HL 87: Carbon: Diamond and others

Time: Friday 9:30–12:30 Location: POT 06

HL 87.1 Fri 9:30 POT 06

Towards optical dynamical nuclear spin polarization of metabolites — •Samuel Müller[1], Jochen Scheuer[1], Christoph Müller[1], Ilai Schwarz[2], Mathen Markham[3], Pelayo Fernandez-Acebal[2], Martin Plenio[1], Boris Naydenov[1], and Fedor Jelezko[1] — [1]Institut für Quantenoptik, Universität Ulm, Germany — [2]Institut für Theoretische Physik, Universität Ulm, Germany — [3]Element Six, Ltd., Ascot, UK

^{13}C magnetic resonance spectroscopy allows a wide range of new applications in magnetic resonance imaging and in a first clinical study this technique already has been demonstrated for imaging prostate cancer [1]. However, due to its small gyromagnetic ratio and low abundance of ^{13}C spins, hyperpolarization of the nuclear spins is required for increasing the sensitivity. In contrast to conventional methods for hyperpolarization at low temperatures and high magnetic field dynamical nuclear polarization (DNP) via optically pumped Nitrogen-Vacancy centers (NV) in diamond allows a high degree of polarization to be reached even at room temperature and low magnetic field. Here we demonstrate DNP of ^{1}H nuclear spins in different molecules on the diamond surface using single shallow NV centers. This is an important step towards nuclear spin hyperpolarization of biomarkers such as ^{13}C in metabolites, e.g. pyruvate.

[1] Nelson, Sarah J., et al. Science translational medicine (2013)

HL 87.2 Fri 9:45 POT 06

Precision measurements of electric fields using NV centers in diamond — •Julia Michl[1], Philipp Neumann[1], Andrej Denisenko[1], Junichi Isoya[2], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart, Germany — [2]Research Center for Knowledge Communities, University of Tsukuba, Japan

As a quantum sensor, the nitrogen vacancy center in diamond can be used most prominently for magnetometry but also for thermometry, piezometry and electrometry.

Whereas the usage of single NV centers can lead to exciting applications for spatial resolution in field imaging, the measurement of an NV ensemble allows for precision measurements. In this fashion, a sensitivity for magnetic fields of under 1 pT/Hz$^{1/2}$ was shown to be possible with an NV ensemble[1].

Here, we show the combination of the precision measurement on NV ensembles with measurement techniques for electrometry already reported for single NVs[2].

Even though the coupling of the NV center electron spin in its ground state to electric fields is comparatively small, the high precision which can be achieved due to the long coherence times of the NV centers even at room temperature raise the prospect of its application as a quantum based electrometer.

[1] T. Wolf et al., PRX, 2015 [2] M. Doherty, NJP, 2014

HL 87.3 Fri 10:00 POT 06

Sub-millihertz magnetic spectroscopy with a nanoscale quantum sensor — •Simon Schmitt[1], Tuvia Gefen[2], Felix M. Stürner[1], Thomas Unden[1], Gerhard Wolff[1], Christoph Müller[1], Jochen Scheuer[1,3], Boris Naydenov[1,3], Matthew Markham[4], Sebastien Pezzagna[5], Jan Meijer[5], Ilai Schwarz[3,6], Martin Plenio[3,6], Alex Retzker[2], Liam P. McGuinness[1], and Fedor Jelezko[1,3] — [1]Institute of Quantum Optics, Ulm University, 89081 Ulm, Germany — [2]Racah Institute of Physics, Hebrew University of Jerusalem, 91904 Jerusalem, Israel — [3]Center for Integrated Quantum Science and Technology (IQST), Ulm University, 89081 Ulm, Germany — [4]Element Six, Harwell Campus, Fermi Avenue, Didcot, OX11 0QR, United Kingdom — [5]Institut für Experimentelle Physik II, Universität Leipzig, 04103 Leipzig, Germany — [6]Institute for Theoretical Physics, Ulm University, 89081 Ulm, Germany

A general limit on the performance of quantum sensors is their coherence time since this sets the maximum time for coherent signal accumulation. Here we discuss a novel quantum sensing technique which allows a frequency resolution beyond the sensor coherence limit to be obtained. The technique also demonstrates an enhanced precision scaling not previously seen in quantum sensing scenarios. Using single nitrogen vacancy centres in diamond we apply this high resolution magnetometry technique to nanoscale NMR spectroscopy.

HL 87.4 Fri 10:15 POT 06

Efficient electrical spin readout of NV$^-$ centers in diamond — •Florian M. Hrubesch, Georg Braunbeck, Felix N. Hartz, Martin Stutzmann, Friedemann Reinhard, and Martin S. Brandt — Walter Schottky Institut and Physik-Department, Technische Universität München

Using pulsed photoionization the coherent spin manipulation and echo formation of ensembles of NV$^-$ centers in diamond are detected electrically realizing contrasts of up to 17 %. The underlying spin-dependent ionization dynamics are investigated experimentally and compared to Monte-Carlo simulations. This allows the identification of the conditions optimizing contrast and sensitivity which compare favorably with respect to optical detection [1].

[1] F. M. Hrubesch, G. Braunbeck, M. Stutzmann, F. Reinhard and M. S. Brandt, arXiv:1608.02459 (2016)

Coffee Break

HL 87.5 Fri 11:00 POT 06

Enhancement of the zero-phonon emission rate of an NV centre in minimally processed diamond — •Daniel Riedel, Patrick Maletinsky, and Richard J. Warburton — Department of Physics, University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland

The precise optical control of the coherent spin associated with the nitrogen vacancy (NV) centre in diamond enables both solid-state-based quantum information experiments and ultra-precise sensing. For future applications it is crucial to improve the interrogation frequency by engineering the photonic modes, for instance by embedding the NV centres into nanophotonic structures. A key challenge is to maintain a stable environment in the diamond in order to preserve the long optical and spin coherence times.

Here, for the first time, we report cavity-assisted Purcell enhancement of the zero-phonon line (ZPL) of a single NV centre in a minimally processed diamond membrane. The membrane is incorporated into a fully tunable Fabry-Perot microcavity, where photons are deterministically coupled to the TEM$_{00}$ mode rendering them suitable for long distance communication. We find a 20-fold enhancement of the ZPL emission photon flux, which corresponds to an overall change in the radiative lifetime from 11 ns out of resonance to 7 ns on resonance.

Our approach constitutes a promising route towards a scalable quantum-network based on solid-state emitters.

HL 87.6 Fri 11:15 POT 06

Wigner crystallization in graphene nanoribbons with zigzag edges — •Alev Devrim Guclu — Izmir Institute of Technology, Izmir, Turkey

We investigate the Wigner crystallization of electrons and holes at the zigzag edges of graphene nanoribbons using many-body configuration interaction method. We show that Wigner crystallization occurs at a surprisingly high electronic density of ~ 0.8 nm^{-1}. In contrast with one-dimensional electron gas, the flat-band structure of the edge states makes the system interaction dominated, facilitating the electronic localization. The Wigner localization is found to affect strongly the magnetic coupling between the nearest neighbor electrons, causing an antiferromagnetic-ferromagnetic phase transition. As the width of the ribbon is decreased to 11 Å, interedge coupling becomes important, hence increased kinetic energy overcomes the long-range Coulomb repulsion and suppresses the Wigner crystallization. Finally, we show that Wigner crystallization can also occurs for holes, albeit weaker than for electrons. This work was supported by The Scientific and Technological Research Council of Turkey (TUBITAK) under the 1001 Grant Project Number 114F331.

HL 87.7 Fri 11:30 POT 06

Voltage-dependent photocurrent spectroscopy in surface-conductive diamond devices — •Philipp Beck[1], Patrick Simon[1], Ankit Rathi[1], Jose A. Garrido[2], and Martin Stutzmann[1] — [1]Walter Schottky Institut und Physik-Department, Technische Universität München, Am Coulombwall 4, 85748 Garching, Germany — [2]Catalan Institute of Nanoscience and Nanotechnology (ICN2), CSIC and The Barcelona Institute of Science and Technology,

Campus UAB, Bellaterra, 08193 Barcelona, Spain

For many applications of nitrogen-vacancy (NV) centers in diamond especially in the field of quantum technology the understanding of their electronic addressability is highly desirable. Based on hydrogen-terminated and thus surface-conductive diamond enriched with NV centers, we fabricate an all diamond device based on selective surface oxidation for the creation of highly insulating potential barriers for surface-conducting holes with widths in the range of 50nm-500nm. Across these hydrogenated-oxidized lateral heterostructures we measure spectrally resolved photocurrent as a function of temperature and illumination intensity and examine the influence of nitrogen-related defects and other defect states on the observed photocurrents. Additionally, we explain a nonlinear I-U characteristics of the photocurrent in these devices by its specific electronic band structure and examine the potential of such structures for an electrical control of the spectral energy of selected defect states.

HL 87.8 Fri 11:45 POT 06

Ballistic and resonant negative photocurrents in single carbon nanotubes — •Carolina Duque Sierra, Christoph Karnetzky, Lukas Sponfeldner, Max Engl, and Alexander W. Holleitner — Walter Schottky Institute and Physics Department, Technical University of Munich, Am Coulombwall 4a, 85748 Garching, Germany

We present ultrafast photocurrent experiments on semiconducting, single-walled carbon nanotubes under a resonant optical excitation of their subbands. We demonstrate that a ballistic transport of the photogenerated charge carriers can be achieved. Moreover, thermionic emission processes to the contacts dominate the photocurrent. In contrast, the charge current without laser excitation is well described by a Fowler-Nordheim tunneling. The time-averaged photocurrent changes polarity as soon as sufficient charge carriers are injected from the contacts, which can be explained by an effective population inversion in the optically pumped subbands. We acknowledge the ERC via the project NanoREAL.

HL 87.9 Fri 12:00 POT 06

Fabrication of Dense Arrays of Nanocrystalline Diamond Nanopillars — •Alexander Schmidt, Johann Peter Reithmaier, and Cyril Popov — Institute of Nanostructure Technologies and Analytics, Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

One-dimensional diamond nanostructures, namely diamond nanopillars, have been prepared using nanocrystalline diamond (NCD) films as starting material. The fabrication process of arrays of nanopillars consisted of their definition by electron beam lithography (EBL) applying gold as a hard mask material and subsequent inductively coupled plasma reactive ion etching (ICP-RIE) with oxygen. Three different pillar diameters were investigated, namely 200, 100 and 50 nm, with different lateral distances ranging from 100 nm to 400 nm in order to determine the minimal resolution, which could be defined depending on the variation of a major process parameter in the EBL process – namely the exposure dose. Furthermore, its influence on the resulting shape of the pillars was investigated. The integration of NV centers within the fabricated diamond nanopillars either during the film growth or by follow-up ion implantation can be used to develop quantum memories.

HL 87.10 Fri 12:15 POT 06

Physics — •Dennis Oing — Uni Due

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