor for spintronics — •Wei Chen[1], Janine George[1], Joel B. Varley[2], Gian-Marco Rignanese[1], and Geoffroy Hautier[1] — [1]Institute of Condensed Matter and Nanoscicence (IMCN), Université catholique de Louvain, Louvain-la-Neuve 1348, Belgium — [2]Lawrence Livermore National Laboratory, Livermore, California 94550, USA

Robust ferromagnetism and attractive semiconducting properties are critical for achieving highly spin-polarized transport in spintronic devices, yet combining the two requirements in one material remains an open problem. Here we conduct a search for concentrated ferromagnetic semiconductors through high-throughput computational screening of over 40000 known compounds. Among the very few identified ferromagnetic semiconductors, we show that the manganese pyrochlore oxide $In_2Mn_2O_7$, hitherto unknown to spintronic applications, is particularly promising for spin transport as it combines a low electron effective mass (0.29 m_0), a large exchange splitting of the conduction band (1.1 eV), good stability in air, and a Curie temperature (130 K) among the highest of concentrated ferromagnetic semiconductors. We rationalize the high performance of $In_2Mn_2O_7$ by the unique hybridization among O-2p, Mn-3d, and In-5s states. We further find that Sn and Mo can be effectively incorporated on the In site while acting as shallow donors, indicative of n-type dopability.

HL 70.3 Thu 15:30 POT 251

Spatial and temporal evolution of electron spins in [110] grown GaAs quantum wells — •Karl Schiller, Sergiu Anghel, and Markus Betz — Experimentelle Physik 2, Technische Universität Dortmund, Otto-Hahn-Straße 4a, 44227 Dortmund, Germany

Spin-orbit interaction (SOI) is a key mechanism in manipulating electron spins in non-centrosymmetric semiconductor heterostructures and can be understood in terms of an effective magnetic field $B_{\rm eff}$ acting on the moving electrons. At the same time, the SOI can serve as a source of dephasing (D'yakonov-Perel mechanism), as the precession frequency becomes dependent on the electron trajectory. However, this mechanism is suppressed in [110] quantum wells (QWs) for spins aligned along the same direction as the $B_{\rm eff}$ and, consequently, long spin lifetimes can be achieved [1].

We have investigated spatial and temporal evolution of optically injected spin distributions for QWs with different thicknesses. For that, we have used non-degenerate and time-resolved magneto-optic Kerr rotation microscopy. The output of a mode-locked Ti:Sapphire oscillator is split into circularly polarized pump pulse at 1.57 eV, which excites a spin distribution, and linear polarized probe pulse to detect it, with its energy depending on the QW thickness. We have observed pronounced anisotropic spin diffusion between the [001] and [1$\bar{1}$0] directions for QW thicknesses of 20 nm, 14 nm and 9.6 nm.

[1] Y. Ohno et al., Phys. Rev. Lett. **83**, 4196 (1999)

HL 70.4 Thu 15:45 POT 251

Extended electron spin dephasing in isotopically purified ZnSe — •Phillip A. Greve[1], Evgeny A. Zhukov[1], Erik Kirstein[1], Nataliia Kopteva[2], Irina A. Yugova[1,3], Alexander Pawlis[4], Dimitri R. Yakovlev[1,5], Alexander Greilich[1], and Manfred Bayer[1] — [1]Experimentelle Physik Technische Universität Dortmund 44221 Dortmund Germany — [2]Spin Optics Laboratory, St. Petersburg State University, Ul'anovskaya 1, Peterhof, St. Petersburg 198504, Russia — [3]Physical Faculty of St. Petersburg State University, 198504 St. Petersburg, Russia — [4]Department Physik, Universität Paderborn, 33098 Paderborn, Germany — [5]Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia

We demonstrate a very long spin dephasing time of electrons bound to defect centers in fluorine-doped isotopically purified ZnSe epilayer. The sample was implanted with fluorine after the MBE growth, which led to a broad defect band of high PL intensity about 0.5 eV under the free exciton transition of ZnSe. Using a time-resolved pump-probe Kerr rotation technique, we were able to measure a dephasing time over 300 ns at cryogenic temperatures. The g factor of 2 indicates a strong localization of electrons. The state characteristics and dependencies on temperature, magnetic field, and sample structure are discussed.

HL 70.5 Thu 16:00 POT 251

Absence of giant Rashba effect in the valence band of CsPbBr3 — •Maryam Sajedi[1,2], Maxim Krivenkov[1,2], Dmitry Marchenko[1], Andrei Varykhalov[1], Jaime Sánchez-Barriga[1], and Oliver Rader[1] — [1]Helmholtz Zentrum Berlin für Materialien und Energie, Albert Einstein Str 15, D-12489, Berlin, Germany — [2]Department of physics, Potsdam University, Am Neuen Palais 10, D-14415, Potsdam Germany

We have employed spin- and angle-resolved photoemission spectroscopy of CsPbBr3 single crystal to verify the presence of Rashba spin-orbit coupling effect in the highest lying occupied state. We uncover the entire three-dimensional Brillouin zone (BZ) momentum-space, and the dispersion of the topmost bulk valence band (VB) at high symmetry R-point. We use density functional theory (DFT) calculations to compare the ground state electronic structure of the particular perovskite compound with corresponding dispersive bands from photoemission (PES) experiments. By direct experimental evidence from the results of spin-resolved band structure experiments, we exclude a large Rashba effect in the global valence band maximum (VBM) at R-point of bulk BZ.

HL 70.6 Thu 16:15 POT 251

Single-shot spin readout of a spin qubit in silicon measured using a neural network — •Tom Struck[1], Javed Lindner[1], Arne Hollman[1], Floyd Schauer[2], Dominique Bougeard[2], and Lars Schreiber[1] — [1]JARA-FIT Institute Quantum Information, RWTH Aachen University, Germany — [2]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Regensburg, Germany

Spin qubits have proven to be a promising candidate for quantum computing, with the field advancing quickly in recent years. One challenge is the fast and reliable qubit state detection. A popular method used for single-shot read-out of an electron spin qubit is spin-selective tunnelling [1,2] combined with charge readout by a single electron transistor (SET). Depending on the qubit's spin state, the SET senses an approx. 60 pA current rise with a statistically distributed timing. Reliable and fast interpretation of the current trace is particularly challenging. Here we compare the traditional current threshold analysis with current trace classification by a neural network. This spin-state classifier is highly noise resilient, allowing a decrease in measurement time by a factor of five. The calculation time per trace is only 30 μs, rendering the implementation of fast-feedback loops possible. [1] J. M. Elzerman et al., Nature 430, 431 (2004) [2] Arne Hollman et al. arXiv:1907.04146v1

HL 70.7 Thu 16:30 POT 251

Spin relaxation induced by valley-orbit coupling in a single Si quantum dot — •Amin Hosseinkhani and Guido Burkard — Department of Physics, University of Konstanz, Germany

The spin of isolated electrons in Silicon quantum dot heterostructures is a promising candidate for quantum information processing. While

silicon offers weak spin-orbit coupling and nuclear-spin free isotopes, the valley degree of freedom in silicon couples to spin and can degrade the qubit performance by opening a relaxation channel. We build on the effective mass theory and find exact solutions for the envelope function of a single quantum dot along the applied electric field. We take into account a few miscuts at the Si/barrier interface and study how the wavefunction evolves in the magnetic field. We then obtain the valley phase and splitting for a single quantum dot spin qubit as a function of the applied magnetic and electric field. These enable us to develop the theory of spin-relaxation induced by valley-orbit coupling. We show that it is important to consider all four physical spin-valley states into the qubit logical states in order to describe the qubit relaxation.