FM 57: Quantum Sensing: Spectroscopy I

Time: Wednesday 14:00–16:00 Location: 2006

Invited Talk FM 57.1 Wed 14:00 2006

Probing and manipulating Andreev Bound States — •Cristian Urbina[1], Leandro Tosi[1], Cyril Metzger[1], Marcelo F. Goffman[1], Hugues Pothier[1], Sunghun Park[2], Alfredo Levy Yeyati[2], Jesper Nygård[3], and Peter Krogstrup[3] — [1]Quantronics Group, SPEC (CNRS), CEA-Saclay, Université Paris-Saclay, France — [2]Departamento de Física Teórica de la Materia Condensada, Condensed Matter Physics Center (IFIMAC) and Instituto Nicolás Cabrera, Universidad Autónoma de Madrid, Spain — [3]Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen, Denmark

The quantum states on which information is stored and manipulated in currently implemented superconducting platforms correspond to bosonic electromagnetic modes of circuits made non-linear by Josephson junctions. I will present experiments on a radically different platform based on Andreev states, which are fermionic, microscopic states in superconducting weak links.

I will first present the coherent manipulation of Andreev states on a fully metallic weak link (a one-atom contact between two Al reservoirs) and then the spectroscopy of a semiconducting weak link (Al-InAs-Al) revealing a "fine structure" in the Andreev spectrum due to the strong spin-orbit coupling in InAs. Such devices could be used to coherently manipulate the spin of a single quasiparticle.

FM 57.2 Wed 14:30 2006

Quantum Sensing using the Stochastic Quantum Zeno Effect — •Matthias M. Müller — Institute of Quantum Control, Peter Grünberg Institut, Forschungszentrum Jülich

The dynamics of quantum systems are unavoidably influenced by their environment and in turn observing a quantum system (probe) can allow one to measure its environment: Dynamical decoupling sequences as an extension of the Ramsey interference measurement allow to spectrally resolve a noise field coupled to the probe [1]. Here, we report also on dissipative manipulations of the probe leading to so-called Stochastic Quantum Zeno (SQZ) phenomena that can be seen as an extension of the Rabi measurement. Recently, we could detect time correlations in the noise through an ergodicity breaking in SQZ dynamics [2], and the concept was experimentally demonstrated with a BEC on a chip [3]. We present a robust method to reconstruct an unkown spectrum from measurements of the survival probability of the SQZ dynamics.

[1] C. L. Degen, F. Reinhard, and P. Cappellaro, Rev. Mod. Phys. 89, 035002 (2017). [2] M.M. Müller, S. Gherardini, and F. Caruso, Sci. Rep. 6, 38650 (2016). [3] S. Gherardini, C. Lovecchio, M.M. Müller, P. Lombardi, F. Caruso, and F.S. Cataliotti, Quantum Science and Technology 2 (1), 015007 (2017). [4] M.M. Müller, S. Gherardini, A. Smerzi, and F. Caruso, Phys. Rev. A 94, 042322 (2016). [5] M.M. Müller, S. Gherardini, and F. Caruso, Scientific Reports 8, 14278 (2018).

FM 57.3 Wed 14:45 2006

Dynamical detection of dipole-dipole interactions in dilute atomic gases — •Benedikt Ames, Edoardo Carnio, Vyacheslav Shatokhin, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

Recent experimental studies have revealed collective effects in fluorescence spectra of dilute atomic gases using a pump-probe measurement scheme within phase-modulated nonlinear spectroscopy [1]. The corresponding spectral features can be discerned down to the lowest experimentally accessible densities of $\sim 10^7\,\mathrm{cm}^{-3}$, and can be interpreted as a sensitive probe of residual dipole-dipole interactions.

To provide a quantitative theoretical description of this phenomenology, we adapt an open quantum system treatment which was already employed [2] to model coherent backscattering from a dilute cloud of atomic (hence, manifestly quantum) scatterers. It includes the retarded interaction as mediated by the quantized vacuum field, and is hence valid across all length scales (or densities). Approximate analytical results are compared to a fully numerical treatment of the resulting master equation, and a first confrontation of our theoretical approach with published experimental data is presented.

[1] L. Bruder et al., Phys. Chem. Chem. Phys. **21**, 2276–2282 (2019)
[2] V. Shatokhin, C. Müller, A. Buchleitner, Phys. Rev. A **73**, 063813 (2006)

FM 57.4 Wed 15:00 2006

Robust optical clock transition in ^{40}Ca^{+} by dynamical decoupling — •Lennart Pelzer[1], Kai Dietze[1], Ludwig Krinner[1], Stephan Hannig[1], Nicolas Spethmann[1], Nati Aharon[2], Alex Retzker[2], Tanja E. Mehlstäubler[1], and Piet O. Schmidt[1,3] — [1]QUEST Institute for Experimental Quantum Metrology, Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem 91904, Israel — [3]Leibniz Universität Hannover, 30167 Hannover, Germany

Optical clocks based on single trapped ions are hindered by long averaging times caused by the quantum projection noise-limited statistical uncertainty. Long probe times on the order of many seconds would significantly reduce the statistical uncertainty. However, currently the phase coherence of available laser systems limits the probe time. We propose to improve the phase coherence of a laser by stabilizing it to a transition in a multi-ion crystal with a large signal-to-noise ratio. Relevant frequency shifts in a crystal of several hundred ^{40}Ca^{+} ions are canceled by employing a continuous dynamical decoupling scheme. Both Zeeman manifolds of the $S_{1/2} \leftrightarrow D_{5/2}$ clock transition in ^{40}Ca^{+} get doubly-dressed by four tailored driving RF-fields to form a robust optical clock transition, essentially free of homogeneous magnetic field and inhomogeneous electric quadrupole and tensor polarizability shifts as well as shifts due to amplitude fluctuations in the driving fields. Experimental results implementing this scheme in our segmented Paul-trap setup will be presented.

FM 57.5 Wed 15:15 2006

Rare-earth electron spin spectroscopy on single Ce^{3+}:YSO — •Thomas Kornher[1], Roman Kolesov[1], Kangwei Xia[2], Dawu Xiao[3], Fiametta Sardi[1], Nan Zhao[3], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart, Stuttgart, Germany — [2]Department of Physics, The Chinese University of Hong Kong, Shatin, Hong Kong, China — [3]Beijing Computational Science Research Center, Haidan District, Beijing, China

Experimental results on optically resolved single Ce^{3+} ions in yttrium orthosilicate (YSO) are presented. The electron spin associated with Ce^{3+} is initialized, and read-out optically at 4 K temperature. Coherent manipulation allows for probing the local environment of the electron spin and shows the influence of the yttrium bath onto the electron spin. Additionally, frozen core effects, predicted by ab initio calculations, can be observed. Spin-lattice relaxation time of $T_1 > 2.6$ ms was measured and spin coherence time T_2 is suggested to be T_1-limited by ab initio calculations. Furthermore, sensing of nearby ^{29}Si nuclear spins is investigated, since Ce^{3+} electron spin can potentially be exploited as interface between photons and proximal, long-lived nuclear spins, such as yttrium and ^{29}Si.

FM 57.6 Wed 15:30 2006

Spectroscopic precision probing of velocity-dependent atom-surface interactions — •Nico Strauss[1] and Stefan Yoshi Buhmann[1,2] — [1]University of Freiburg, Germany — [2]Freiburg Institute for Advanced Studies (FRIAS), Germany

The Casimir-Polder force between atoms or molecules and is of quantum mechanical origin and forms the basis of quantum friction, which is predicted to occur when two objects move at distance on the order of nanometers relative to each other. Frequency-selective reflection spectroscopy [1] is a tool for determining atomic transition frequencies and linewidths from a changes in the reflection coefficients of a modulated laser beam incident on the boundary between a dielectric and a gas of moving atoms. It is so sensitive that it has been successfully used to verify surface-induced shifts of the energies of extremely short-lived excited states. Here, we propose to push the limits of the tool a step further by detecting velocity-dependent surface-induced shifts of transmission frequencies and linewidths [2]. We start by laying out the basic theory of such velocity-dependent effects which are intricately related to quantum friction. We then discuss how motion-induced quantum vacuum effects are expected to manifest themselves in the reflection signal.

[1] J. Klatt, R. Bennett and S. Y. Buhmann, Phys. Rev. A **94**, 063803 (2016).

[2] M. Ducloy and M. Fichet, J. Phys. **II**, 1529 (1991).

FM 57.7 Wed 15:45 2006

Mid-Infrared Spectroscopy with Nonlinear Interferometers — •Chiara Lindner, Sebastian Wolf, Jens Kiessling, and Frank Kühnemann — Fraunhofer Institute for Physical Measurement Techniques IPM, Heidenhofstraße 8, 79110 Freiburg, Germany

Spontaneous parametric down-conversion (SPDC) is one of the most important sources for entangled photon pairs in quantum optics. Its application in nonlinear interferometers is the foundation of quantum imaging and spectroscopy. Nonlinear interferometers rely on a quantum effect: The signal photons of two SPDC-sources show interference if the corresponding idler photons are indistinguishable. Any absorption of the idler photons in between the sources lowers the visibility of both signal and idler interference contrast. This allows measuring the absorption and dispersion of samples in the mid-IR range by detecting the interference pattern of the visible photon counterparts.

In our work, we present a nonlinear interferometer for mid-infrared spectroscopy in Michelson-configuration. Hereby, we infer the spectral information on the mid-infrared light directly from the visible interference pattern without the need for spectral selection. Using non-collinear broadband SPDC created in a periodically poled lithium niobate crystal, our interferometer covers a large spectral bandwidth ($> 100\,\mathrm{cm}^{-1}$ in mid-infrared) in one single measurement. With different poling periods and crystal temperatures, an infrared spectrum ranging from 3.2-3.8 μm wavelength is demonstrated. Our experimental results are discussed and compared to other works in our field.