Abstracts of Poster Session

②

Oct 14, 17:15-18:45

Q-1

Bistable Photon Emission in Hybrid-QED

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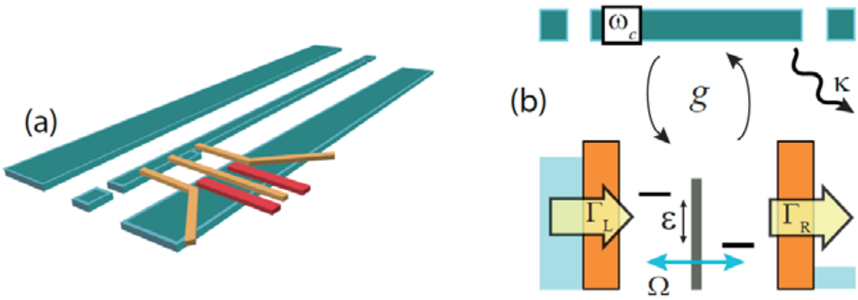
We study the photon emission from a double quantum dot coupled to a microwave cavity [1,2]. We predict that the resulting photonic statistics exhibit a dynamic bistability, which we validate by showing that the distribution describing these statistics has the shape of a tilted ellipse. The switching rates which describe the bistability can be extracted from the electrical current and the shot noise in the quantum dots, and used to predict this elliptic form of the photonic distribution. Our results may be useful for more deeply characterizing the single-atom lasers based on gate-defined quantum dots as the gain medium.

[1] N. Lambert, F. Nori, and C. Flindt, Phys. Rev. Lett. 115, 216803 (2015),

[2] N. Lambert, C. Flindt, and F. Nori, Europhysics Letters 103, 17005 (2013).



(a) Schematic layout of a double quantum dot coupled to a microwave transmission line cavity.

(b) Within the dot, electrons flow from left to right, and pass through a double-well potential which couples to the cavity.

Q-2

Non-perturbative and non-Markovian environments: exact solvers and applications

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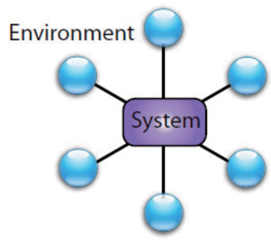
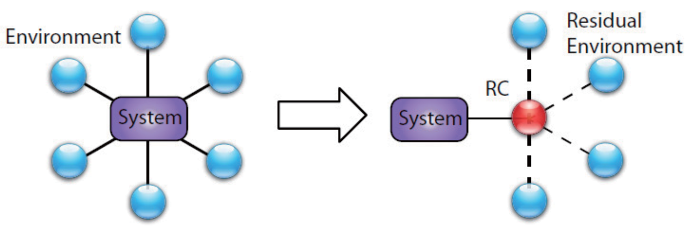
To theoretically model and understand quantum devices we must understand their interaction with the environment. Many perturbative approaches have been developed, but is becoming apparent that these fail in many physical situations, and that a non-perturbative and dynamic environment can have a profound effect on applications. We have extended an existing approach (the HEOM method of Tanimura and Kubo), and also developed a new approach (the reaction-coordinate method), and applied both of them to a range of physical examples and applications.



The environment is typically composed of infinite degrees of freedom. Methods based on perturbation theory are typically pursued, but break down when the coupling to the environment is of the same order as the internal system frequencies.



One approach to deal with this difficult problem is to identify the dominant degrees of freedom in the environment, and model those explicitly, while treating the rest perturbatively

Q-3

Quantum optics with giant artificial atoms

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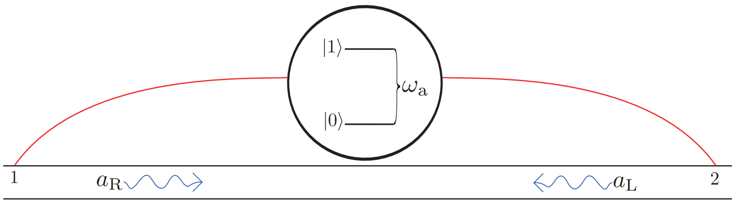
In quantum optics experiments with both natural and artificial atoms, the atoms are usually small enough that they can be approximated as point-like compared to the wave- length of the electromagnetic radiation they interact with. However, a recent experiment coupling a superconducting qubit to surface acoustic waves shows that a single artificial atom can be coupled to a bosonic field at several points which are wavelengths apart [1]. This situation could also be engineered with an xmon qubit coupled to a microwave transmission line [2].

Here, we present results of theoretical studies of such “giant artificial atoms” [2,3,4]. In the Markovian regime, where the travel time between coupling points is negligible, we find that interference effects due to the positions of the coupling points give rise to a frequency dependence for the strength of the coupling between the giant artificial atom and its surroundings [2]. The Lamb shift of the atom is also affected by the positions of the coupling points. We discuss possible applications for these frequency dependencies (which can be designed). In the non-Markovian regime, where the distance between coupling points is large, an excited giant atom exhibits revivals and non-exponential decay [3]. In this regime, we have also studied novel features that occur in the correlation function $g^2(t)$. Finally, we also explore setups with several giant atoms coupled to a transmission line in various configurations [4].

A sketch of a giant artificial atom, coupled to right- and left-moving modes in a one-dimensional transmission line at two points which are wavelengths apart.



[1] M. V. Gustafsson *et al.*, Science **346**, 207 (2014)
[2] A. F. Kockum *et al.*, Phys. Rev. A **90**, 013837 (2014)
[3] L. Guo *et al.*, in preparation (2016)
[4] A. F. Kockum *et al.*, in preparation (2016)

Q-4

Second Harmonic Generation in Topological insulators

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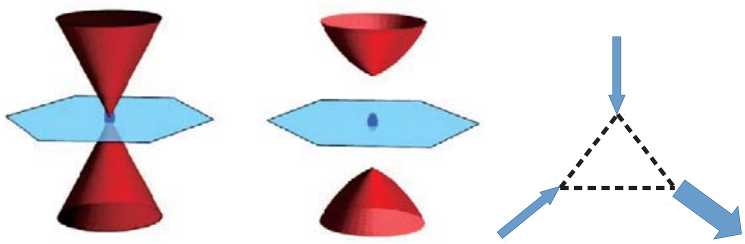
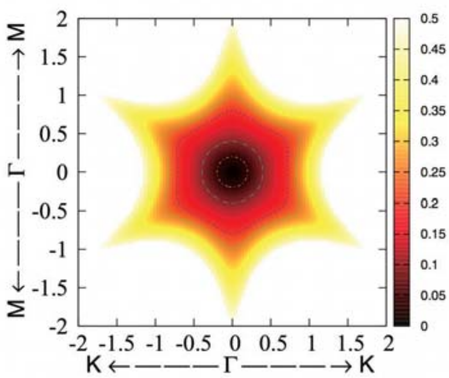
The metallic surface states of a topological insulator support helical Dirac fermions protected by topology with their spin locked perpendicular to their momentum. They can acquire mass through magnetic doping or through hybridization of states on opposite faces of a thin sample and thus an out of plane spin component (Sz) was introduced. The Fermi cross section changes from circular to a snowflake shape as the chemical potential is increased above the Dirac point because of a hexagonal warping which also changes the spin texture, the orbital magnetic moment, the matrix element for optical absorption, and the circular dichroism. We find that the second harmonic generation described by a nonlinear response function will not vanish in the long wave length limit (q→0) only when the hexagonal warping and the gap coexist.





Q-5

Nonreciprocal Transport in Noncentrosymmetric Superconductors

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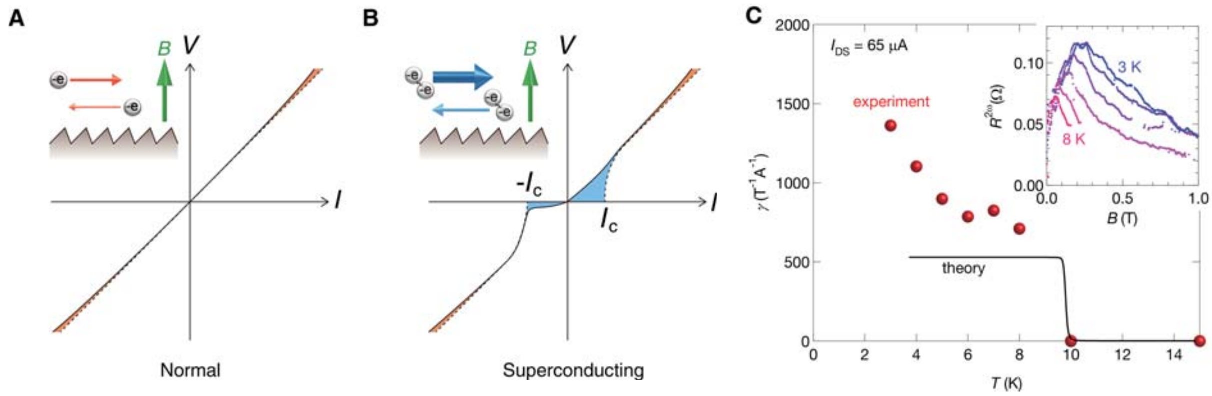
In noncentrosymmetric systems, magnetochiral anisotropy (or nonreciprocal transport) such as direction dependent resistivity appears under a magnetic field. In practice, however, the magnetochiral anisotropy in a bulk material is very small (Fig. A). Here, we report that once a noncentrosymmetric material enters into its superconducting fluctuation regime, the magnetochiral anisotropy is strongly enhanced (Fig. B) by a factor of $(\epsilon_{\mathrm{F}}/\Delta)^3$, with the Fermi energy ϵ_{F} and the superconducting gap Δ.

As a representative material of noncentrosymmetric superconductors, we have studied 2H-MoS_2 under the electric-double-layer transistor configuration. We have observed the large enhancement of the magnetochiral anisotropy in the superconducting fluctuation regime, and the results are consistent with the theoretical predictions (Fig. C).



Q-6

Anomalous Thermal Hall Effect in a disordered Weyl ferromagnet

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Thermal Hall effect is a heat analog of the Hall effect, namely, the heat current flows perpendicular to a temperature gradient. According to the Wiedemann-Franz law, the Lorenz ratio $L^{ij} \equiv \kappa^{ij}/T\sigma^{ij}$ goes to the universal value $L_0 \equiv \pi^2 k_{\mathrm{B}}^2/3e^2$ in electronic systems at low temperature, in which κ^{ij} and σ^{ij} are the thermal and electric (Hall) conductivities, and T is temperature. At finite temperature, we can investigate effects of inelastic scattering by the breakdown of the Wiedemann-Franz law.

In spite of its usefulness, it is theoretically difficult to calculate κ^{xy}. This is because $T\kappa^{xy}$ is not expressed by the Kubo formula $T\tilde{\kappa}^{xy}$ alone but is corrected by the heat magnetization $2M_{\mathrm{Q}z}$. Recently, I found a "vector potential" coupled to the energy current and established the Keldysh formalism for calculating $T\tilde{\kappa}^{xy}$ and $2M_{\mathrm{Q}z}$ even in disordered or interacting systems [1].

Here I apply this formalism to a disordered Weyl ferromagnet which exhibits the anomalous (thermal) Hall effect. I first quantum-mechanically calculate κ^{ij} and σ^{ij} on an equal footing and reproduce the Wiedeman-Franz law. This is the first step towards a unified theory of the anomalous Hall effect at finite temperature, where inelastic scattering by magnons is relevant.

[1] A. Shitade, Prog. Theor. Exp. Phys. **2014**, 123I01 (2014).

Q-7

Antiferromagnetic nuclear spin helix and topological superconductivity in ^{13}C nanotubes

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We investigate the Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction arising from the hyperfine coupling between localized nuclear spins and conduction electrons in interacting carbon nanotubes made of ^{13}C. Using the Luttinger liquid formalism, we show that the RKKY interaction is sublattice dependent, resolving the inconsistency between the earlier work and the spin susceptibility calculation in noninteracting nanotubes. The RKKY interaction forms $q=\pm 2k_F$ peaks with the Fermi wave number k_F, and induces a novel antiferromagnetic nuclear spin helix with a spatial period π/k_F (Fig. 1). The transition temperature reaches up to several tens of mK, due to the feedback effect through the Overhauser field from the ordered nuclear spins. The nuclear spin helix, combining spin and charge degrees of freedom, results in a synthetic spin-orbit interaction, which is crucial for nontrivial topology. In the presence of the proximity-induced superconductivity, this system has a potential to realize Majorana fermions without the need of fine tuning the external parameters, such as chemical potential and magnetic field (Fig. 2).

Fig. 1 Illustration of the antiferromagnetic nuclear spin helix in ^{13}C nanotubes.

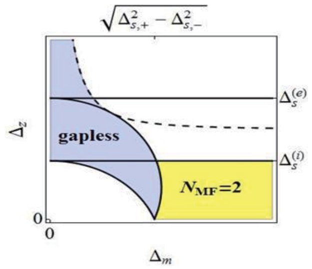

Fig. 2 phase diagram

Q-8

Equal-spin Andreev Reflection between Spin-resolved Quantum Hall Bulk State and Superconductor

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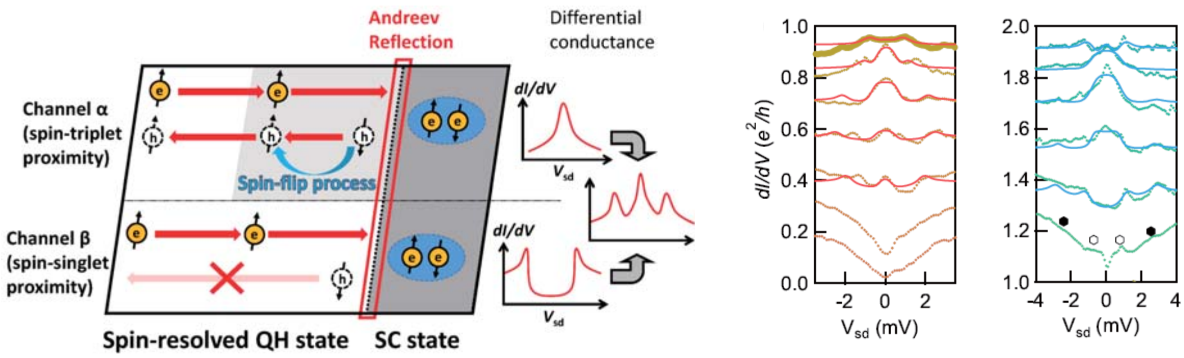
A junction between superconductor and normal conductor is a platform to study the Andreev reflection, in which the incident electron is reflected as a hole having the opposite spin direction. Recently the supercurrent through the ferromagnet or halfmetal has been reported. This contradicted results were explained by the "equal-spin" Andreev reflection intermediated by the spin-flip process. We will report on observation of this "equal-spin" Andreev reflection between superconducting NbTi and spin-resolved quantum Hall bulk state of InAs quantum well having strong spin-orbit interaction. The obtained differential conductance has sub-gap feature on the zero-bias region and additional side peaks out of the sub-gap feature. The peculiar structures are explained by the model with assumption that there are two channels, one of which contributes to the "equal-spin" Andreev reflection and the other contributes the conventional Andreev reflection. Our results will pave the way for superconducting spintronics on semiconductor.



Q-9

Fractional charge in 1D quantum dots array

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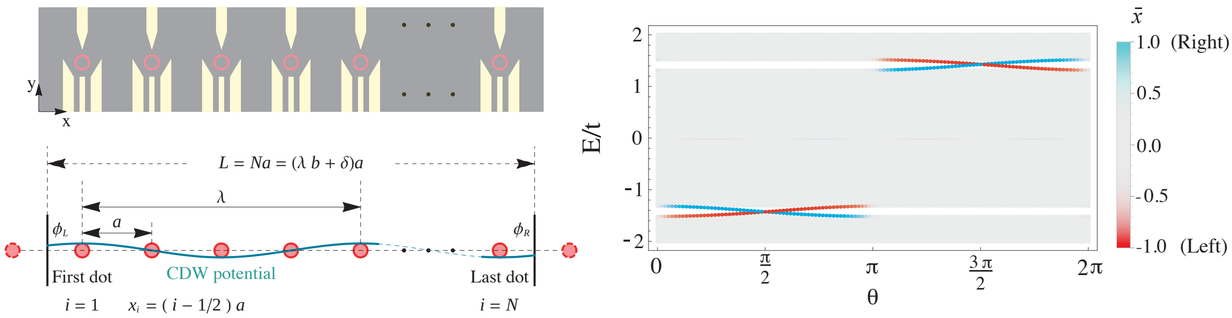
We show that fractional charges can be realized at the boundaries of a linear array of tunnel-coupled quantum dots in the presence of a periodically modulated onsite potential. While the charge fractionalization mechanism is similar to the one in polyacetylene, here the values of fractional charges can be tuned to arbitrary values by varying the phase of the onsite potential or the total number of dots in the array. We also find that the fractional boundary charges, unlike the in-gap bound states, are stable against static random disorder. We discuss the minimum array size where fractional boundary charges can be observed.



Q-10

Atomistic spin dynamics with a semi-quantum thermostat

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The use of classical Heisenberg models to understand the dynamical and thermodynamical properties of magnetic materials is now common place. Hamiltonians can be parameterised in exquisite detail from first principles or neutron scattering measurements. However there are issues with even a qualitative comparison with experiments and theory because of the disregard for the quantum nature of spin. The differences can be especially large in the low temperature regime which are sometimes required for experiments. In this talk I will present a modified approach which obeys quantum statistics but retains the classical spin vectors which make this approach easy to use and useful for dynamics. The results show an excellent agreement with theory and experiments allowing truly quantitative calculations to be performed.

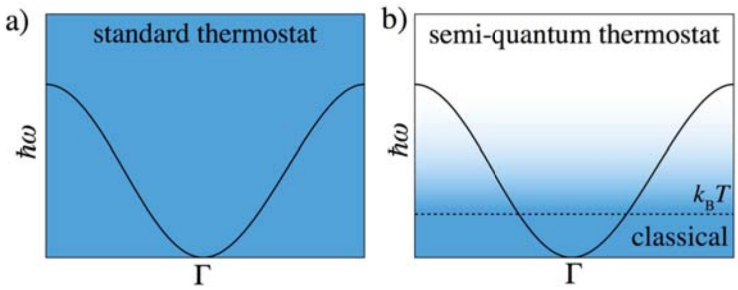

Fig. 1 - Classical vs. semi-classical approach

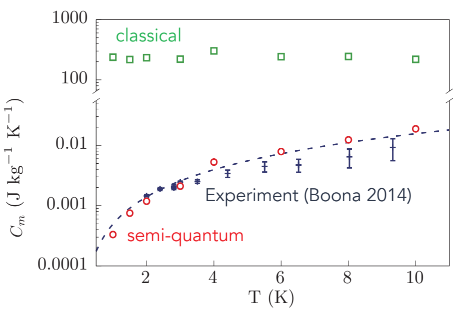

Fig. 2 - Magnon specific heat of YIG

Q-11

Development of (110) GaAs quantum wells for emission layers of spin-controlled lasers

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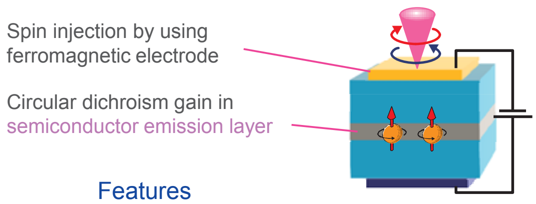
Spin-controlled lasers, which enable electron spin information to convert light polarization, have become a focus of interest as next-generation light sources [1]. Semiconductor quantum wells (QWs) are crucial building blocks of the spin lasers. We conducted systematic measurements of the surface morphology, photoluminescence (PL) intensity, carrier lifetime τ_c, and spin relaxation time τ_s of the GaAs/AlGaAs(110) QWs grown with different growth conditions to examine the possibility of using them as the emission layer of spin lasers. Excellent surface flatness and high PL intensity (I_{PL}) were obtained from the samples with growth temperature ≥ 450 °C and As/Ga flux ratio ≥ 40. We also found that the high-quality (110) QWs exhibit high spin-detection sensitivities $\eta = [\tau_s/(\tau_s+2\tau_c)] \geq 0.3$; these values have never been reached so far in the (100) QWs. The results suggest that the (110) QWs obtained are certainly superior to the existing (100) QWs in the emission layer of the spin lasers [2-4].

[1] J. Sinova *et al.*, *Nat. Mater.* **11**, 368 (2012). [2] Y. Ohno *et al.*, *Phys. Rev. Lett.* **83**, 4196 (1999). [3] S. Iba *et al.*, *J. Appl. Phys.* **118**, 083901 (2015). [4] S. Iba *et al.*, *Jpn. J. Appl. Phys.* in press.

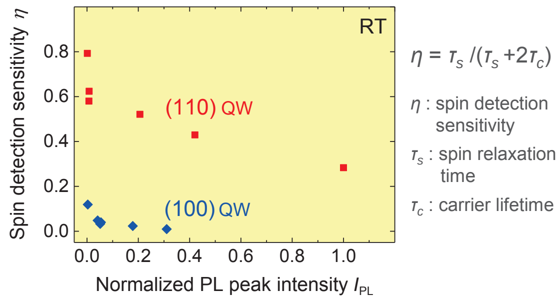
Spin-controlled laser (spin laser)



Features

- Circularly polarized coherent output
- Threshold current reduction
- High speed modulation
- Spin amplification & transmitter

High spin detection sensitivity and PL intensity of (110) QWs



$\eta = \tau_s/(\tau_s+2\tau_c)$

η : spin detection sensitivity

τ_s : spin relaxation time

τ_c : carrier lifetime

Q-12

Ground State Electroluminescence

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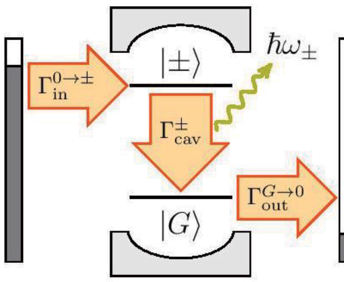
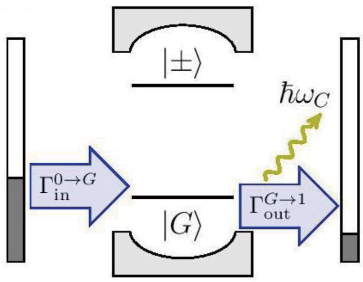
Electroluminescence, the emission of light in the presence of an electric current, provides information on the allowed electronic transitions of a given system. It is commonly used to investigate the physics of strongly coupled light-matter systems, whose eigenfrequencies are split by the strong coupling with the photonic field of a cavity. In this work, we showed that, together with the usual electroluminescence, systems in the ultrastrong light-matter coupling regime emit a uniquely quantum radiation when a flow of current is driven through them. While standard electroluminescence relies on the population of excited states followed by spontaneous emission, the process we describe herein extracts bound photons from the dressed ground state and it has peculiar features that unequivocally distinguish it from usual electroluminescence.



Schematics for standard electroluminescence. Electrons enter the system in an excited state, which decays emitting a photon at the polaritonic frequency.



Schematics for ground state electroluminescence. Electrons enter the system in the ground state which cannot decay. However, in the ultra-strong coupling regime, electrons can get out the system leaving one photon (at the bare cavity) frequency inside the cavity.

Q-13

Single photon-electron pairs generation from polarization entangled photon pairs

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[2] *Lehrstuhl fur Angewandte Festkörperphysik Ruhr-Univ. Bochum*
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Quantum entanglement has been studied in solid physics to realize distributed photonic quantum communication based on a quantum repeater. Nevertheless it is still challenging to experimentally demonstrate the entanglement between stationary solid qubits and photonic qubits [1, 2]. Here we try to generate the entanglement between an electron spin and a photon polarization by combining generation of polarization entangled photon pairs and coherent quantum state transfer from single polarized photons to single electron spins in a GaAs laterally defined quantum dots [3, 4]. In this work, we generated single entangled photon pairs using spontaneous parametric down conversion in a Type-II BBO crystal, and demonstrated coincidence measurement on the electron transferred from one of the entangled paired photons and the remaining photon.

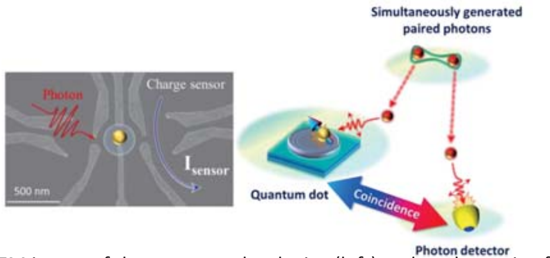

Fig.1 SEM image of the quantum dot device (left) and a schematic of the experiment setup (right)

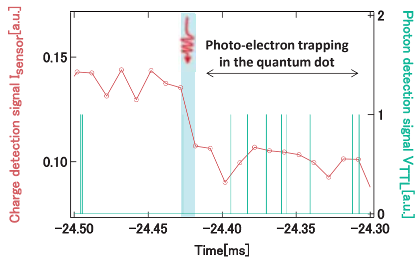

Fig.2 Time trace of the coincidence signals

1] K.De.Greve, *et al.*, Nature **491**, 421 (2012). [2] W.B.Gao, *et al.*, Nature **491**, 426 (2012) . [3] R.Vrijen and E.Yablonovitch, Physica E **10**, 569 (2001). [4] T.Fujita, *et al.*, arXiv 1504.03696(2015).

Q-14

Charge and spin dynamics in a quantum dot-lead coupled system

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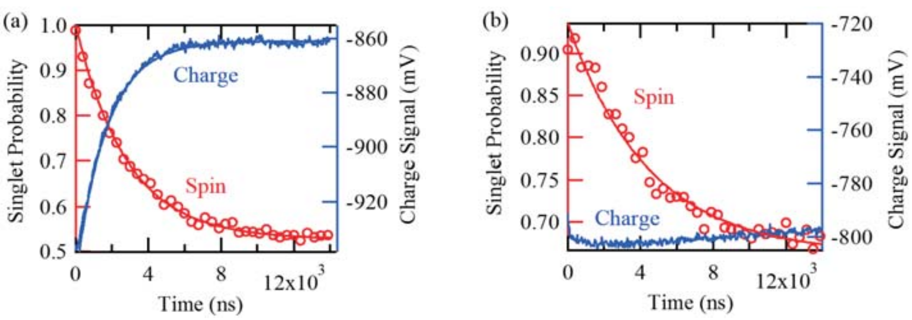
Electron spins in semiconductor quantum dots (QDs) are considered good candidates for quantum bits in quantum information processing. In this research field, control and readout of the spin states have been developed and established. We apply these techniques to explore spin dynamics in a hybrid system which consists of a QD and an open electronic reservoir. We observe spin relaxations in a QD under the effect of the coupling to a lead. By comparing the spin signals with the charge relaxation signals, we examine the mechanism of the spin state evolutions [Fig.(a) first- , (b) second-order tunneling process]. These results will be important in the exploration of further spin dynamics in QD-lead hybrid systems and utilized for spin manipulation.



Q-15

Measuring the time dependence of a Rabi oscillation of an electron spin in a semiconductor quantum dot

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[2]*RIKEN Center for Emergent Matter Science (CEMS), Wako, Saitama 351-0198, Japan*
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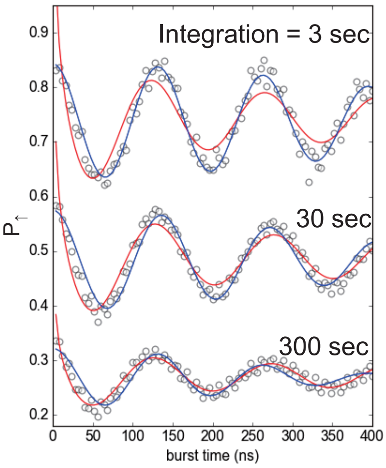
A Rabi oscillation of an electron spin in a semiconductor quantum dot (QD) has been demonstrated using electron spin resonance. Especially in III-V semiconductor QDs, the spin dynamics is influenced by nuclear spin fluctuation (σ) through the hyperfine interaction. Previous work on a GaAs QD [1] demonstrates the Rabi oscillations of two different regimes ($f_{\mathrm{Rabi}}/\sigma \gg 1$ and $f_{\mathrm{Rabi}}/\sigma \lesssim 1$) by changing the Rabi frequency f_{Rabi}. The Rabi oscillations of these two regimes are approximated by the following equation: $P_{\uparrow}(t_{\mathrm{MW}}) = A\exp(-(t_{MW}/T_2^{\mathrm{Rabi}})^2)\cos(2\pi f_{\mathrm{Rabi}} t_{\mathrm{MW}}) + B$ (in $f_{\mathrm{Rabi}}/\sigma \gg 1$) [i], and $P_{\uparrow}(t_{\mathrm{MW}}) = A t_{\mathrm{MW}}^{-0.5}\cos(2\pi f_{\mathrm{Rabi}} t_{\mathrm{MW}} + \pi/4) + B$ (in $f_{\mathrm{Rabi}}/\sigma \lesssim 1$) [ii], respectively.

We observe Rabi oscillations of these two regimes by fixing the f_{Rabi}, but changing σ by decreasing the data acquisition time to study the impact of the measurement time. The figure shows the Rabi oscillations measured with different integration times fitted by equation [i] (blue) and [ii] (red). With 3 sec integration time, the data is well fitted by the blue curve ($\sigma \ll f_{\mathrm{Rabi}}$). On the other hand, the data is well fitted by the red curve ($f_{\mathrm{Rabi}}/\sigma \lesssim 1$) for larger integration times. This indicates that σ increases by increasing the integration time in agreement with the recent work [2].



Reference
[1] J. Yoneda et al., PRL (2014).
[2] M. R. Delbecq et a., PRL (2016).

Q-16

Transport properties of InAs nanowires on hexagonal boronnitride

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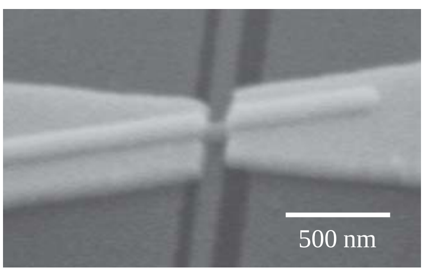
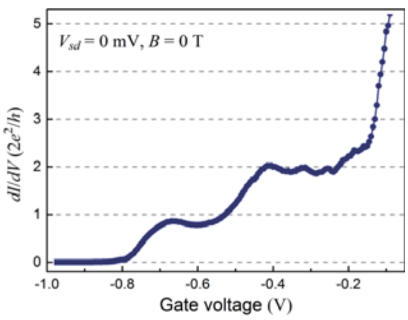
InAs nanowires, which have a surface charge accumulation layer and exhibit a strong spin-orbit interaction, are predicted to be good candidates for the observation of helical states and furthermore Majorana bound states in a hybrid superconductor device. Although ballistic transport in nanowires plays an important role in creating a topological phase transition in proximitized nanowires, conductive electrons in the accumulation layer experience strong surface roughness scattering and ionized impurity scattering such that the transport is entirely diffusive. Here, to suppress such scatterings we employ hexagonal boronnitride as a gate dielectric, and demonstrate conductance quantization in InAs nanowires at zero magnetic field.





Q-17

Proximity induced triplet supercurrent in Nb/(In, Fe)As/Nb junctions

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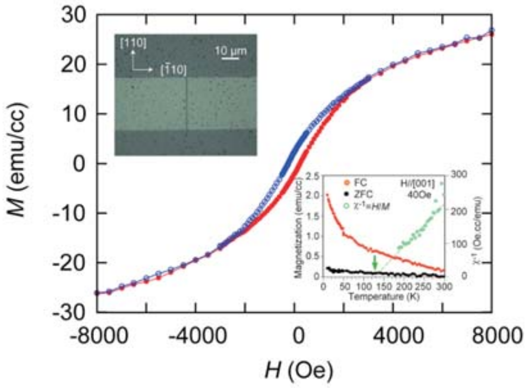
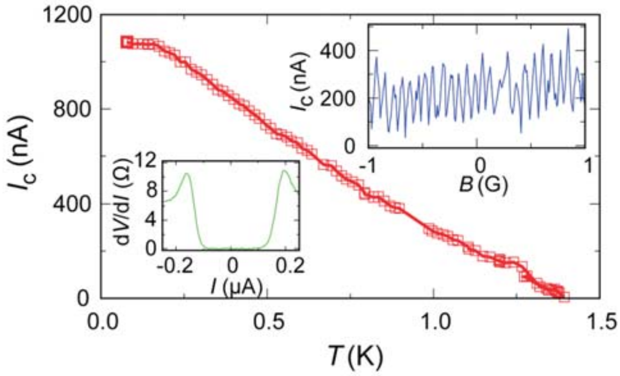
Superconductor/ferromagnet/superconductor (SFS) junctions exhibit attractive phenomena such as π junction states or triplet Cooper pairs. In order to explore such spin-related superconducting phenomena, we fabricated Nb based SFS junctions on an n-type ferromagnetic semiconductor (In,Fe)As.

Figure 1 represents the *M*-*H* curve of the (In,Fe)As in the sample and the insets show a optical micrograph and the temperature dependence of the magnetization. The (In,Fe)As exhibits clear hysteresis and its Curie temperature is about 120 K. We observed clear zero resistance states, namely finite triplet supercurrent, as shown in the lower left inset of Fig.2. The critical currents exhibit oscillation as a function of the magnetic fields, suggesting the existence of superconducting coherence in the (In,Fe)As due to the Josephson effect. The temperature dependence also indicates the superconducting proximity effect in the (In,Fe)As.





Q-18

Construction of van der Waals magnetic tunnel junction using ferromagnetic layered dichalcogenide

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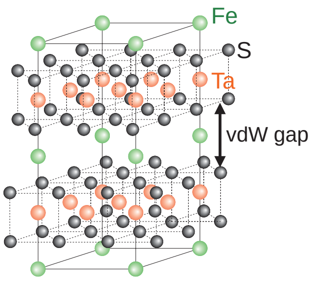
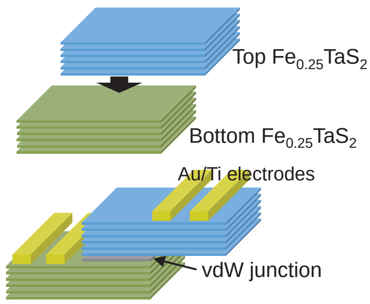
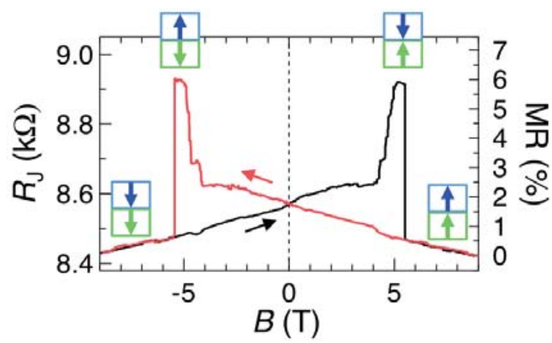
We investigate the micromechanical exfoliation and van der Waals (vdW) assembly of ferromagnetic layered dichalcogenide $Fe_{0.25}TaS_2$. The vdW interlayer coupling at the Fe-intercalated plane of $Fe_{0.25}TaS_2$ allows exfoliation of flakes. A vdW junction between the cleaved crystal surfaces is constructed by dry transfer method. We observe tunnel magnetoresistance in the resulting junction under an external magnetic field applied perpendicular to the plane, demonstrating spin-polarized tunneling between the ferromagnetic layered material through the vdW junction.







Q-19

Cluster-multipole-driven Anomalous Hall Effect in antiferromagnets

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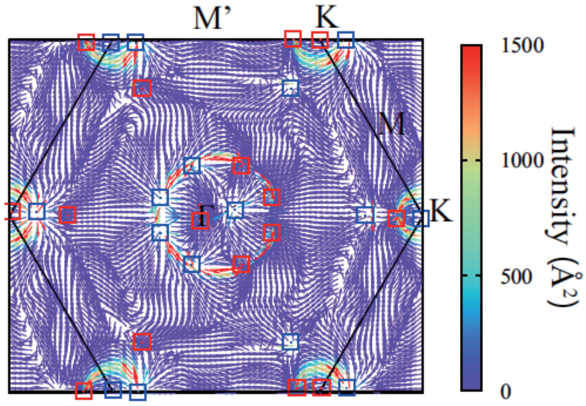
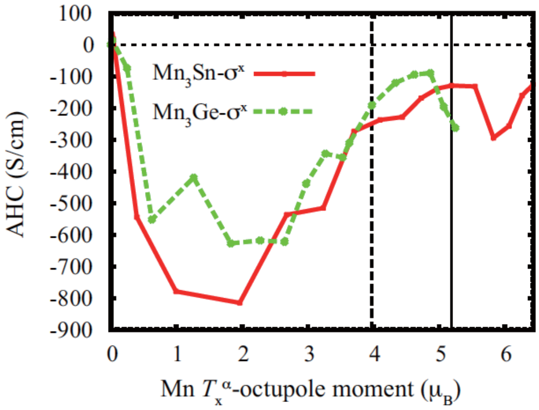
Modern formalism of intrinsic anomalous Hall conductivity (AHC), which expresses AHC as non-vanishing effect of Berry curvatures, has provided profound insight of anomalous Hall effect (AHE). We have investigated the electronic structure, Berry curvature (left figure), Weyl node's chirality (blue (+1) and red (-1) squares in left figure), and AHC (right panel) in the antiferromagnetic (AFM) states of $Mn_3\boldsymbol{Z}$ ($\boldsymbol{Z}$ =Sn, Ge) by first-principles calculations. We show that the AFM states of $Mn_3\boldsymbol{Z}$ produce a number of Weyl nodes and generate complex flows of Berry curvature around the Fermi level (Left figure). We provide a comprehensive theoretical framework of AHC for general magnetic systems by introducing order parameters using multipole formalism for magnetic clusters and show that the AFM states of $Mn_3\boldsymbol{Z}$ are characterized by an octupolar moment. We show that the new order parameters, generalized from the ordinary magnetization, make it possible to discuss AHE for AFM systems in the same framework of AHE for ordinary ferromagnetic systems.





Q-20

Spin resonance effects in parallel-coupled quantum dots

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Electrical detection of spin resonance is examined theoretically for a system of two parallel-coupled quantum dots. The energy levels of the two dots are adjusted so that the first dot is occupied by a single spin during the dynamics [1]. The second dot is a tunnel-coupled to metallic leads allowing current to flow through the system (Figure 1). We shown that in the presence of an oscillating magnetic field and for a specific gate voltage regime current flows only when the applied microwave frequency equals the Zeeman splitting of the single spin. This results in a current peak indicative of the single-spin resonance. From the general current plot the lowest two-electron levels can be mapped-out (Figure 2). Thus, for example, in the presence of spin-orbit interaction the size of the anticrossing gap can be estimated [2]. The system studied here is relevant to silicon devices where spin impurities are often coupled to quantum dots as well as to coupled donor-dot systems.

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[2] Giavaras and Nori, in preparation.

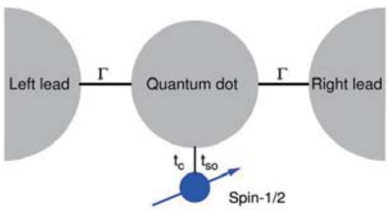

Figure 1: Physical system.

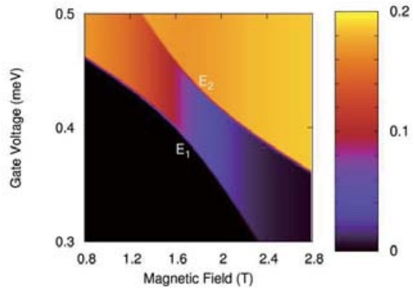

Figure 2: Electrical current through the quantum dot due to electron-spin-resonance, in the presence of spin-orbit-interaction.

Q-21

Effects of skew scattering on non-dissipative transport properties

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For non-dissipative transport phenomena, such as the anomalous Hall effect (AHE) and the spin Hall effect (SHE), the skew scattering plays an important role [1-3]. Its contributions to AHE and SHE are proportional to the inverse of the impurity concentration, and thus dominant in clean systems, but they are known to vanish for the two-dimensional Rashba model with the point-like (non-magnetic) impurity potential [4]. It is of interest to find any conditions for the skew scattering to contribute, and the way to enhance the effects.

In order to reveal these points, we calculate the skew scattering terms (Fig.1) for AHE and SHE for the following two systems; (1) a general single-band model, and (2) three-dimensional Dirac electrons as a simple multi-band model. In both models, point-like nonmagnetic impurities are assumed as electron scatterers. For model (1), we found that the skew-scattering term vanishes if the damping of electrons is independent of spin.

In contrast, for model (2), in which the damping of electrons is spin-independent, the skew scattering does contribute to SHE. This is because the damping is band-dependent, and this works to simulate the spin-dependent scattering (in the case of single-band model).

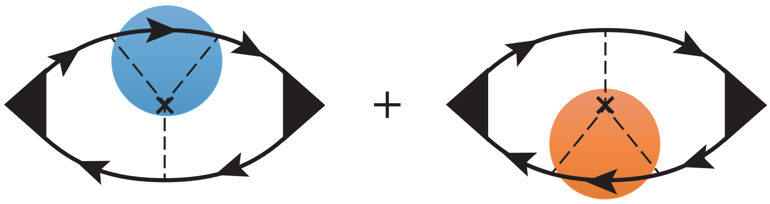

Fig. 1

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Q-22

Large Chern number in films of transition metal oxides

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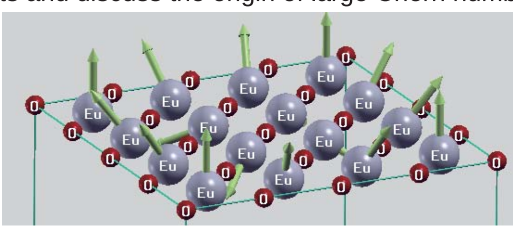
Skyrmion crystals could show large anomalous Hall conductivity(AHC) which changes drastically as a function of Fermi level[1], and thus we expect large anomalous Nernst effect as well[2].

Such AHC is attributed to spin chirality[3] generated by non-trivial spin structure, and its realization in realistic materials is searched for both theoretically[4] and experimentally[5][6].

However, the origin of such energy dependence of AHC is not clear yet, and therefore the purpose of this study is to understand it from first principles calculations by varying spin structures.

We calculated energetics of magnetic structures and Chern numbers of each band[7], which is the contribution of the band to AHC, in films of transition metal oxides by first principles code OpenMX[8]. In this presentation, we report the results and discuss the origin of large Chern number.



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Q-23

Lowering electron temperature for measurement of spin relaxation in quantum dots

G. Allison[1], J. Yoneda[1,2], K. Takeda[1,2], T. Otsuka[1,2], T. Nakajima[1,2], M. R. Delbecq[1,2], S. Amaha[1], A. Noiri[1,2], T. Ito[1,2], A. Ludwig[3], A. D. Wieck[3], and S. Tarucha[1,2]

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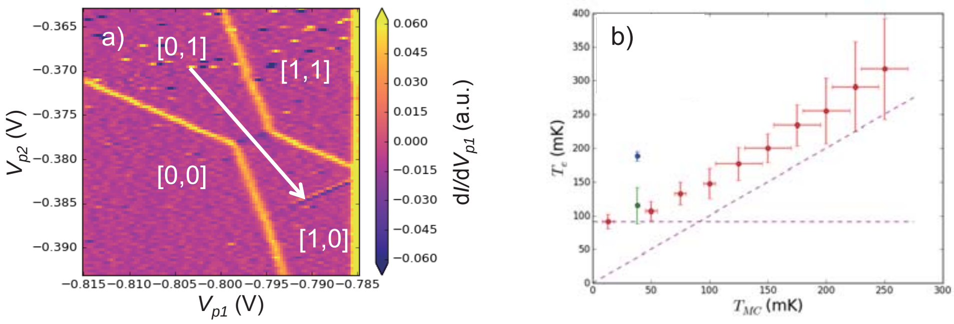
Quantum dots (QDs) coupled to electron reservoirs (i.e. electric leads) are good platforms to study open and/or non-equilibrium systems. Furthermore a new coupling regime showing non-trivial dynamics may be reachable if measurements are performed over very short time scales and at low temperatures. In this work we present our efforts to reduce the electron temperature (T_e) of a double QD system. T_e is determined from analysis of the charge transition as a function of gate voltages as an electron moves from the left to the right QD (indicated by the arrow in the stability diagram shown in Fig. a) and compared with the temperature of the dilution refrigerator (Fig. b).



Q-24

Quantum Monte-Carlo study of quantum spin ice under a [111] magnetic field

T. A. Bojesen[1] and S. Onoda[1,2]

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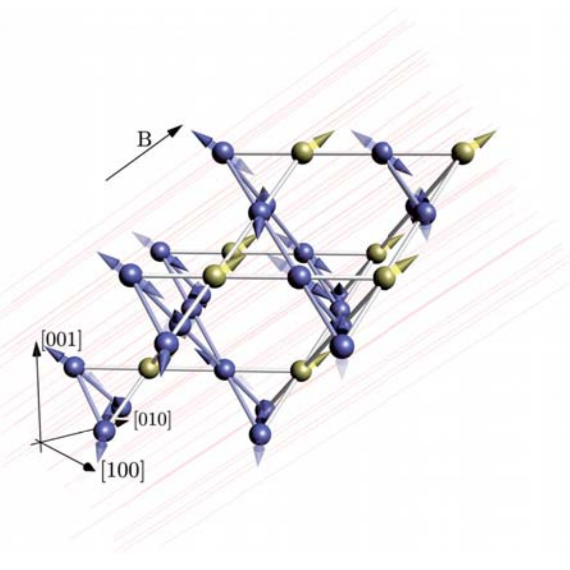
The quest for novel quantum spin liquids (QSL) has been an intriguing issue in condensed matter physics. Recent quantum Monte-carlo (QMC) simulations have demonstrated a crossover from a pyrochlore spin ice to a U(1) QSL ground state when nearest neighbor spin flip exchange interactions are turned on. [Y. Kato and S. Onoda, Phys. Rev. Lett. 115, 077202 (2015)]

In this work we have investigated the fate of the U(1) QSL under a [111] magnetic field using extensive unbiased QMC simulations. It is found that the classical-to-quantum crossover on cooling - confirmed at zero magnetic field in the previous study - continues to moderately high magnetic field. Kagomé ice entropy and magnetization plateaux appears in an intermediate temperature and field region, which is followed by a release of the entropy at lower temperatures. Predictions for the spin-polarized neutron scattering profile and transport coefficients are made on a basis of the simulations.



Q-25

High-Fidelity Readout of Two-Spin Correlations Using a Metastable Charge State in Triple Quantum Dots

T. Nakajima[1], M. R. Delbecq[1], T. Otsuka[1], P. Stano[1], S. Amaha[1], J. Yoneda[1], A. Noiri[2], K. Kawasaki[2], K. Takeda[1], G. Allison[1], A. Ludwig[3], A. D. Wieck[3], and S. Tarucha[1,2]

[1]RIKEN Center for Emergent Matter Science (CEMS), Wako, Saitama 351-0198, Japan
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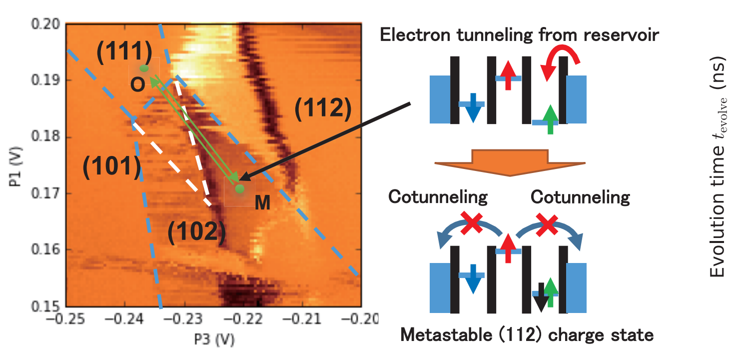
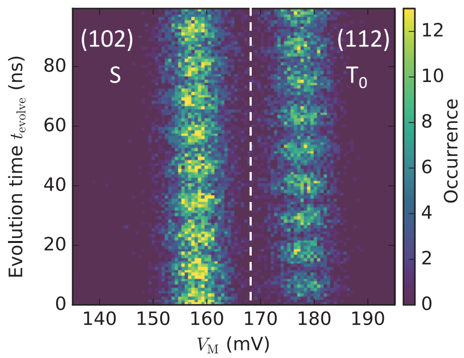
Probing electron spin correlations is an essential ingredient for spin-based quantum information processing and for studying mesoscopic quantum spin dynamics. In semiconductor quantum dots, the Pauli spin blockade is an established spin-to-charge conversion technique used to distinguish a spin singlet and triplets.

In this work, we demonstrate a new spin-to-charge conversion technique using a metastable charge state in triple quantum dots, which significantly improves the signal-to-noise ratio and the reliability. As shown in the left figure, spin-blocked states are transferred to a stable charge state by loading an extra electron from a reservoir. This allows for high-fidelity single-shot readout of spin correlations in a quantum dot array as demonstrated in the histogram plot in the right figure.





Q-26

Centre resonance frequency shift of a strongly driven silicon quantum dot spin qubit

K. Takeda[1], J. Kamioka[2], J. Yoneda[1], T. Otsuka[1], M.R. Delbecq[1], G. Allison[1], T. Nakajima[1], T. Kodera[2], S. Oda[2], and S. Tarucha[1]

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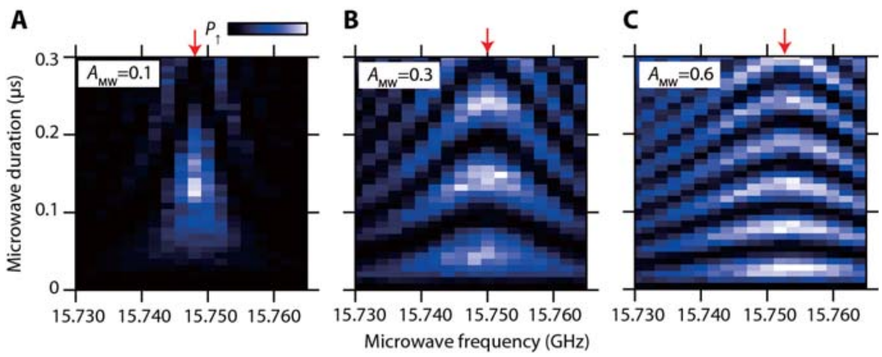
Electron spins in silicon quantum dots are one of the most promising candidates for implementing high-fidelity qubits in solid-state quantum computing. Here we report the effect of strong microwave excitation of a Si/SiGe spin qubit with a micro-magnet field gradient. To increase the qubit fidelity, it is straightforward to apply large microwave power to increase the Rabi oscillation frequency (f_{Rabi}) and therefore increase the number of possible operations within the coherence time. However, as the microwave power is increased, in addition to the increasing f_{Rabi}, we observe a shift of the centre resonance frequency of several MHz. To implement a high-fidelity qubit, the frequency shift has to be taken into account since it causes an unwanted phase accumulation for the qubit. We finally show that the qubit phase accumulation can be reduced by the quadrature microwave control.



Q-27

High-fidelity spin control in an enriched Si/SiGe quantum dot with a micromagnet

J. Yoneda[1], K. Takeda[1], T. Otsuka[1], T. Nakajima[1], M.R. Delbecq[1], G. Allison[1], T. Honda[2], T. Kodera[2], S. Oda[2], Y. Hoshi[3], N. Usami[4], K.M. Itoh[5], and S. Tarucha[1]

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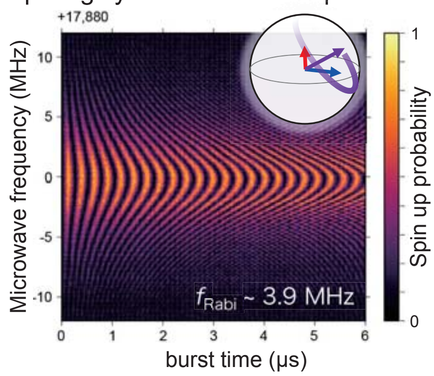
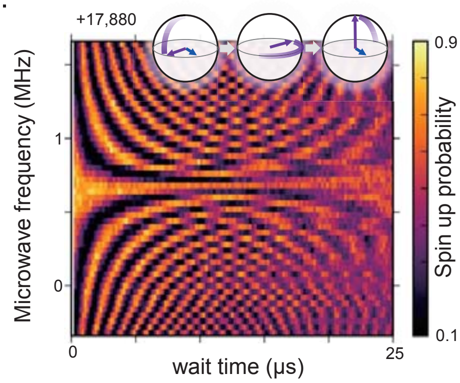
Improving control fidelities well beyond the fault-tolerant threshold is imperative to alleviate stringent requirements on quantum processing architectures. In a scalable quantum-dot-qubit platform, fidelities just above the surface-code threshold have been achieved either by use of isotopically purified materials or local magnetic fields of a proximal micromagnet. Here we demonstrate that by unifying these approaches, one can obtain high compatibility of long phase coherence (T_2*~20 μs) and fast controllability (T_π ~ 40 ns), to realize < 0.1 % error rate per qubit gate. These results provide a promising route to large-scale, fault-tolerant quantum computing systems based on quantum-dot spins.





Q-28

Magnetic Analogue of Superconductivity in Quantum Spin Ice

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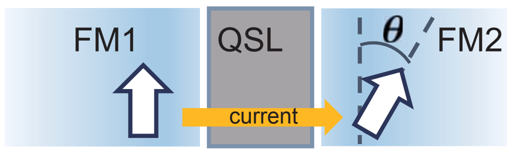
RIKEN, Wako, Saitama 351-0198, Japan

We discuss unconventional magnetic interference phenomena of spinons coupled with emergent U(1) gauge field which is considered to be a relevant description of quantum spin ice systems.

Quantum spin ice monopoles are deconfined bosonic quasiparticles which carry a fractionalized spin-1/2 charge. When they show a Bose-Einstein condensation, a magnetic order appears as in the Higgs ferromagnetic phase of Yb2Ti2O7 [1]. In an analogue of superconducting systems, the condensation behaves like that of Cooper pairs. Naively, magnetic analogue of Josephson effects are expected to occur at a junction systems of quantum spin liquid, which corresponds to insulating barrier in usual Josephson junctions, terminated by two domains having different ferromagnetic moment directions. This might show a remarkable contrast to the conventional ferromagnets where spin waves have dissipation and damping.

For the calculation of a proximity effect of ferromagnetic phases to a quantum spin liquid phase, we perform the gauge mean field theory proposed in Ref.[2] dealing with spatially dependent gauge fields in the junction system. The transport of monopole charges is investigated by imposing a boundary condition specific to ferromagnetic domains and/or introducing domains in basic parameters to produce such a junction systems. A possible relevance of the results to ultraslow spin relaxation observed in some Yb2Ti2O7 samples is discussed.



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Q-29

Hybrid cQED architecture as a model system for non-equilibrium physics in condensed matter

M. Marx[1,2], G. Allison[1], M. R. Delbecq[1,2], K. Takeda[1,2], T. Nakajima[1,2], J. Yoneda[1,2], T. Otsuka[1,2] and S. Tarucha[1,2]

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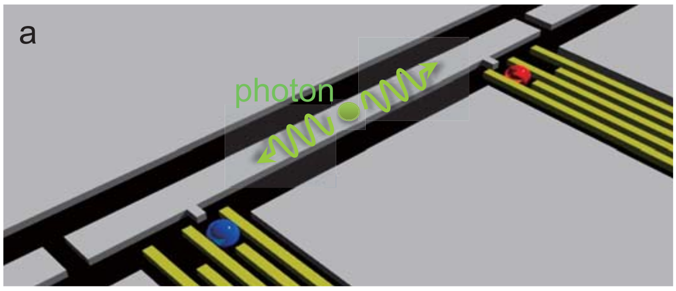
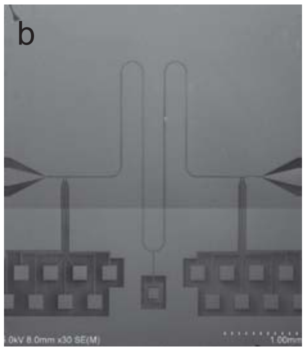
[2]*Department of Applied Physics, University of Tokyo, Bunkyo-ku, Tokyo 113-8656, Japan*

As the number of Quantum Dots used in arrays for semiconductor based quantum computing increases one needs to think of a way to transfer information coherently from one block of quantum dots to another. We show a scheme (figure a) to implement this using SiGe quantum dots and a superconducting cavity (figure b). When the superconducting cavity is tuned to be occupied by no more than one photon this photon may be used to coherently transfer information between the two quantum dots. This is an important step towards an enlarged quantum dot architecture. It has been shown by other groups that a charge state in one dot can be transferred to and read out using the resonator. Due to the weak magnetic coupling we need to engineer an electric coupling to couple to the spin.
This system is further interesting as it is an ideal platform to simulate various condensed matter systems which cannot be solved classically.





Q-30

Detection and control of the charge states of a quintuple quantum dot in a scalable multiple quantum dot architecture

Takumi Ito[1, 2], Tomohiro Otsuka[1, 2], Shinichi Amaha[1], Matthieu R. Delbecq[1, 2], Takashi Nakajima[1, 2], Jun Yoneda[1, 2], Kenta Takeda[1, 2], Giles Allison[1], Akito Noiri[1, 2], Kento Kawasaki[1, 2] and Seigo Tarucha[1, 2, 3]

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Multiple Quantum dots (QDs) can offer intriguing fermionic Hubbard models and are also proposed to implement spin-based quantum computing. However, further scale up of the QD system beyond quadruple QDs requires technical advances. In this work, we realize a semiconductor quintuple quantum dot (5QD) or series coupled five quantum dots with a new sample architecture relevant for further scaling up the QD system. Figures show the stability diagram measured for the left three dots QD_1 to QD_3 (a), and the right three dots QD_3 to QD_5 (b) using the left, and right charge sensors, respectively. Multiple QDs have complicated charge configurations, which need to be defined in multiple voltage planes. Therefore, we divide the 5QD into two triple QDs each having two reservoirs and one charge sensor to predominantly address the nearest three dots. This technique will be applicable to multiple QDs in a scalable manner.