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Quantum control and measurement of spins in laser cooled gases[1]

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Quantum information processing (QIP) requires three important ingredients: (i) preparing a desired initial quantum state, usually highly pure; (ii) controlling the dynamical evolution, usually via a desired unitary transformation; (iii) measuring the desired information encoded in the final quantum state. Many physical platforms are being developed for QIP, including trapped ions, semiconductor quantum dots, and atoms in optical lattices. In these cases, it is the spins of the system that encode the quantum information. Spins are natural carriers of quantum information given their long coherence times and our ability to control them with a variety of external electromagnetic fields. In addition, spins in laser-cooled atomic gases are an excellent testbed for exploring QIP protocols because of our ability to initially prepare highly pure states and employ the well-developed tools of quantum optics and coherent spectroscopy. In this talk I will give an overview of recent theory and experiment in the control and measurement of spins in laser-cooled atomic gases. We consider the hyperfine magnetic sublevels in the ground electronic states of ^{133}Cs, a 16-dimensional Hilbert space. We can explore all three ingredients described above: preparation of an arbitrary superposition state, evolution through an arbitrary unitary matrix, and readout through quantum state reconstruction of the full density matrix. We employ the tools of optimal quantum control and quantum estimation theory. The implementation involves atoms controlled by radio-frequency, microwave, a optical fields, and measured via polarization spectroscopy. The experiment is performed in the group of Prof. Poul S. Jessen, University of Arizona. This work was supported by the National Science Foundation.

[1]Quantum Control of Spins in Laser-Cooled Atomic Gases