M. Grinolds, M. Warner, K. Greve, Y. Dovzhenko, L. Thiel, R. Walsworth, S. Hong, P. Maletinsky, A. Yacoby

Subnanometre resolution in three-dimensional magnetic resonance imaging of individual dark spins

Nature Nanotechnology **9**, 279–284 (2014)

Magnetic resonance imaging (MRI) has revolutionized biomedical science by providing non-invasive, three-dimensional biological imaging1. However, spatial resolution in conventional MRI systems is limited to tens of micrometres2, which is insufficient for imaging on molecular scales. Here, we demonstrate an MRI technique that provides subnanometre spatial resolution in three dimensions, with single electron-spin sensitivity. Our imaging method works under ambient conditions and can measure ubiquitous 'dark' spins, which constitute nearly all spin targets of interest. In this technique, the magnetic quantum-projection noise of dark spins is measured using a single nitrogen-vacancy (NV) magnetometer located near the surface of a diamond chip. The distribution of spins surrounding the NV magnetometer is imaged with a scanning magnetic-field gradient. To evaluate the performance of the NV-MRI technique, we image the three-dimensional landscape of electronic spins at the diamond surface and achieve an unprecedented combination of resolution (0.8 nm laterally and 1.5 nm vertically) and single-spin sensitivity. Our measurements uncover electronic spins on the diamond surface that can potentially be used as resources for improved magnetic imaging. This NV-MRI technique is immediately applicable to diverse systems including imaging spin chains, readout of spin-based quantum bits, and determining the location of spin labels in biological systems.

T. Rosskopf, A. Dussaux, K. Ohashi, M. Loretz, R. Schirhagl, H. Watanabe, S. Shikata, K. M. Itoh, and C. L. Degen

Investigation of Surface Magnetic Noise by Shallow Spins in Diamond

Phys. Rev. Lett. **112**, 147404 (2014)

We present measurements of spin relaxation times (T1,T1ρ,T2) on very shallow (≲5 nm) nitrogen-vacancy centers in high-purity diamond single crystals. We find a reduction of spin relaxation times up to 30 times compared to bulk values, indicating the presence of ubiquitous magnetic impurities associated with the surface. Our measurements yield a density of 0.01–0.1μB/nm2 and a characteristic correlation time of 0.28(3) ns of surface states, with little variation between samples and chemical surface terminations. A low temperature measurement further confirms that fluctuations are thermally activated. The data support the atomistic picture where impurities are associated with the top carbon layers, and not with terminating surface atoms or adsorbate molecules. The low spin density implies that the presence of a single surface impurity is sufficient to cause spin relaxation of a shallow nitrogen-vacancy center.

H. Tahara, Y. Ogawa, F. Minami, K. Akahane, and M. Sasaki

Long-Time Correlation in Non-Markovian Dephasing of an Exciton-Phonon System in InAs Quantum Dots

Phys. Rev. Lett. **112**, 147602 (2014)

We have observed a time-correlated frequency fluctuation in non-Markovian dephasing of excitons in InAs quantum dots using a six-wave mixing technique. In this measurement, the arrival times of the excitation pulses were controlled to eliminate the influence of Markovian dephasing and to measure the pure non-Markovian behavior. The experimental result shows that the time correlation of the frequency fluctuation due to exciton-phonon interactions was maintained in the quantum dots for over 10 ps. This long-time correlation is caused by the modification of the phonon coupling distribution.

Oskar Vafek, James M. Murray, and Vladimir Cvetkovic
Superconductivity on the Brink of Spin-Charge Order in a Doped Honeycomb Bilayer
Phys. Rev. Lett. **112**, 147002 (2014)

Using a controlled weak-coupling renormalization group approach, we establish the mechanism of unconventional superconductivity in the vicinity of spin or charge ordered excitonic states for the case of electrons on the Bernal stacked bilayer honeycomb lattice. With one electron per site, this system, physically realized in bilayer graphene, is unstable towards a spontaneous symmetry breaking. Repulsive interactions favor excitonic order, such as a charge nematic and/or a layer antiferromagnet. We find that upon adding charge carriers to the system, the excitonic order is suppressed, and unconventional superconductivity appears in its place, before it is replaced by a Fermi liquid. We focus on firmly establishing this phenomenon using the renormalization group formalism within an idealized model with parabolic touching of conduction and valence bands.

Erlend G. Tveten, Alireza Qaiumzadeh, and Arne Brataas
Antiferromagnetic Domain Wall Motion Induced by Spin Waves
Phys. Rev. Lett. **112**, 147204 (2014)

Spin waves in antiferromagnets are linearly or circularly polarized. Depending on the polarization, traversing spin waves alter the staggered field in a qualitatively different way. We calculate the drift velocity of a moving domain wall as a result of spin wave-mediated forces and show that the domain wall moves in opposite directions for linearly and circularly polarized waves. The analytical results agree with micromagnetic simulations of an antiferromagnetic domain wall driven by a localized, alternating magnetic field.

D. Tanese, E. Gurevich, F. Baboux, T. Jacqmin, A. Lemaître, E. Galopin, I. Sagnes, A. Amo, J. Bloch, and E. Akkermans
Fractal Energy Spectrum of a Polariton Gas in a Fibonacci Quasiperiodic Potential
Phys. Rev. Lett. **112**, 146404 (2014)

We report on the study of a polariton gas confined in a quasiperiodic one-dimensional cavity, described by a Fibonacci sequence. Imaging the polariton modes both in real and reciprocal space, we observe features characteristic of their fractal energy spectrum such as the opening of minigaps obeying the gap labeling theorem and log-periodic oscillations of the integrated density of states. These observations are accurately reproduced solving an effective 1D Schrödinger equation, illustrating the potential of cavity polaritons as a quantum simulator in complex topological geometries.

Y. Liu, Y. Y. Li, S. Rajput, D. Gilks, L. Lari, P. L. Galindo, M. Weinert, V. K. Lazarov & L. Li
Tuning Dirac states by strain in the topological insulator Bi2Se3
Nature Physics **10**, 294 (2014)

Three-dimensional Bi-chalcogenide topological insulators exhibit surface states populated by massless Dirac fermions that are topologically protected from disorder scattering1. Here, we demonstrate that these states can be enhanced or destroyed by strain in the vicinity of grain boundaries on the surface of epitaxial Bi2Se3(0001) thin films. Using scanning tunnelling and transmission electron microscopy, we show that the low-angle tilt grain boundaries in Bi2Se3(0001) films consist of arrays of alternating edge dislocation pairs. Along the boundary, these dislocations introduce periodic in-plane compressive and tensile strains. From tunnelling spectroscopy experiments and first-principles calculations, we find that whereas the energy of the Dirac state shifts in regions under tensile strain, a gap opens in regions under compressive strain, indicative of the destruction of the Dirac states at the surface. These results demonstrate that Dirac states can be tuned by strain at the atomic scale.