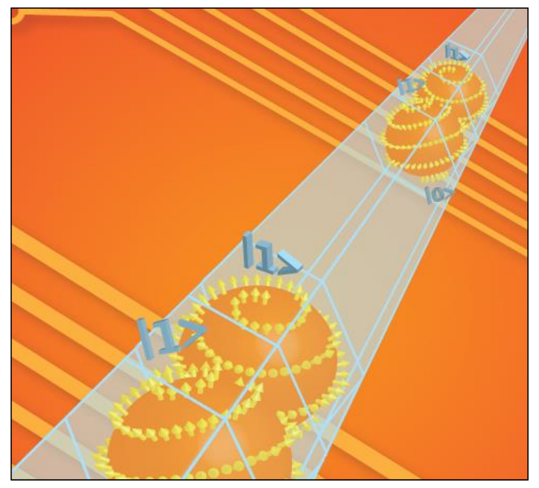
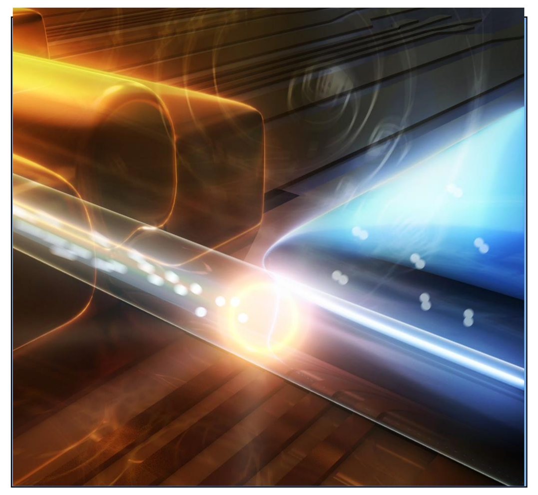
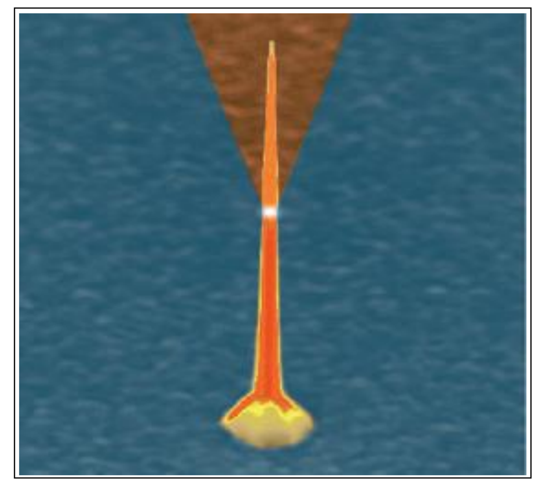
Quantum Science and Technology based on Semiconductor Nanowires



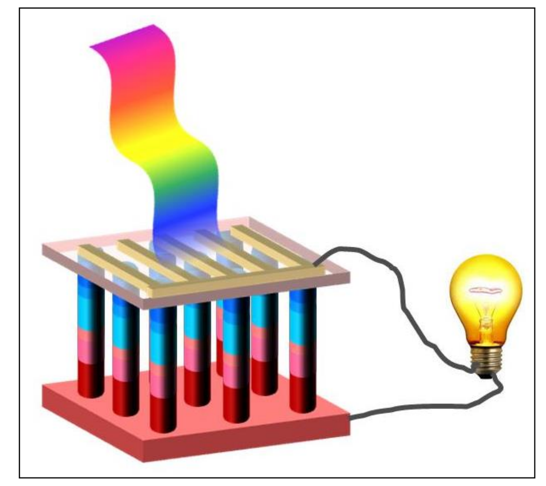
Quantum bits



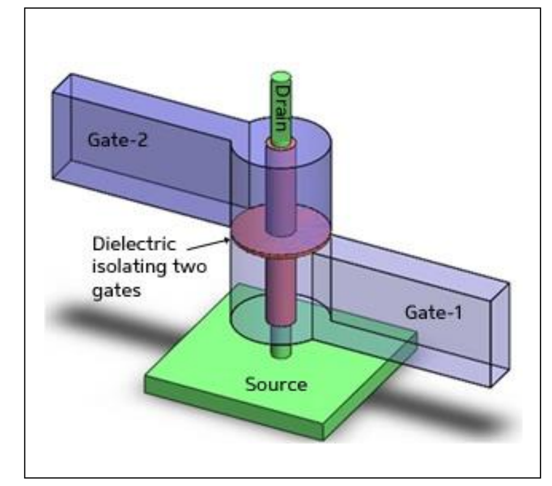
Majorana Fermions



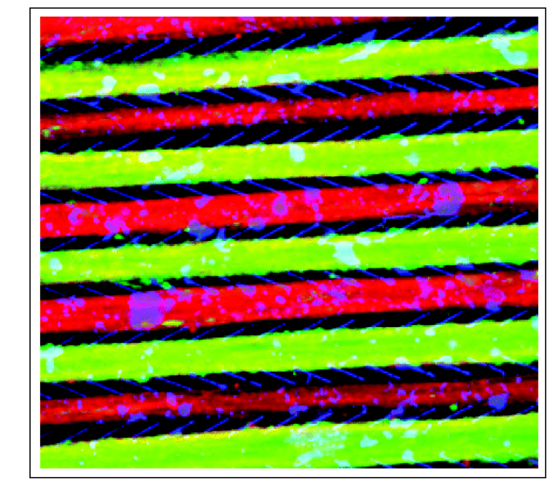
Single Photon Sources



Solar Cells



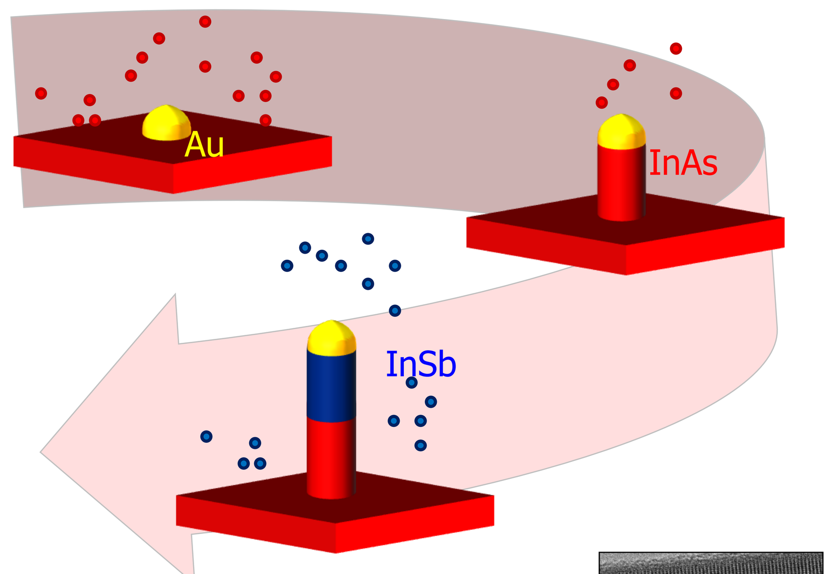
CMOS Architectures



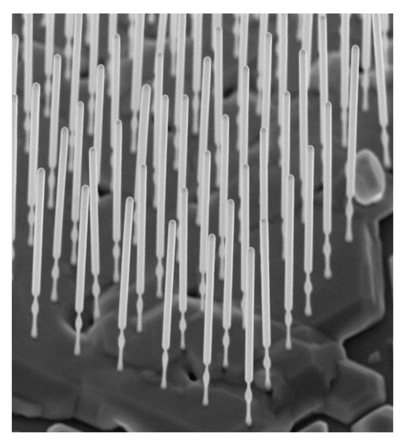
Bio-nanotechnology

Growth of Semiconductor Nanowires

Vapor-Liquid-Solid mechanism with Au catalyst



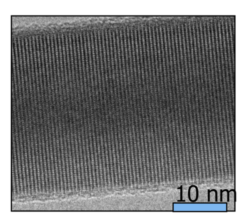
high aspect ratio InSb nanowire on InAs stems
Plissard et al Nano Letters 2012



Crystal growth (collaborations)

Nanofabrication

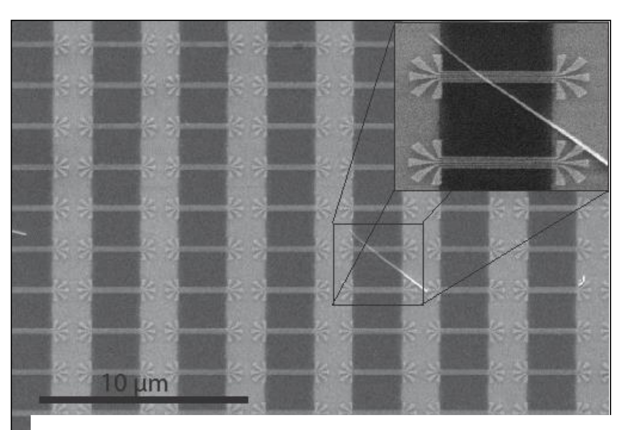
Low-T electrical measurements

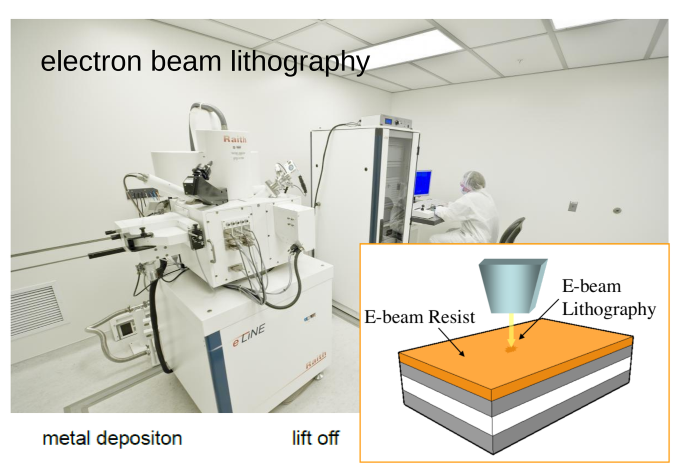


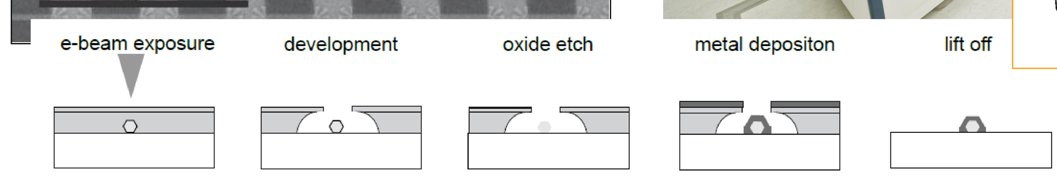
perfect single crystal InAs (TEM image)

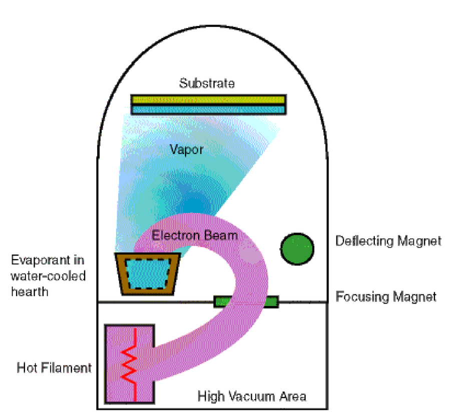
Nanowires offer a flexible material toolkit

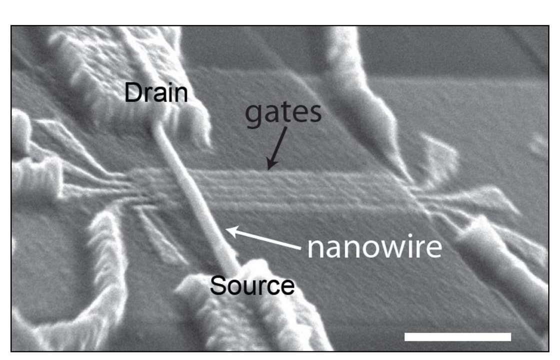
Device Fabrication: Cleanroom







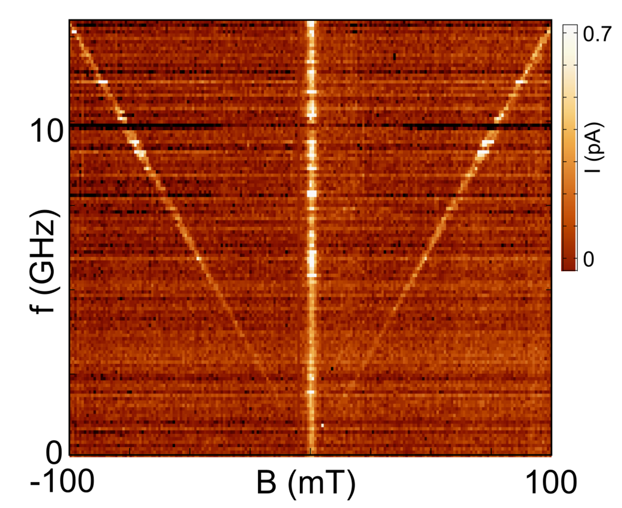




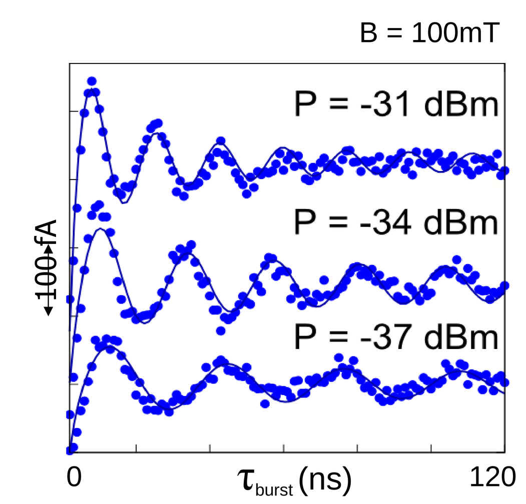
Research: Spin-orbit qubit in a nanowire (Nature 2010)

Motion of electrons can influence their spins through a fundamental effect called spin–orbit interaction. This interaction provides a way to control spins electrically and thus lies at the foundation of spintronics. Even at the level of single electrons, the spin–orbit interaction has proven promising for coherent spin rotations. Here we implement a spin–orbit quantum bit (qubit) in an indium arsenide nanowire, where the spin–orbit interaction is so strong that spin and motion can no longer be separated. In this regime, we realize fast qubit rotations and universal single-qubit control using only electric fields; the qubits are hosted in single-electron quantum dots that are individually addressable. We enhance coherence by dynamically decoupling the qubits from the environment. Nanowires offer various advantages for quantum computing: they can serve as one-dimensional templates for scalable qubit registers, and it is possible to vary the material even during wire growth. Such flexibility can be used to design wires with suppressed decoherence and to push semiconductor qubit fidelities towards error correction levels. Furthermore, electrical dots can be integrated with optical dots in p–n junction nanowires. The coherence times achieved here are sufficient for the conversion of an electronic qubit into a photon, which can serve as a flying qubit for long-distance quantum communication.

spin-orbit qubit is a quantum yo-yo: spin rotates when electron is moved back and forth

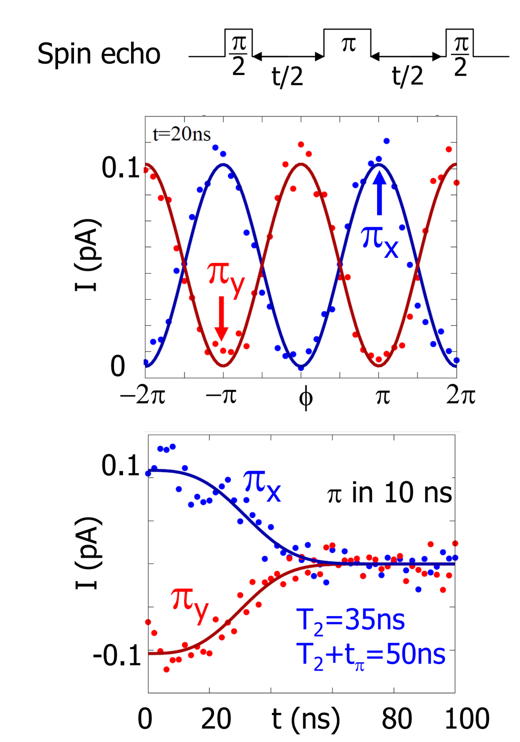


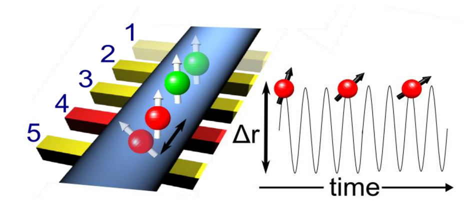
electric dipole spin resonance

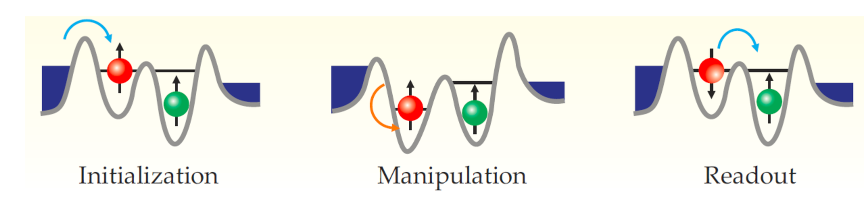


Coherent Rabi Oscillations

Universal single qubit control

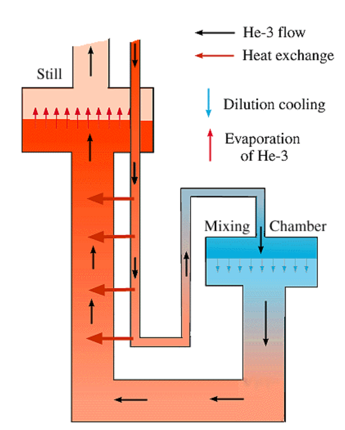




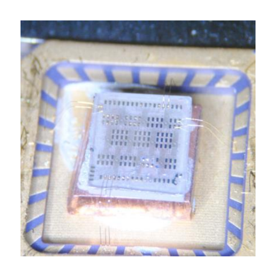


Spin-orbit qubit control protocol: electrical pusles applied to the gate electrodes that define a double quantum dot

Quantum Transport Measurements



Dilution refrigerators help reach temperatures as low as few milliKelvin. They operate by circulating He3 gas in a closed loop. The milliKelvin cooling occurs in the mixing chamber where He3 is diluted in He4.

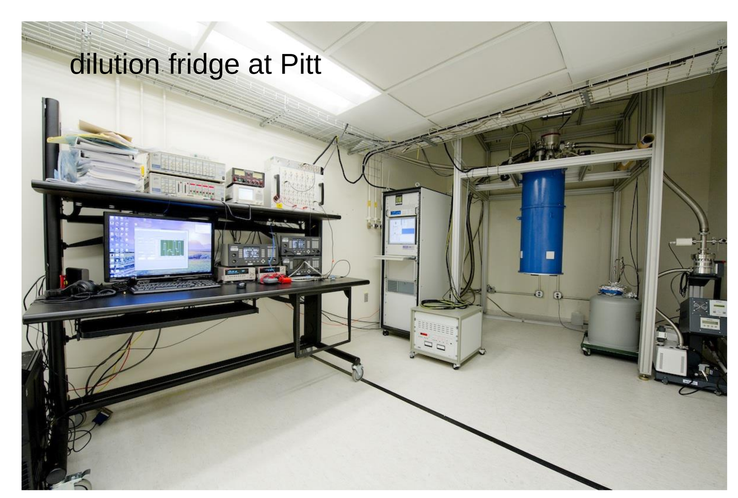


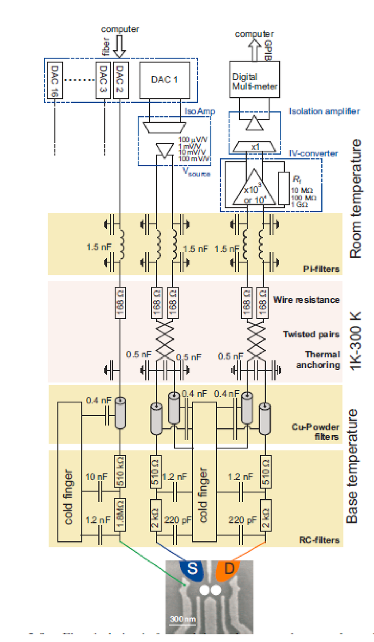
bonded chip

Nanoscale devices fabricated in the cleanroom are wirebonded to gold chip carriers and loaded into a dilution fridge. The chips are cooled down in order to allow for low-energy quantum effects to manifest themselves and not be masked by thermal broadening. Measurements are often performed at high magnetic fields (several Tesla) created by superconducting magnets.

Ultra-Low Temperatures

CF refrigerator and gas handling system





Ultralow noise electronics and heavy fitering are required to perform measurements on devices such as quantum dots, Majorana transistors and superconducting interferometers.

Megapixel scan of a double quantum dot