DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

UCL

PhD Studentship in "Quantum Engineering in Low Dimensional Semiconductors"

Duration of study: Full time-four years fixed term

Starting date: October 2019

Application deadline: Closing date for application is June 30, 2019 or until the position is filled.

Primary Supervisor: Dr Sanjeev Kumar

PhD Project Description:

The experimental PhD work involves engineering quantum effects which bring out new physical phenomena for advances in quantum physics and for application in future quantum technologies. The work will involve the manipulation and measurement of electron wavefunctions in systems of restricted dimensionality and observation of effects down to the single electron level. The candidate will spend considerable time in the cleanroom for fabricating high-quality nanoscale devices for subsequent detailed low-noise measurements at ultra-low temperatures down to 10mK and large magnetic field upto 14 Tesla. It may be noted a proper training will be provided for device fabrication and low-noise measurements, and there will be many opportunities for career and professional development via UCL training programme.

A system which is of considerable interest is a narrow one-dimensional (1D) channel (a quantum wire) formed within a high mobility two-dimensional electron gas (2DEG) in a semiconductor heterostructure. By means of forming metal gates on the surface of semiconductor heterostructure, the electron gas can be "electrostatically confined" into any particular shape such as a 1D or 0D system, It is intended to form integrated quantum circuits which combine different quantum effects for new functions, this follows the philosophy that "*complexity brings new rules of physics*".

Specific projects are listed below:

1. This project is inspired by our recent discovery of fractional quantisation of conductance in the absence of a magnetic field in a 1D electron gas. There have been numerous theoretical suggestions that this might occur, more or less since the discovery of the magnetic field induced Fractional Quantum Hall Effect, but the surprising feature is that we found it in a relaxed 1D system which was never considered before. The strong repulsion in a 1D system causes a line of electrons to split into two or more and then form a particular configuration which we are studying both experimentally and

theoretically. This new configuration corresponds to the creation of an “entity” comprising a number of electrons which behaves as if it was a new particle, or quasi-particle, with an effective fractional charge. These only live in the quantum wire and decay into normal electrons as they diffuse into a 2D electron system, definitive determination of the fractional charge is dependent on measurements such as quantum shot noise. These findings open up a new area with applications in quantum computation as the new fractions possess a resistance to decoherence.
2. Investigate the role of spin alignment when the lowest energy of a particular array of electrons forces the spins to align and lock together as electrons travel through the sample. We have recently shown that there is a transition to a ferromagnetic exchange interaction as a controllable 1D system is narrowed leading to a spin polarisation dependent on the length over which the interaction occurs. This can be exploited to form spin transistor structures in which transitions may occur between charge and spin currents. This will allow the creation of new spintronic functions and also studies of integrated quantum circuits in which both spin and charge can be controlled.
3. Design and investigate systems which create entangled electrons which can be described by a single wavefunction and whose properties are linked. This has been observed for photons and we have designs which will allow entangled electrons to be created and then dynamically separated. Performing spin operations on entangled electrons will open new perspectives in quantum information.

In brief, the students will have a rare opportunity to witness and gain hand on experience on some remarkable quantum mechanical effects which we observe in our laboratory on a daily basis! On completion of the project, they will have gained not only scientific insight of the quantum physics of discrete and integrated devices, but also learned and experienced state-of-the-art technologies and advanced low-noise measurement systems at ultralow temperatures in the milliKelvin regime. The deep physics which they will learn and the techniques they will experience may well shape their future research, academic or industry career.

Funding: This is a fully funded 4-year PhD studentship to cover the **Home/UK and EU students** tuition fees plus a stipend of £16,777/year (2019/2020) tax-free for living costs (increasing with inflation).

Eligibility

Applicants must meet the EPSRC eligibility conditions to be eligible for the award – in summary this typically means that applicants must have no restrictions on their right to live in the UK permanently and have been resident in the UK for three years immediately prior to the studentship commencing. EU Citizens who have not been residing in the UK for the past 3 years may be eligible for a fees only award. Please see EPSRC’s website for further details:

https://epsrc.ukri.org/skills/students/help/eligibility/

Qualifications required: Candidates should have or expect to achieve an excellent degree(s) (BEng/BSc/MEng/MSc) in Physics, Materials Science, Electronic Engineering, Computer Science or related discipline with either first class or higher second class.

How to apply: Please send your academic CV with an expression of interest to Dr S Kumar (sanjeev.kumar@ucl.ac.uk) including contact details of three potential referees.