ALLIANCE 3: QUANTUM NANOELECTRONICS

Research axes and facilities

With the reduction of size of electronic circuits, their properties deviate dramatically from the classical laws of electronics to enter the quantum world. Rather than considering quantum effects as limiting effects, new functionalities are inspired by them. The research challenges proposed by the “Quantum Nanoelectronics” Alliance are of great scientific and technological importance.

On a fundamental basis, microscopic mechanisms of electronic properties are investigated such as electron-electron interaction, coulomb blockade, decoherence, proximity effect and Andreev reflection. Quantum engineering is addressed with superconducting qubits, sources of entangled electrons, electronic coolers. The issue of coupling a few quantum bits together or with a controlled environment such as a microwave cavity is a new step towards quantum computing and quantum optics with microwave photons. New quantum bits based on coherent spin manipulation are studied in various nanostructures from SiGe or AlGaAs quantum dots to ultimately sophisticated nano-MOSFET. All these research topics show a very strong potential and are strongly connected to the future of nanoelectronics through the so-called “Beyond CMOS” and “More than Moore” strategies.

The quest for new materials offering new properties for new functionalities is at the heart of the Alliance. The discovery of graphene (2010 Nobel Prize in Physics), the realization of topological insulators, carbon nanotube or molecular devices, the addressing of individual self-assembled SiGe dots or the discovery of superconductivity in diamond and silicon, are permanently boosting this activity.

The Alliance benefits from this unique ensemble of expertise and exploits the specific expertise of Grenoble for the fabrication of nanomaterials and nanostructures (Alliance 9), as well as strong collaborations with “Theoretical and Computational Physics” (Alliance 8). The proximity of LANEF with the CEA/LETI offers a unique access to highest quality silicon based nanostructures. The development of new instrumental techniques like ultra low temperature scanning probes, noise measurements or very high frequency response is a long-standing tradition of Grenoble’s scientific community and is strongly represented in the Alliance.

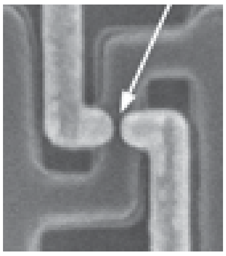
Actions within LANEF

Nanofabrication and instrumental development.

With the development of nanofabrication tools for high quality material preparation, it is now possible to realize complex multi-terminal nanodevices that are entirely quantum coherent. To probe the properties of such nano-objects and new materials, state-of-the art instrumental techniques are necessary and need to be implemented usually at very low temperature. Within LANEF, the “quantum nanoelectronics” Alliance aims to design, fabricate and probe quantum circuits exploiting the quantization of charge, flux, photons and phonons.

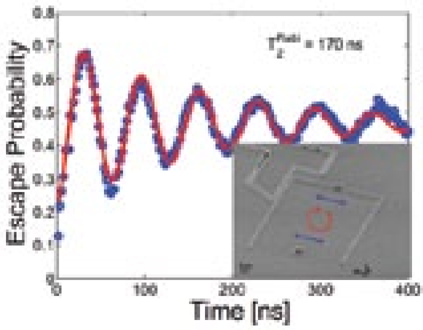
Scanning Tunneling Microscope in a dilution refrigerator

Coherent Spintronics. The building block for spin-based quantum computing with long coherence and relaxation times is investigated in depth. Together with AlGaAs 2 dimension electron gas quantum dots, other systems such as molecules or quantum dots in other materials are very promising. The ultimate electron spin coding at the nanoscale can also be obtained by using individual dopants in silicon-based devices.



Silicon NanoMOSFET with two gates separated by 16 nm fabricated using the LETI facility

Superconducting Circuits. As superconductivity correlates the quantum phase of the conduction electrons, nanostructures coupling a nano-object to a superconductor provide a powerful way to probe and manipulate its quantum state - the nano-object can be a quantum dot, a nanowire, a molecule or a graphene sheet. Superconducting nanostructures offer also possibilities for qubit manipulation, quantum electrodynamics, electronic cooling, single photon production and detection, metrological electron pumps, sources of entangled electrons.



Rabi oscillations of a dcSQUID phase qubit fabricated using Nanofab and PTA facilities

KEY FIGURES: **40 Permanent scientists from INAC, LPMMC, NEEL**
50 PhD students and postdocs, 30-40% with a master obtained outside of Grenoble
Strong collaborations with Delft, Helsinki, Pisa, Karlsruhe, Harvard
R&D and industry: LETI, LITEN

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