RCAST Winter Seminar on Quantum Physics

New Year Greetings to All!

We always thank you for your continuing support to our research and education work.

Next month, we invite two world-leading researchers, *Joerg Wunderlich* and *M. F. Gonzalez-Zalba,* from Hitachi Cambridge Laboratory in UK at our Institute to have an opportunity to hear their recent activities. We welcome you to join us on this seminar to foster new interactions and collaborations.

New Year, 2018

Ryohei Kanzaki
Director, RCAST, UTokyo

- Date/time : February 16 (Friday), 2018 / 14:00-16:00
- Place : ENEOS Hall, 1st Floor, Building 3-S
  Research Center for Advanced Science and Technology (RCAST)
  The University of Tokyo (UTokyo)
  4-6-1 Komaba, Meguro-ku, Tokyo 153-8904, JAPAN
- Registration : Registration fee is free.
  Since the capacitance of the Hall is limited (100), only university and public-related research institute personnel are accepted.
  Please register by mail to international@rcast.u-tokyo.ac.jp
- Contents
  - 14:00-14:15 Introduction on Hitachi Cambridge Laboratory
  - 14:15-15:00 **“Towards antiferromagnetic spintronics”**
    - *Dr. Joerg Wunderlich*
  - 15:00-15:15 Coffee break
  - 15:15-16:00 **“Quantum computing with silicon transistor”**
    - *Dr. Fernando Gonzalez-Zalba*

＊ Language : English (No interpretation available)

Inquiry and Registration

: *international@rcast.u-tokyo.ac.jp / Strategic Planning Office / RCAST*

Towards antiferromagnetic spintronics: From spin Hall effect towards electrically driven magnetization reversal of antiferromagnets and electrical readout of reversed antiferromagnetic states

Joerg Wunderlich

Modern magnetic storage technologies are based on classical spin-transfer magneto resistance and torque effects enabling the detection and manipulation of magnetisation in ferromagnets by spin-polarised currents. [1]

A promising new development in spintronics research considers antiferromagets as active elements for robust magnetic storage and ultrafast information processing. Antiferromagnets possess a microscopic staggered magnetic order with no overall magnetization, resulting in much faster dynamics (~THz) than the one of ferromagnets (~GHz). [2, 3]

Although antiferromagnets have been known for about eighty years, their (spin) transport properties have only attracted interest lately. This is because it was believed to be difficult to manipulate and to detect the magnetic state of antiferromagnets. For example, only strong applied magnetic fields can affect the antiferromagnetic order directly and conventional ST effects proposed to read and write antiferromagnets require rather perfect antiferromagnetic model systems. [4, 5]

However, large magnitude anisotropic magneto-resistance effects in the tunnelling transport regime have indicated the possibility to detect antiferromagnetic order electrically. [6-8] In these experiments, low magnetic field manipulation of the anti-ferromagnetic state was realised indirectly by an exchange-coupled ferromagnet.

Apart from spin transfer torque (STT), also relativistic current induced spin-orbit torque (SOT) effects due to the inverse spin Galvanic effect [9-12] and/or the Spin Hall effect [9, 11] can be used to manipulate magnetic moments. [13-19] SOT effects require broken inversion symmetry and were first observed in a ferromagnetic semiconductor with bulk inversion asymmetric of the crystal lattice. [13] They are present also in systems with structurally broken inversion symmetry [14-16] and can reverse efficiently and fast the magnetisation of thin ferromagnetic films by SOT-driven DW propagation. [18, 19]

Most importantly, SOT effects can also act on the magnetic states of antiferromagnets. [20] They have been observed in antiferromagnetic thin films with structural inversion asymmetry [21] and SOT-driven switching of antiferromagnetic states has been very recently realised in CuMnAs, a system with locally broken inversion symmetry of the individual magnetic sublattices. [22]

In my talk I will discuss potentially large magnitude magneto resistance and current induced SOT effects able to detect and to manipulate ultrafast and magnetic field independent the staggered magnetic order of antiferromagnets. Finally, I will discuss the electrical detection of of reversed antiferromagnetic states which are switched by current pulses of opposite polarity.

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Quantum computing with silicon transistor

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Introduction

The silicon metal-oxide-semiconductor transistor is the workhorse of the microelectronics industry. It is the building block of all major electronic information processing components such as microprocessors, memory chips and telecommunications microcircuits. By shrinking its size generation after generation the computational performance, memory capacity and information processing speed has increased relentlessly. However, the process of miniaturization is bound to reach its fundamental physical limits in the next decades.

New computing paradigms are hence paramount to overcome the technical limitations of silicon technology and continue increasing the computation performance beyond simple multi-core approaches. Quantum computing – based on computing with interacting two-level quantum systems or qubits- offers exponential speed-up over several classical algorithms [1-3] and it is hence one of the most sought-after alternatives to conventional computing. However, finding the optimal physical system to process quantum information and scale it up to the large number of qubits necessary to run the aforementioned algorithms remains a major challenge. Paradoxically, we are now starting to see that silicon technology itself could offer an optimal platform on which to fabricate spin-based scalable quantum circuits: Quantum computing with silicon transistors fully profits from the most established industrial technology to fabricate large scale integrated circuits while facilitating the integration with conventional electronics for fast data processing of the binary outputs of the quantum processor; all this offering long electron spin coherence times [4].

Results

In this talk, I will present a series of results on fully depleted silicon-on-insulator (FD-SOI) transistors at miliKelvin temperatures that demonstrate this technology can provide a platform for high-integration spin qubit architectures. Firstly, I will report the formation of a tunnel coupled double quantum dot (DQD) at the top-most edges of the transistor, as the building block for implementing charge and spin qubits [5,6]. By using split-gate electrodes we independently control the charge occupation of the system down to the few-electron limit. Measurements of the charge and spin state of the system are done via *in-situ* dispersive gate-based radio-frequency reflectometry [7-10], see Fig 1.

Finally, I will present a set of experiments that demonstrate the potential to scale FD-SOI technology to a large number of qubits and interface them naturally with conventional binary FD-SOI transistors [11].

Overall, our results open up the possibility to operate compact transistor technology as electron spin qubits and demonstrate the potential of split-gate FD-SOI technology as a hardware for quantum computing.

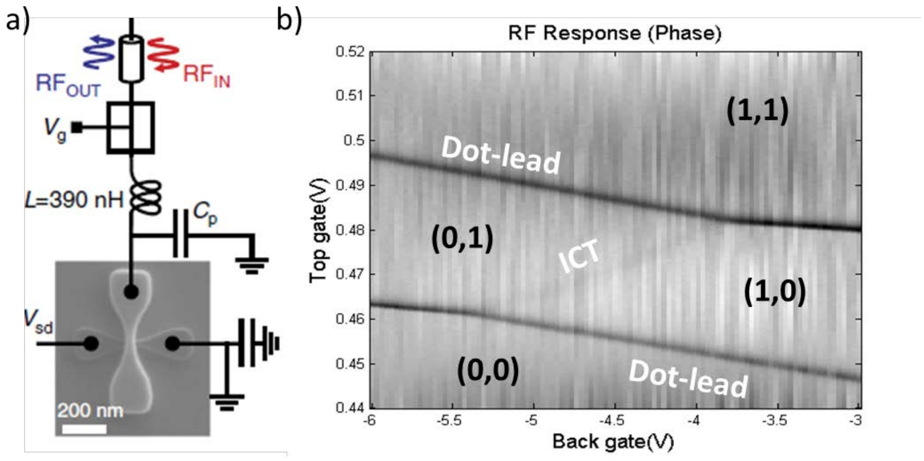

Fig. 1: Gate-based dispersive readout of the quantum state of a double quantum dot. a) Radio-frequency set up for gate-based reflectometry. A LC resonator is directly connected to the gate of the quantum device. b) Stability diagram showing the few-electron regime in a double quantum dot measured dispersively (RF phase response). The numbers (n,m) indicate the number of electrons in the double quantum dot.

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