FM 30: Quantum Sensing: Applications I

Time: Tuesday 14:00–16:00 Location: Aula

Invited Talk FM 30.1 Tue 14:00 Aula

Quantum Sensors on the way to commercial opportunities — •Kai Bongs — Physics and Astronomy,University of Birmingham

The UK Quantum Technology Programme is set to reach 1bn GPB over the next few years. This programme is focused on realising the economic benefit promised by quantum technologies, with quantum sensors being a front-runner in industry engagement. I will report on the current developments and future plans of the UK National Quantum Technology Hub in Sensors and Timing and present the main application-led strands in moving forward.

FM 30.2 Tue 14:30 Aula

Single-atom quantum probes for ultracold gases using nonequilibrium spin dynamics — Quentin Bouton[1], •Jens Nettersheim[1], Daniel Adam[1], Tobias Lausch[1], Daniel Mayer[1], Felix Schmidt[1], Eberhard Tiemann[2], and Artur Widera[1] — [1]Department of Physics and Research Center OPTIMAS Technische Universität Kaiserslautern, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany

Quantum probes are atomic-sized devices mapping information of their environment to quantum mechanical states. By improving measurements and at the same time minimizing perturbation of the environment, they form a central asset for quantum technologies. Here, we present a realization of single-atom quantum probes for local thermometry based on the spin dynamic of individual neutral Caesium (probe) atoms in an ultracold gas (bath) of Rubidium atoms. The competition of inelastic endo- and exoergic spin-exchange processes map the temperature onto the quasi-spin population of the probe. The sensitivity of the thermometer can be adjusted via the external magnetic field changing the Zeeman energy splitting. Sensitivity can also be enhanced, if temperature information is obtained from the nonequilibrium dynamic, instead of the steady-state distribution, of the probe, maximizing the information obtained per inelastic collision and thus minimizing the perturbation of the bath. Moreover, our probe is not restricted to measure temperature, but it allows sensing any mechanism affecting the total collisional energy in a spin-exchange collision, such as the magnetic field.

FM 30.3 Tue 14:45 Aula

Quantum dots as charge detectors for nanoscale defect tomography — •Jens Kerski[1], Pia Lochner[1], Arne Ludwig[2], Andreas D. Wieck[2], Annika Kurzmann[1], Axel Lorke[1], and Martin Geller[1] — [1]Faculty of Physics and CENIDE, University Duisburg-Essen, Germany — [2]Chair of Applied Solid State Physics, Ruhr-University Bochum, Germany

Self-assembled semiconductor quantum dots (QDs) can be used as single-photon sources in visionary applications in quantum information technologies. However, spin and charge noise in the vicinity destroy the needed Fourier-transform limited linewidth [1].

In this contribution, we use a single quantum dot as a nanoscale electrometer to investigate the charging process of individual defects with electrons from the nearby n-doped back contact. Spectral and time-resolved resonance fluorescence measurements allow us to identify four nearby defect states by small shifts in the resonance energy of the exciton transition [2]. From the occupation probability of the individual states, the position of these defects in the growth direction, as well as their binding energy were determined. Their spatial position allowed to identify the states as defects.

Our results give rise to further investigations, e.g. triangulation of individual defects using multiple QDs, optical transport measurements at a single QD [3] and nanoscale low level transient spectroscopy.

[1] A. V. Kuhlmann et al., Nature Physics 9, 570-575 (2013).
[2] J. Houel et al., Phys. Rev. Lett. 108, 107401 (2012).
[3] A. Kurzmann et al., Phys. Rev. Lett. in press (2019).

FM 30.4 Tue 15:00 Aula

The photonic Bose–Einstein condensate as a precision quantum sensor — •Stefan Yoshi Buhmann[1,2] and Robert Bennett[1,2] — [1]University of Freiburg, Germany — [2]Freiburg Institute for Advanced Studies (FRIAS), Germany

Photonic Bose–Einstein condensates have recently been realised as a new quantum state of light. Here, the photons inside a driven dye-filled cavity macroscopically occupy the ground state. We demonstrate that this extreme selectivity of the ground state can be exploited to construct a quantum sensor for the intra-cavity medium.

We propose to monitor the polarisation degree of freedom of the photonic Bose–Einstein condensate signal emerging from the cavity [2]. When introducing anisotropic or chiral molecules into the cavity, this polarisation will be governed by the handedness or the orientation of these molecules, respectively. In this way, enantiomeric excess or molecular anisotropy can be monitored in real time with unprecedented precision [3].

[1] J. Klaers, J. Schmitt, F. Vewinger, M. Weitz, Nature **468**, 545 (2010).

[2] R. I. Moodie, P. Kirton, J. Keeling, Phys. Rev. A **96**, 043844 (2017).

[3] R. Bennett, Y. Gorbachev, S. Y. Buhmann, preprint arXiv:1905.07590 (2019).

FM 30.5 Tue 15:15 Aula

Quantum Technology Competence Center (QTZ) at PTB — •Nicolas Spethmann — Physikalisch-Technische Bundesanstalt (PTB), 38116 Braunschweig, Germany

Quantum technologies will have a substantial impact on German economy. PTB as the National Metrology Institute of Germany has a long tradition in quantum technology and performs world-leading research in several fields, with a focus on quantum sensing and metrology. Examples include, but are not limited to, precise quantum standards for electrical quantities, ultracold atoms and ion traps, sensitive sensors for magnetic fields, single photon sources and detectors and ultrastable and precise optical clocks. This expertise in quantum technology, together with PTB's mission to support industry in metrology as a governmental body, puts PTB into an ideal and natural position to transfer quantum technology from science to application in collaboration with industry and academia. For this task, PTB has recently established the Quantum Technology Competence Center (QTZ) at PTB. The QTZ will focus on the development of user-friendly and robust components for quantum sensing and metrology and on providing calibrations, services and user facilities accessible for external partners from industry and academia. Furthermore, QTZ will offer hands-on training and seminars for quantum technology and support start-ups. In my talk, I will introduce the QTZ and report on latest activities and future plans.

FM 30.6 Tue 15:30 Aula

Analyzing semiconductor quantum dot under mechanical strain tuning — •Marco Schmidt, Marcel Darmstädter, Sarah Fischbach, Arsenty Kaganskiy, Sven Rodt, Tobias Heindel, and Stephan Reitzenstein — Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany

Advanced applications of quantum information processing require sources of single, indistinguishable photons as well as polarization entangled photon pairs as key building blocks. Semiconductor quantum dots (QPs) are excellent single-photon emitters and accomplish these requirements. The spectral properties, e.g. emission energy, fine structure splitting and binding energy, of QPs determined by the self-assembled growth and and can be manipulated by applying external mechanical strain. We demonstrate a tunable single-photon source based on an InGaAs QD inside a thin GaAs membrane that is bounded to a piezoactuator via the flip-chip goldbonding technique. Optical and quantum optical studies of the system will be presented which include the stabilization of the QD emission energy, tuning of the fine structure splitting and quantum tomographic measurements to demonstrate the emission polarization entangled photon pairs.

FM 30.7 Tue 15:45 Aula

Experimental Saturation of the Heat-Bath Algorithmic Cooling bound — •Durga B Rao Dasari[1], Sebastian Zaiser[1], Chun Tung Cheung[2], Sadegh Raeisi[3], and Joerg Wrachtrup[1] — [1]3. Physics Institute, University of Stuttgart, Stuttgart, Germany — [2]Chinese University of HongKong, Shatin, HongKong, China — [3]Sharif University of Technology, Tehran, Iran

Heat-Bath Algorithmic cooling (HBAC) techniques provide ways to selectively enhance the polarization of target quantum subsystems. However, the cooling in these techniques is bounded. Here we report the first experimental observation of the HBAC cooling bound. We use HBAC to hyperpolarize nuclear spins in diamond. Using two carbon nuclear spins as the source of polarization (reset) and the 14N nuclear spin as the computation bit, we demonstrate that repeating a single cooling step increases the polarization beyond the initial reset polarization and reaches the cooling limit of HBAC. We benchmark the performance of our experiment over a range of variable reset polarization. With the ability to polarize the reset spins to different initial polarizations, we envisage that the proposed model could serve as a testbed for studies on Quantum Thermodynamics.