"Quantum Computing at the Speed of Light"

ABSTRACT
Harnessing quantum states for information storage and manipulation (in so called “qubits”) is the objective of quantum computing, with the potential to revolutionize technology in areas of great importance to society (e.g. cryptography, database searching, quantum simulation of advanced materials, software validation and verification). This potential has led to the search for suitable quantum hardware by researchers around the world. Although considerable progress has been made in implementations based on atomic and molecular systems (e.g. ion traps, nuclear magnetic resonance, and cavity quantum electron dynamics), a solid state architecture will ultimately be required to achieve scaling to a practical level. Semiconductor quantum dots are especially promising for such an application because the associated computing platform would leverage the established base of semiconductor device fabrication capabilities at the heart of traditional computers as well as photonic and telecommunication infrastructure that could enable the integration of quantum and classical computing hardware. The state-of-the-art for quantum control in semiconductor quantum dots is much less advanced than in other quantum hardware implementations due to the need to: (i) understand and mitigate sources of decoherence; and (ii) develop suitable control strategies in the solid state environment. Progress in these areas has occurred at a breathtaking pace in recent years, laying the groundwork for a scalable, solid state quantum computing architecture. In this seminar, I will describe our recent demonstration of deterministic control of distant, solid state qubits encoded in excitons in semiconductor quantum dots [1–3]. In these experiments, we have employed a technique called optimal quantum control (OQC), in which one tailors the phase and amplitude of the control Hamiltonian through femtosecond pulse shaping techniques. Such an approach has been applied to the optimization of quantum gates in atomic and molecular systems [4–6]. The extension of OQC to a system of solid state qubits in the experiments described in this seminar represents an important step forward on the path to developing scalable quantum hardware. We show that the use of pulse engineering techniques, together with the short time scale of the control pulse relative to the decoherence time of the qubits, enables high fidelity multi-qubit control despite differing dipole moments and transition energies for different qubits. Our findings pave the way towards small quantum simulators that could exploit complex instruction sets [7] to manipulate multiple qubits in parallel using suitably shaped control pulses.