Fabricating single atom lattices to explore quantum science and technology

UCL Lead department: London Centre for Nanotechnology

Lead Supervisor: Neil Curson and Taylor Stock (joint 1st supervisors)

Project Summary:

The student will explore the quantum nature of devices fabricated with nanoscale dimensions. The underlying physics to be studied and exploited is that of spin-1/2 particles (fermions) interacting with a user-defined periodic potential. In our case the periodic potential is defined by the location of deterministically placed dopant atoms in the host silicon lattice, and the spins are the valence electrons of these dopants. These experiments will address many-body quantum physics topics that have been puzzling scientists for decades, such as those of the metal-insulator transition (Mott-Hubbard physics), and will lead to the development of quantum simulators, which are a fast route to performing quantum computation. The project is practical in nature and involves the fabrication of few and single dopant atom devices from silicon samples where the dopants are incorporated into silicon by using the tip of a scanning tunnelling microscope (STM) to pattern a single atomic layer of hydrogen, providing a masking layer to incorporate the dopants. Contacts are then made to these devices using standard cleanroom processing technology. Devices will be made to enable electrical, microwave and optical measurements to be performed, with the student performing measurements with collaborators in research groups who have expertise in these areas. In particular, magnetotransport electrical measurements are performed at cryogenic temperatures at the Paul Scherrer Institute in Zurich, as well as at UCL. The mapping of electronic charge states and the coupling of quantum components (e.g. qubits) will be performed partly at McGill University in Canada. The student will also investigate protocols for scaling up our device making effort along the lines of a Quantum Atomic-scale Device Foundry, with the ultimate aim of providing companies and universities with devices on a commercial basis. Our strong links with IBM, Keysight Technologies, IHP Microelectronics, Zyvex Labs, Quantum Brilliance, Nanolayers Research Computing and the National Physical Laboratory will help guide us with these developments. UCL collaborators are Steven Schofield (STM) and Mark Buitelaar (cryogenic measurements).