$^{88}Sr^{+}$ 445-THz Single-Ion Reference at the 10^{-17} Level via Control and Cancellation of Systematic Uncertainties and Its Measurement against the SI Second

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We describe experiments and measurements on a trapped and laser-cooled single ion of $^{88}Sr^{+}$ which, when probed on its reference $5s\ ^2S_{1/2} \rightarrow 4d\ ^2D_{5/2}$ transition at 445 THz, provides an optical frequency standard of evaluated accuracy outperforming the current realization of the SI second. Studies are presented showing that micromotion-associated shifts of the standard can be reduced to the 10^{-18} level and uncertainties in the blackbody-induced shifts for the current system are at the low 10^{-17} level due to the relatively well-known polarizability of the strontium ion system and careful choice of the trap structure. The current evaluated systematic shifts for the ion transition are at a fractional uncertainty of 2×10^{-17}. An absolute frequency measurement performed over a two-month period relative to a maser referenced to the SI second via Global Positioning System time transfer has determined the center frequency for the transition at ν_{SD}=444 779 044 095 485.5±0.9 Hz (1σ).

Observation of entanglement between a quantum dot spin and a single photon

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We report the observation of quantum entanglement between a semiconductor quantum dot spin and the colour of a propagating optical photon. The demonstration of entanglement relies on the use of fast, single-photon detection, which allows us to project the photon into a superposition of red and blue frequency components. Our results extend the previous demonstrations of single-spin/single-photon entanglement in trapped ions, neutral atoms and nitrogen–vacancy centres to the domain of artificial atoms in semiconductor nanostructures that allow for on-chip integration of electronic and photonic elements. As a result of its fast optical transitions and favourable selection rules, the scheme we implement could in principle generate nearly deterministic entangled spin–photon pairs at a rate determined ultimately by the high spontaneous emission rate. Our observation constitutes a first step towards implementation of a quantum network with nodes consisting of semiconductor spin quantum bits.

Giant spin orbit interaction due to rotating magnetic fields in graphene nanoribbons

Jelena Klinovaja and Daniel Loss
arXiv:1211.2739 [cond-mat.mes-hall]

We theoretically study graphene nanoribbons in the presence of spatially varying magnetic fields produced e.g. by nanomagnets. We show both analytically and numerically that an exceptionally large Rashba spin orbit interaction (SOI) of the order of 10 meV can be produced by the non-uniform magnetic field. As a consequence, helical modes exist in armchair nanoribbons that exhibit nearly perfect spin polarization and are robust against boundary defects. This paves the way to realizing spin filter devices in graphene nanoribbons in the temperature regime of a few Kelvins. If a nanoribbon in the helical regime is in proximity contact to an s-wave superconductor, the nanoribbon can be tuned into a topological phase sustaining Majorana fermions.

Tunneling Spectroscopy of Quasiparticle Bound States in a Spinful Josephson Junction

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arXiv:1211.3954 [cond-mat.mes-hall]

The spectrum of a segment of InAs nanowire, confined between two superconducting leads, was measured as function of gate voltage and superconducting phase difference using a third normal-metal tunnel probe. Sub-gap resonances for odd electron occupancy – interpreted as bound states involving a confined electron and a quasiparticle from the superconducting leads, reminiscent of Yu-Shiba-Rusinov states – evolve into Kondo-related resonances at higher magnetic fields. An additional zero bias peak of unknown origin is observed to coexist with the quasiparticle bound states.

RKKY interaction in carbon nanotubes and graphene nanoribbons

Jelena Klinovaja and Daniel Loss
arXiv:1211.3067 [cond-mat.mes-hall]

We study Rudermann-Kittel-Kasuya-Yosida (RKKY) interaction in carbon nanotubes (CNTs) and graphene nanoribbons in the presence of spin orbit interactions and magnetic fields. For this we evaluate the static spin susceptibility tensor in real space in various regimes at zero temperature. In metallic CNTs the RKKY interaction depends strongly on the sublattice and, at the Dirac point, is purely ferromagnetic (antiferromagnetic) for the localized spins on the same (different) sublattice, whereas in semiconducting CNTs the spin susceptibility depends only weakly on the sublattice and is dominantly ferromagnetic. The spin orbit interactions break the SU(2) spin symmetry of the system, leading to an anisotropic RKKY interaction of Ising and Moryia-Dzyaloshinsky form, besides the usual isotropic Heisenberg interaction. All these RKKY terms can be made of comparable magnitude by tuning the Fermi level close to the gap induced by the spin orbit interaction. We further calculate the spin susceptibility also at finite frequencies and thereby obtain the spin noise in real space via the fluctuation-dissipation theorem.

Fluctuation driven topological Hund insulator

Jan Carl Budich, Björn Trauzettel, and Giorgio Sangiovanni
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We investigate in the framework of dynamical mean field theory a two-band Hubbard model based on the Bernevig-Hughes-Zhang Hamiltonian describing the quantum spin Hall (QSH) effect in HgTe quantum wells. In the presence of interaction, we find that a system with topologically trivial non-interacting parameters can be driven into a QSH phase at finite interaction strength by virtue of local dynamical fluctuations. For very strong interaction, the system reenters a trivial insulating phase by going through a Mott transition. We obtain the phase diagram of our model by direct calculation of the bulk topological invariant of the interacting system in terms of its single particle Green's function.

Josephson effect in superconducting wires supporting multiple Majorana edge states

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We study superconducing-normal-superconducting (SNS) Josephson junctions in 1D topological superconductors which support more than one Majorana end mode. The variation of the energy spectrum with the superconducting phase is investigated by combining numerical diagonalizations of tight-binding models describing the SNS junction together with an analysis of appropriate low-energy effective Hamiltonians. We show that the 4π-periodicity characteristic of the fractional DC Josephson effect is preserved. Additionally, the ideal conductance of a NS junction with a topological supraconductor, hosting two Majorana modes at its ends, is doubled compared to the single Majorana case. Last, we illustrate how a non-zero superconducting phase gradient can potentially destroy the phases supporting multiple Majorana end states.

Dependence of the Dresselhaus spin-orbit interaction on the quantum well width

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We measured the Dresselhaus spin-orbit interaction coefficient β_1 for (001)-grown $GaAs/Al_{0.3}Ga_{0.7}As$ quantum wells for six different well widths w between 6 and 30 nm. The varying size quantization of the electron wave vector z-component $\langle k_z^2\rangle \sim (\pi/w)^2$ influences $\beta_1 = -\gamma\langle k_z^2\rangle$ linearly. The value of the bulk Dresselhaus coefficient $\gamma=(-11\pm2)$ eVÅ^3 was determined. We discuss the absolute sign of the Landé g factors and the effective momentum scattering times.