Quantum information II

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Detailed plan of the lectures:

I. Basics of operation of quantum computers in absence of decoherence (absence of errors in ubitary operations)

1) Elements of classical information theory and algorithmic complexity theory: algorithms, Turing's machines, Turing's theses, examples of classes of algorithmic complexity (P, NP, etc).
2) Information processing and physics: the relationship between the laws of physics and the computational capabilities of machines (computers) described by these laws. Classical bits vs quantum bits (qubits). How would a quantum computer work?
) The universality of a quantum computer using one- and two-qubit gates. Basic quantum logic gates. The Solovay-Kitaev theorem.
4) Practical interlude: examples of physical implementations of qubits and single- and two-qubit gates.
5) Quantum computing: Deutsch-Jozsa algorithm, Grover's algorithm, quantum Fourier transform, Shor's algorithm (outline).

II. Basics of open systems theory

1) Mixed states - introducing a reduced density matrix, and adding "classical" randomness to the general description of states. Description of mixed states of two-level systems. Von Neumann entropy of the reduced state of a subsystem and its relationship with entanglement.
2) Decoherence as a source of errors in quantum calculations. Quantum open systems. Examples: pure dephasing of the qubit in the case of pure and mixed environmental states, spontaneous recombination (Breit-Wigner theory), interaction of the qubit with a source of classical noise.
3) Formal approaches to the dynamics of open systems: Kraus operators, quantum channels. What is total positivity and why is (almost) everyone is so worried about it.

4) Formal decoherence theory in the case of Markovian dynamics of an open quantum system. Physical conditions of its applicability. Examples of when this theory works and when it doesn't work.

III. Protecting quantum computer calculations and quantum memory against decoherence

1) Basics of quantum error correction.
2) Dynamic decoupling of the qubit from the environment - coherence protection. Spin echo and multipulse sequences.
3) Qubit as a spectrometer of environmentas noise - how to take advantage of decoherence to do something useful.