HL 79: Quantum information systems: Si vacancies and NV centers (with TT)

Time: Thursday 15:00–17:00 Location: ER 164

HL 79.1 Thu 15:00 ER 164

Spin Physics of vacancy-related defects in silicon carbide — •Michel Bockstedte[1,2] and Felix Schütz[1] — [1]Lst. Theor. Festkörperphysik, Friedrich-Alexander Universität Erlangen-Nürnberg, 91058 Erlangen, Germany — [2]FB Materialwissenschaften & Physik, Universität Salzburg, 5020 Salzburg, Austria

SiC as a semi conductor fullfills all necessary requirements[1] for implenting qubits via defect electron spins, such as the silicon vacancy, the di-vacancy or a complex of a silicon vacancy and a nitrogen impurity. The spin-selective fluorescence in contrast to the prototypical NV-center in diamond operates in the spectral range favorable for telecom applications. Spin-manipulation of the intrinsic centers was demonstrated even at room temperature.[2,3] For the silicon vacany in SiC inter system crossings (ISCs) from high to yet unknown low spin states govern the spin-relaxation. By DFT and a DFT-based CI-hamiltonian we analyze the spin physics of the defect in 4H-SiC. Experimentally observed luminescence lines can be assigned to the inequivalent defect sites corobarating the experimental findings. Owing to the spin (S=3/2) and a stronger electron-phonon coupling in the excited state, ISCs destinct from the NV-center are predicted.

[1] J. R. Weber *et al.*, PNAS **107**, 8513 (2010).
[2] F. Koehl *et al.*, Nature**479**, 84 (2011).
[3] V. A. Soltamov *et al.*, Phys. Rev. Lett. **108** 226402 (2012)

HL 79.2 Thu 15:15 ER 164

SiC nano-crystalline NIR emitters based on optically excited and spin polarized defects — •F. Fuchs[1], A. Muzha[2], N. Tarakina[3,4], D. Simin[1], M. Trupke[5], P. Baranov[6], V. Dyakonov[1,3,7], A. Krueger[2,3], and G. Astakhov[1] — [1]Exp. Physics VI, University of Würzburg — [2]Institute of Organic Chemistry, University of Würzburg — [3]Wilhelm Conrad Röntgen RCCM, University of Würzburg — [4]Exp. Physics III, University of Würzburg — [5]Vienna Center for Quantum Science and Technology, TU Wien — [6]Ioffe Institute, St. Petersburg — [7]ZAE Bayern, Würzburg

The unification of luminescent markers for bioimaging and spin centers for quantum sensing [1] is challenging; especially when aiming for the ideal NIR window, stability and non-toxicity. Bulk silicon carbide (SiC) is a favored candidate despite its large band gap, which we could mitigate by the introduction of silicon vacancy defects—exhibiting NIR emission—via neutron irradiation. With a milling procedure, we fabricated SiC nano crystals ranging from 600nm down to 60nm in size, with a further fragmentation of the latter into clusters of high crystalline quality (size ca. 10 nm) separated by amorphous material. The luminescence of the vacancies persists in all size fractions, moreover, we detected room-temperature spin resonance [2]. This leads to new perspectives: defects in nano crystalline SiC as in-vivo luminescent markers and simultaneously as magnetic field or temperature sensors [3].

[1] Riedel et al.: Phys. Rev. Lett. 109, 22 (2012)
[2] Fuchs et al. arXiv: 1409.0756v1
[3] Kraus et al.: Sci. Rep. 4, 5303 (2014)

HL 79.3 Thu 15:30 ER 164

Coherent Spin Manipulation of Si-Vacancies in Silicon Carbide at Ambient Conditions — •Dmitrij Simin[1], Andreas Sperlich[1], Victor Soltamov[2], Pavel Baranov[2], Georgy Astakhov[1], and Vladimir Dyakonov[1,3] — [1]Experimental Physics VI, Julius Maximilian University of Wuerzburg, 97074 Wuerzburg — [2]Ioffe Physical-Technical Institute, 194021 St. Petersburg, Russia — [3]ZAE Bayern, 97074 Wuerzburg

For already over two decades, quantum information processing has been the hot topic in the field of information theory. To recognize and to employ the most suitable material and information carrier from the vast amount of possibilities is the declared goal of ongoing research activities all over the world. Among others, a promising candidate are Si-vacancies in Silicon Carbide [1], where spin control has been successfully conducted at ambient conditions [2, 3]. In our recent work we go one step further and present the successful time-resolved manipulation of the spin of the Si-Vacancies at ambient conditions using the pulsed-ODMR technique. We observed Rabi-oscillations in an ensemble of defects and determined spin-relaxation properties, demonstrating high potential of SiC for various quantum applications.

[1] D. Riedel et al., Phys. Rev. Lett. 109, 226402 (2012)
[2] H. Kraus et al., Nat. Phys. 10, 157-162 (2014)
[3] H. Kraus et al., Sci. Rep. 4, 5303 (2014)

HL 79.4 Thu 15:45 ER 164

Charge state control of nitrogen-vacancy centers in diamond — •Patrick Simon[1], Moritz V. Hauf[1], Ankit Rathi[1], Philipp Neumann[2], Helmut Fedder[2], Jörg Wrachtrup[2], Friedemann Reinhard[1,2], and Jose A. Garrido[1] — [1]Walter Schottky Institut, Physik-Department,Technische Universität München, Am Coulombwall 4, 85748 Garching, Germany — [2]3. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

The nitrogen-vacancy (NV) defect in diamond is a promising candidate for quantum information processing or sensing purposes. In most applications reliable control of the charge state of the NV is of utmost importance.

In this work we demonstrate that the charge state of NV centers can be controlled using an in-plane gated diamond nanostructure based on selective surface termination. Applying a gate voltage changes the band bending at the hydrogen terminated diamond surface such that reversible charge state switching is enabled. We observed full control of NVs from a non-fluorescent state, potentially NV^+, across NV^0 to NV^-

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Investigating the positively charged nitrogen-vacancy center in diamond as a long lived quantum memory — •Matthias Pfender[1], Nabeel Aslam[1], Christian Burk[1], Denis Antonov[1], Sebastian Zaiser[1], Helmut Fedder[1], Philipp Neumann[1], Patrick Simon[2], José A. Garrido[2], Martin Stutzmann[2], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart — [2]Walter Schottky Institut, Technische Universität München

The nitrogen-vacancy defect in diamond is one of the major candidates for a solid-state quantum processor. Its electron spin can be readout and initialized optically. Adjacent nuclear spins (e.g. ^{14}N, ^{15}N, ^{13}C) can be employed as inherently robust qubits [1], readout is facilitated via the electron spin in a QND measurement with T_1 lifetimes of several minutes. However, for strongly coupled nuclear spins, the coherence time is limited by the T_1 lifetime of the electron spin ($\approx$ 5ms). In Si:P, this obstacle could be overcome by ionizing the P donor to a spinless charge-state [2]. In this work, we employ in-plane gate structures to deterministically switch the charge state of near-surface NVs from NV^- over NV^0 to NV^+ [3], while investigating the electron spin properties using the nitrogen nuclear spin as a probe. Since the positive charge state has no unpaired electrons, the nuclear spin coherence time is prolonged beyond the 5ms imposed by the NV^- electron spin.

[1] Waldherr, G. et al., Nature 506, 204 (2014).
[2] Saeedi, K. et al., Science 342, 830 (2013).
[3] Hauf, M. V. et al., Nano Lett. 14, 2359 (2014).

HL 79.6 Thu 16:15 ER 164

A cavity-mediated quantum CPHASE gate between nitrogen-vacancy electronic spin qubits in diamond — •Guido Burkard[1] and David Awschalom[2] — [1]Department of Physics, University of Konstanz, D-78457 Konstanz, Germany — [2]Institute for Molecular Engineering, University of Chicago, Chicago, IL 60637, USA

While long spin coherence times and efficient single-qubit quantum control have been implemented successfully in nitrogen-vacancy (NV) centers in diamond, the controlled coupling of remote NV spin qubits remains challenging. Here, we propose and analyze a controlled-phase (CPHASE) gate for the spins of two NV centers embedded in a common optical cavity and driven by two off-resonant lasers. In combination with previously demonstrated single-qubit gates, CPHASE allows for arbitrary quantum computations. The coupling of the NV spin to the cavity mode is based upon Raman transitions via the NV excited states and can be controlled with the laser intensities and relative phase. We find characteristic laser frequencies at which a laser photon is only scattered into the cavity mode if the NV center spin is $|m_s = 0\rangle$, and not in the case $|m_s = -1\rangle$, or vice versa. The scattered photon can be reabsorbed by another selectively driven NV center and generate a conditional phase (CPHASE) gate. Gate times below 20 ns are within reach, several orders of magnitude shorter than typical NV spin coherence times. The separation between the two NV centers is only limited by the extension of the cavity.

[1] G. Burkard, D. D. Awschalom, arXiv: 1402.6351 (2014).

HL 79.7 Thu 16:30 ER 164

Long-range two-qubit gate between nuclear spins in diamond mediated via an optical cavity — •Adrian Auer and Guido Burkard — Department of Physics, University of Konstanz, D-78457 Konstanz, Germany

Nitrogen-vacancy (NV) centers in diamond represent a promising possibility for a solid-state based realization of a qubit due to their excellent electron- and nuclear-spin coherence properties. Single-qubit gates for the nitrogen nuclear spin have been implemented [1]. Here, we extend an earlier proposal [2] for cavity-mediated coupling between NV electron spins and develop a scheme to implement a universal two-qubit gate between ^{14}N or ^{15}N nuclear spins. By virtually exciting a single NV center with an external laser field, a photon can be scattered into a surrounding cavity; we show that this process depends on the spin state of the nitrogen nucleus. For the two-qubit gate, we consider two NV centers coupled to a common cavity mode and each being excited individually. Virtual cavity excitation can then mediate an effective interaction between the NV nuclear spin qubits, generating a controlled-Z gate. Operation times for the gate implementation are found to be below 100 nanoseconds, which is orders of magnitude faster than the decoherence time of nuclear spin qubits in diamond.

[1] S. Sangtawesin *et al.*, Phys. Rev. Lett. **113**, 020506 (2014).
[2] G. Burkard and D. D. Awschalom, arXiv:1402.6351.

HL 79.8 Thu 16:45 ER 164

Linear polarization properties of the NV^{-} center photoluminesence in diamond — •Dion Braukmann[1], Jörg Debus[1], Vladimir L. Korenev[2], Vitalii Yu. Ivanov[3], Dmitri R. Yakovlev[1], and Manfred Bayer[1] — [1]Experimentelle Physik 2, Technische Universität Dortmund, 44227 Dortmund, Germany — [2]Ioffe Physical-Technical Institute, Russian Academy of Science, 194021 St. Petersburg, Russia — [3]Institute of Physics, Polish Academy of Sciences, 02668 Warsaw, Poland

The negatively charged nitrogen-vacancy (NV^{-}) center in diamond has been studied in recent years on account of possible applications in quantum information processing, spin-electronics and, e.g., biophotonics. Particular focus has been drawn onto its optical properties. We report on polarization-dependent optical studies of NV^{-} centers in diamond subjected to high magnetic fields of up to 10 T. We observe asymmetric Zeeman splitting of the zero-phonon line photoluminescence, a strong optical alignment as well as Faraday rotation at room temperature. The linear polarization properties of the NV^{-} photoluminescence are studied as function of the diamond crystal orientation in the stationary and time-resolved regimes.