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ABSTRACTS

Superhigh-throughput Multi-dimensional NMR Spectroscopy

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NMR (nuclear magnetic resonance) has continued to evolve into a technology tour de force for interrogating the atomic details of matter. It is no revelation that semiconductor integrated circuits are an enormously successful technology that forever changed—and dramatically improved—the way we live. While the two technological paradigms have remained largely orthogonal, a number of interesting and potent applications can be born of their marriage. I will discuss our program for ultrahigh-throughput NMR quantum coherence spectroscopy exploiting silicon chips with applications from drug discovery to nuclear spintronics.

Carbonaceous Molecular Bearings

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The turn of the twenty-first century welcomed the triumphant arrival of nanoscience/nanotechnology. The advent of nanocarbons, such as fullerenes and carbon nanotubes, along with the development of state-of-the-art single molecule imaging methods for the analysis of their motion at the nanoscale, was essential to make the Feynman's "plenty-of-room-at-the-bottom" prediction insightful and realistic. The elemental machinery of nanotube molecules, observed at the single-molecule level, provided proof-of-principle images of nanoscale molecular machines in action, and the observation of ultralow friction at the carbonaceous interface indeed demonstrated the uniqueness of nanocarbon systems and, moreover, the feasibility of Feynman's "Let the bearings run dry" statement in the nanoscale world. There still lies a wide chasm, however, between the single-molecule level and the real macroscopic world, where the Avogadro's number, as well as the statistical ensemble behaviours of molecules, take control over everyday phenomena. In our efforts in creating and understanding carbonaceous machinery, we have demonstrated a concise and scalable access to nanomachinery and provided a statistical evidence for the rolling motion of nanoscale molecular bearings functioning under ensemble dynamics.

Through this process, we have also proposed a measure of length of nanotube (http://www.orgchem2.chem.tohoku.ac.jp/finite/), which may be utilized to cultivate the molecular pictures of nanotubes. In the presentation, our recent studies on structural chemistry of nanotube bearings will be disclosed.

Nuclear resonance in quantum Hall systems

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Dynamic nuclear polarization and its resistive detection are achieved in GaAs two-dimensional (2D) systems by current flow at n = 2/3 spin phase transition [1] or quantum Hall breakdown at the integer fillings [2]. They are also realized in InSb 2D systems by current flow at n = 2 spin phase transition which is realized in a tilted magnetic field thanks to extremely large g-factor [3]. Such manipulation and detection of nuclear polarization open us highly-sensitive resistively-detected nuclear resonance measurements in quantum Hall systems.

The pump and probe nuclear magnetic resonance (NMR) measurements provide us nuclear relaxation information and NMR spectrum where Knight shift is sensitive to electron spin polarization. The spin polarization of high-quality 2D system is precisely estimated from this Knight shift measurement [4]. The detailed analysis of the shift gives us information of a spatial distribution of spin polarized electrons [5]. The novel method measuring nuclear polarization distribution manifests unique many body effect. Sudden change in nuclear polarization distribution suggests a strong interaction between electron spin and nuclear spin ensembles when electron spins have the Goldstone mode [6].

The nuclear resonance can be achieved by not only magnetic resonance but also electric resonance. The electric quadrupolar coupling has been demonstrated to manipulate nuclear spins in a bulk GaAs and a depleted quantum well by an oscillating electric field [7,8]. Such electrical manipulation also operates in the quantum Hall regime, especially in the localized regime, reflecting penetration of the oscillating electric field [9]. The electric resonance with different mechanism is also demonstrated, where nuclear manipulation is achieved by a domain structure oscillation [10]. These electric controls are more attractive than magnetic control from the view point of a spatial resolution. A successful combination of the electric nuclear resonance and scanning gate technique enables us a spatial imaging of the nuclear resonance signal in the quantum Hall regime [11] as the first step toward nanometer scale nuclear resonance imaging.

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Imaging Quantum Materials with Low Voltage Electron Microscopy

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A fascinating class of quantum materials is atomically layered materials such as graphene or hexagonal boron nitride (h-BN). The properties of such materials differ strongly from those of their three-dimensional bulk state. Depending on the composition, quantum materials may act as conductors, insulators, semiconductors or even as superconductors. We report on the frontiers of imaging and characterization of several unique quantum materials systems, reaching from defect formation in graphene to the characterization of hybrid quantum materials. We use a C_s corrected Zeiss Libra TEM running at low voltage (40 & 80 KeV) to image Quantum Materials. In this TEM we examine the positioning of the Hg and Co atoms on the graphene lattice. At the same time, we observe the effect of the copper and mercury on the pi electrons in graphene with Raman spectroscopy. Furthermore, we have examined graphene based hybrid structures, such as graphene oxide embedded in a vanadium pentoxide nanofiber matrix. We have used Low Voltage TEM to visualize NV centers in diamond. With electron energy loss spectroscopy (EELS) we measure the amount of energy loss of the NV centers corresponding to the Raman energy. This includes inter and intraband transitions but also a component of Cherenkov radiation. Hence we use a low acceleration voltage of only 40 kV to reduce the background noise of the Cherenkov radiation in the spectra. This combination proved to be an excellent tool to understand the astonishing mechanical and electronic properties of Quantum Materials.

Quantum Nanophotonics and Nanomechanics with Diamond

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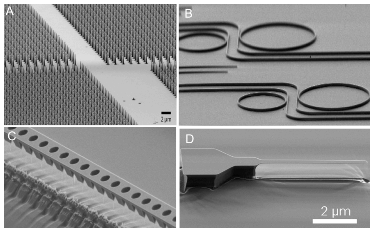
Diamond possesses remarkable physical and chemical properties, and in many ways is the ultimate engineering material - “the engineer’s best friend!” For example, it has high mechanical hardness and large Young’s modulus, and is one of the best thermal conductors. Optically, diamond is transparent from the ultra-violet to infra-red, has a high refractive index (n = 2.4), strong optical nonlinearity and a wide variety of light-emitting defects. Finally, it is biocompatible and chemically inert, suitable for operation in harsh environment. These properties make diamond a highly desirable material for many applications, including high-frequency micro- and nano-electromechanical systems, nonlinear optics, magnetic and electric field sensing, biomedicine, and oil discovery. One particularly exciting application of diamond is in the field of quantum information science and technology, which promises realization of powerful quantum computers capable of tackling problems that cannot be solved using classical approaches, as well as realization of secure communication channels. At the heart of these applications are diamond's luminescent defects—color centers—and the nitrogen-vacancy (NV) color center in particular. This atomic system in the solid-state possesses all the essential elements for quantum technology, including storage, logic, and communication of quantum information.

I will review recent advances in nanotechnology that have enabled fabrication of nanoscale optical devices and chip-scale systems in diamond that can generate, manipulate, and store optical signals at the single-photon level. Examples include a room temperature source of single photons based on diamond nanowires[1] (Figure A) and plasmonic appertures[2], as well as single-photon generation and routing inside ring[3] (Figure B) and photonic crystal resonators [4]. Novel, fabrication technique[5] – *angled-etching* - suitable for realization of nanophotonic[6] (Figure C) and nanomechanic[7,8] (Figure D) devices in bulk diamond crystals will also be discussed. Our work on diamond based on-chip frequency combs[9] will also be discussed.



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Exploring Condensed Matter Physics Using NV Center Based Nano-Scale Magnetometry

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Correlated-electron systems support a wealth of magnetic excitations, ranging from conventional spin waves to exotic fractional excitations in low-dimensional or geometrically-frustrated spin systems. Probing such excitations on nanometre length scales is essential for unravelling the underlying physics and developing new spintronic nanodevices. However, no established technique provides realspace, few-nanometre-scale probing of correlated-electron magnetic excitations under ambient conditions. Magnetometry based on single nitrogen-vacancy (NV) centres in diamond has recently been shown to provide both high sensitivity and spatial resolution under ambient conditions. In this talk I will describe the use NV magnetometry for exploring such correlated electron physics. As a first example we focus on spin-wave excitations in a ferromagnetic microdisc, and demonstrate local, quantitative, and phase-sensitive detection of the spin-wave magnetic field at ~ 50 nm from the disc. We map the magnetic-field dependence of spin-wave excitations by detecting the associated local reduction in the disc's longitudinal magnetization. In addition, we characterize the spin-noise spectrum by NV-spin relaxometry, finding excellent agreement with a general analytical description of the stray fields produced by spin-spin correlations in a 2D magnetic system. These complementary measurement modalities pave the way towards imaging the local excitations of systems such as ferromagnets and antiferromagnets, skyrmions, atomically assembled quantum magnets, and spin ice.

Spin current in various non-equilibrium systems

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Generation and utilization of a flow of spin angular momentum, spin current, are the key concept of today's spin science and spintronics. Spin current is now detectable owing to the discovery of the inverse spin Hall effect [1], and many spin-driven effects have been discovered by using the inverse spin Hall effect. Here we review some of such spin-driven effects; heat-spin conversion [2-4], plasmon-spin conversion [5], and sound-spin conversion.

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