

PhD Thesis Defense NAEIMEH BEHBOOD 'Generation of Macroscopic Spin Singlets in Cold Atomic Ensembles'

NAEIMEH BEHBOOD

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Friday, April 17, 11:00. ICFO Auditorium

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Quantum information with cold atoms and non-classical light

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This thesis describes the generation of macroscopic spin singlets in a cold atomic ensemble by performing quantum non-demolition measurement. Toward this goal we have implemented a realtime shot-nose limited detection system, incoherent feedback and spin state preparation via optical pumping, an upgraded absorption imaging system and coherent

rotation of atomic spin via magnetic field control.

Working with a magnetically sensitive atomic system triggered the development of a vector field magnetometry technique. We demonstrate a fast three-axis optical magnetometer using cold, optically trapped 87Rb gas as a sensor. By near-resonant Faraday rotation we record the free-induction decay following optical pumping to obtain the three field components and one gradient component. A single measurement achieves shot-noise limited sub-nT sensitivity in 1 ms, with transverse spatial resolution of about 20 micrometer. We make a detailed analysis of the shot-noise-limited sensitivity.

We apply entropy removal by measurement and feedback to a cold atomic spin ensemble. Using quantum non-demolition probing by Faraday rotation measurement, and feedback by weak optical pumping, we drive the initially random collective spin variable F toward the origin F = 0. We use inputoutput relations and ensemble quantum noise models to describe this quantum control process and identify an optimal two-round control procedure. We observe 12 dB of spin noise reduction, or a factor of 63 reduction in phase-space volume. The method offers a non-thermal route to generation of exotic entangled states in ultra-cold gases, including macroscopic singlet states and strongly correlated states of quantum lattice gases.

We generate approximate singlet states using the tools of measurementinduced spin squeezing: quantum non-demolition measurement and coherent magnetic rotations . By squeezing all three spin components, we approach the zero spin noise. Using a cold Rubidium atomic ensemble and nearresonant Faraday rotation probing, we have observed up to 3 dB of squeezing relative to the standard quantum limit, and a violation of the generalized spin squeezing inequality by more than 5 standard deviations.

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