List of Potential Projects for PHYS771/ECE770

NMR (R. Laflamme):

1) Overview of solid state NMR
(not only the IQC approach..)
2) Introduction to Optimal quantum control theory

Superconducting Quantum Circuits (F. Wilhelm):

1) The Quantronium
As an upgrade to the Cooper pair box charge qubit, the so-called Quantronium or charge-phase qubit has been proposed and implemented. The project aims at studying literature to point out how it works and why it has improved coherence compared to the simple Cooper pair box.

2) The flux qubit
The flux qubit is related to SQUIDs and can thus build on a huge body of practical experience. This project aims at explaining why it is a qubit and review the latest experiments.

3) Reading out qubits by switching vs. frequency shift
Qubit detectors in superconductors convert the qubit state to the critical current of an effective Josephson device. That current can be read with dissipative and with dispersive methods. One example for each method shall be introduced and compared.

4) Slow noise and echo - theory and experiment
One piece of decoherence that can hardly be engineered away is slow, 1/f noise. This project will describe experimental evidence for its importance and review how to suppress its impact using Echo techniques.

Photonic QIPD (G. Weihs):

1) Unitary operators and linear optics
An often cited paper by M. Reck et al is entitled "How to build any unitary operator in your lab" referring to linear optics. In what sense is this true and when does it fail. Show the relation between the mode representation and the evolution in multi-photon Fock space.

2) Linear optic quantum computation
After the celebrated KLM paper there was a series of papers suggesting alterntive implementations of linear optic two-qubit gates. Compile a survey of these and compare them regarding their efficiency and resource requirements.

Photonic Quantum Cryptography (N. Lutkenhaus):

1) Comparison of performance of QKD experiments

There are several implementations of quantum key distribution already in existence. The goal of this project is to go through some of the publications understanding the precise set-up, the noise models and to evaluate the performance against one common (given) security evaluation.

2) Literature Research: Imperfections of QKD implementations

The security analysis of QKD depends on modeling properly sources and detectors. However, life always carries surprises and often the way to succeed for an eavesdropper may be to go for the differences between models and the real device. Goal of this project is to understand publications going into that direction and to show what the dangers are and how to protect against them.

Photonic Quantum Detection (H. Majedi):

1- Survey of Single-Photon Detectors:

A variety of optical detection processes and techniques can be employed to achieve Single-Photon Detectors (SDPs). Photoconductive response in semiconductors and Photo-kinetic or photo-resistive responses in superconductors can be engineered in various geometrical device structures, junction and waveguides to acquire higher quantum efficiency, higher signal to noise ratio, minimum dark count and faster response time. A comprehensive comparison among the various SPDs based on their figure of merits is the subject of this project.

2- Application of Photodetection Probability Theory to Superconducting-based Single-Photon Detectors:

Photodetection probability theory considers the interaction of electromagnetic wave to initially bound electrons. In light of this theory, the probability that the photo-excited electron makes a transition from the bound state to the free state within a specific time interval can be calculated. The application of this theory to a superconducting condensate and quantitative analysis of detector efficiency is the subject of this project.