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Quantum Control nd Measurement of Spins in Cold Atomic Gases

IVAN DEUTSCH, University of New Mexico

Spins are natural carriers of quantum information given their long coherence time and our ability to precisely control and measure them with magneto-optical fields. Spins in cold atomic gases provide a pristine environment for such quantum control and measurement, and thus this system can act as a test-bed for the development of quantum simulators. I will discuss the progress my group has made in collaboration with Prof. Jessen, University of Arizona, to develop the toolbox for this test-bed. Through its interactions with rf and microwave magnetic fields, whose waveforms are designed through optimal control techniques, we can implement arbitrary unitary control on the internal hyperfine spins of cesium atoms, a 16 dimensional Hilbert space (isomorphic to 4 qubits). Control of the collective spin of the ensemble of many atoms is performed via the mutual coupling of the atomic ensemble to a mode of the electromagnetic field that acts as a quantum data bus for entangling atoms with one another. Internal spin control can be used to enhance the entangling power of the atom-photon interface. Finally, both projective and weak-continuous measurements can be performed to tomograhically reconstruct quantum states and processes.