Quantum computing with electron spins in silicon

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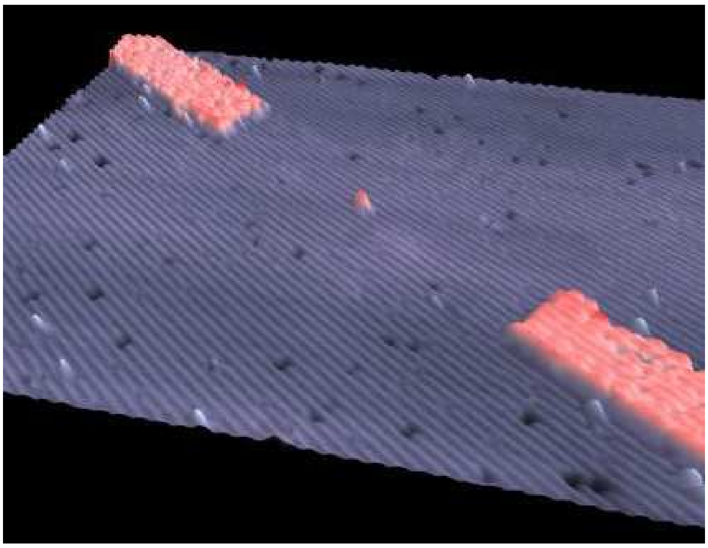
In 1982, the Nobel prize-winning physicist, Richard Feynman, thought up the idea of a 'quantum computer'- a computer that harnesses the power of quantum mechanics to perform information processing tasks billions of times faster than any state-of-the-art silicon-based computer. From being a purely mathematical dream thirty years back, quantum computation has now emerged as a key area of research, combining expertise from quantum physics, mathematics, and computer science.



A (single-electron) transistor (in red) made by accurately positioning a single P atom (red spot in the middle) on the surface of a silicon crystal (blue), with a scanning tunnelling microscope (STM) tip [4].

One of the promising approaches for realizing a practical quantum computer is to encode information in the spin states of an electron, confined within a silicon crystal. A complete quantum computing architecture using electronic spin states requires development of means to isolate, initialize, manipulate, entangle, coherently transport, and finally detect spins. Over the last decade, enormous progress has been made in developing many of these functionalities, which has not only demonstrated unprecedented control on a purely quantum mechanical system [1-3], but also enabled nanofabrication of electronic devices at sub-nanometer length scales [4-7]. In this talk, following a brief introduction to (spin) quantum computing, I will present some of the key achievements made towards realization of a spin quantum computer in silicon.

1. ***A single-atom electron spin qubit in silicon***, J.J. Pla, K.Y. Tan, J.P. Dehollain, W-H. Lim, J.J.L. Morton, D.N. Jamieson, A.S. Dzurak, A. Morello, Nature 489, 541 (2012).

2. ***Coherent singlet-triplet oscillations in a silicon-based double quantum dot***, B. M. Maune, M. G. Borselli, B. Huang, T. D. Ladd, et. al., *Nature* 481, 344 (2012)

3. ***Single-shot readout of an electron spin in silicon***, A. Morello, J.J. Pla, F.A. Zwanenburg, K.W. Chan, H. Huebl et. al., Nature 467, 687 (2010)

4. ***A single-atom transistor***, M. Fuechsle, J.A. Miwa, S. Mahapatra, H. Ryu, S. Lee, O. Warschkow, L.C.L. Hollenberg, G. Klimeck and M.Y. Simmons, Nature Nanotechnology 7, 242 (2012).

5. ***Ohm's Law Survives to the Atomic Scale***, B. Weber, S. Mahapatra, H. Ryu, S. Lee, A. Fuhrer, et. al., Science 335, 64 (2012)

6. ***Spin readout and addressability of phosphorus-donor clusters in Silicon***, H. Büch, S. Mahapatra, R. Rahman, A. Morello and M.Y. Simmons, Nature Communications 4, 2017 (2013).

7. ***Engineering independent electrostatic control of atomic-scale (~4 nm) silicon double quantum dots***, B. Weber, S. Mahapatra, T.F. Watson and M.Y. Simmons, Nano Letters 12, 4001 (2012).