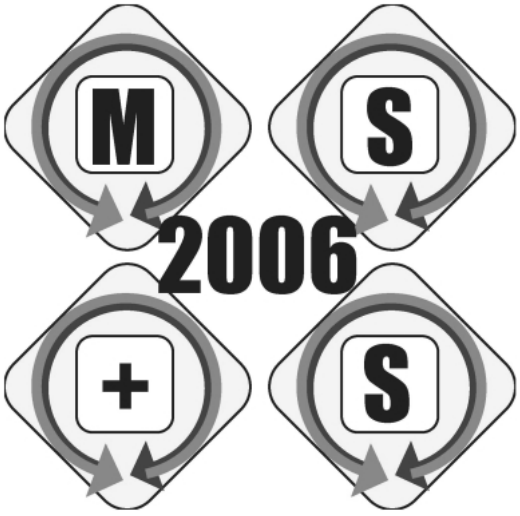
Solid State Quantum Bits are in Action—Conference Report on "Mesoscopic Superconductivity and Spintronics 2006"

From February 27 to March 2, NTT Basic Research Laboratories (NTT BRL) and CREST-JST (Core Research for Evolutional Science and Technology, Japan Science and Technology Agency) held an international symposium on physics entitled "Mesoscopic Superconductivity and Spintronics" (MS+S2006) at NTT Atsugi R&D Center. These fields have recently been attracting considerable attention from scientific researchers and engineers because they are fundamental areas that may lead to the physical realization of quantum information processing and computation. MS+S is a series of biennial symposia that started in 2000.

Many distinguished researchers in these fields from all over the world have joined every event and given important presentations. It is now recognized as an important international symposium on mesoscopic physics although, strangely, it is better known among European and American researchers than Japanese ones. MS+S2006 included 46 oral presentations and approximately 80 poster presentations.

At the symposium this year, we were impressed by the fact that mesoscopic superconductivity is attracting attention in terms of applications in addition to the academic interest that dominated MS2000. This has accompanied the development of research on superconducting quantum bits (SCQ), which are basic elements of quantum computers.

Professor J. Martinis of UC Santa Barbara, Professor F. W. J. Hekking of Centre National de la Recherche Scientifique and Université Joseph Fourier, Professor D. Esteve of CEA-Saclay, Professor J. Clark of UC Berkeley, Professor C. J. P. M. Harmans of Delft University of Technology, Dr. K. Semba of NTT BRL, Dr. Y. Nakamura of NEC, Dr. Wallraff of Swiss Federal Institute of Technology Zurich and Yale University, and Professor A. Ustinov of University of Erlangen-Nuremberg gave talks on new results in their SCQ experiments. These people represent almost all the research groups throughout the world that actually have SCQs in operation.



Single quantum bits can now be controlled almost perfectly. Next, we have to move on to experiments with two or more bits, including an investigation of quantum entanglement between quantum bits. In this respect, Professor J. Martinis's group has had the greatest success. They observed two-quantum-bit entanglement and provided the quantum tomography charts of their system. On the other hand, the Yale University group showed the entanglement between their SCQ and a transmission line resonator, and the NTT BRL group demonstrated entanglement manipulation of their SCQ and a sub-millimeter LC resonance circuit coupled system, which is known as "vacuum Rabi oscillation" in the field of quantum electrodynamics. These two studies are the first clear demonstrations of entanglement in macroscopic quantum objects. The NEC group analyzed their SCQ and found some important properties of noise that caused decoherence in it.

We also found that rapid progress is being made in spintronics. In particular, electrical ways of manipulating spins in semiconductor systems generated great interest in this symposium. A talk on the generation and detection of spin entanglement in double quantum dots was presented by Professor C. Marcus

of Harvard University. Dr. S. Sasaki of NTT BRL described a gate-controlled RKKY interaction in a double quantum dot-quantum wire coupled system. Much attention has focused on the spin-orbit interaction in semiconductors because it can produce an effective magnetic field without a real magnetic field. Professor D. Awschalom of UC Santa Barbara demonstrated optical detection of the spin Hall effect in GaAs and InGaAs, where spin up and down electrons were accumulated at opposite edges without any external magnetic fields.

Gate control of spin precession in InGaAs 2DEGs (two-dimensional electron gases) was reported by Professor J. Nitta of the CREST project and Tohoku University. Professor H. Ohno of Tohoku University observed current-induced domain wall motion in GaMnAs. This was due to the interaction between spin-polarized current and localized spins inside a magnetic domain.

Midway through the symposium, a special lecture on entanglement manipulations with trapped ions was given by Dr. H. Häffner of Innsbruck. Most participants were surprised by the admirable skill shown in manipulating ions although they were not very familiar with the system.

The symposium welcomed approximately 200 participants, of whom a quarter were from overseas. They have now returned home with the dream of fruitful interaction between fundamental physics and information sciences, which will become common in the near future.