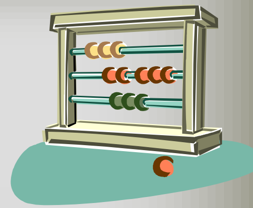
CU Physics Department Colloquium



Monday, October 15, 2007 4:15pm 428 Pupin

Sankar Das Sarma - University of Maryland

"Computing with quantum knots: Non-Abelian anyons and topological quantum computation"

Ordinary quantum computation uses simple quantum two level systems (e.g. electron or nuclear spins, atomic hyperfine states, etc.) as quantum bits ('qubits') with one- and two-qubit unitary operations serving as universal quantum gates. The main problem is quantum decoherence, the inevitable continuous leakage of a quantum state due to its interaction with the environment. Very stringent quantum error correction protocols, i.e. quantum noise reduction procedure, must be employed to keep such qubit states alive and coherent during the computation. In sharp contrast to such noise-reduced quantum computation, a revolutionary alternative idea is to build an effectively 'deaf' quantum computer which is topologically immune to quantum decoherence. Such an inherently fault tolerant topological quantum computer is completely protected from any local perturbation induced by the environment and uses the time-space braiding (i.e. creating suitable quantum knots) of non-Abelian anyonic quasiparticles for quantum computation. The topological quantum computer is thus a 'natural' quantum computer where local quantum errors are suppressed at the hardware level due to the non-local topological nature of the ground state, thus completely eliminating the need or necessity for any software-based quantum error correction. Whether such a fault-tolerant natural topological quantum computer can be built or not depends on the existence in nature of suitable topological quantum phases of matter and our ability to manipulate and braid their non-Abelian anyonic quasiparticles. Prospects for topological quantum computation will be discussed critically in this talk from a combined experimental and theoretical perspective. I will discuss a number of physical systems, e.g. fractional quantum Hall states, chiral p-wave superconductors, p-wave cold atom superfluids, suitably designed cold atom optical lattices, frustrated quantum magnetic systems, Josephson junction arrays, rotating BEC systems, etc. where the possibility for doing topological quantum computation has been discussed in the recent literature. I will provide a perspective on how realistic such ideas are and discuss the (very difficult) physics issues which would have to be addressed before laboratory topological quantum computation can happen. I will also provide an elementary introduction to the concepts of topological phase, anyons, and non-Abelian braiding statistics. The interdisciplinary subject of topological quantum computation brings together topology, conformal field theory, fractional quantum Hall effect, Chern-Simons-Witten theory, and materials science.

Hosted by Aaron Pinczuk