PHYSICS DEPARTMENT COLLOQUIUM

" Spin-orbit coupling effect on quantum transport in chaotic semiconductor dots "

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Spin-orbit coupling is a relativistic phenomenon which gives rise to the spin relaxation of electrons diffusing through disordered semiconductor structures and also transforms their weak localisation (a quantum interference effect observed at low temperatures) into anti-localisation. In semiconductor heterostructures and quantum wells, the origin of spin-orbit coupling in the electron Hamiltonian can be traced back to the crystalline symmetry and band structure of the underlying material, and to the properties of interfaces involved in the formation of two-dimensional electron system.

In this lecture, it will be shown that the effect of spin-orbit coupling on spin relaxation of carriers and their quantum transport properties is dramatically reduced by the geometrical confinement of orbital electron motion. The proposed analytical description of spin-orbit (SO) coupling in small-size objects, such as quantum dots, is based upon a unitary (non-Abelian) gauge transformation, which eliminates the SO coupling from the Hamiltonian describing electrons in a locally twisted spin-coordinate frame in the lowest order, but introduces the effective magnetic field of the opposite sign for spin 'up' and 'down' electrons. As a tutorial example, this will be used to interpret the anisotropy of spin splitting of the electron spectrum observed in the resonant tunnelling studies of quantum dot states [5].

Quantum transport characteristics of lateral semiconductor dots with chaotic electron motion inside them are very sensitive to the exact symmetries of the electron Hamiltonian in them. The latter are reflected by the sign and magnitude of the weak localisation part of dot conductance, and by the size of the variance of universal conductance fluctuations. The theory based upon the above-mentioned unitary transformation method has enabled us to give a complete analytical treatment to the quantum transport problem in chaotic dots with a weak SO coupling [1,2]. We have classified relevant symmetry classes with different distinct symmetries and characterised crossovers between them, in agreement with the unexpected magneto-resistance behaviour in chaotic quantum dots observed by the Harvard group [3,4].

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