

GIORGIO COLANGELO

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PhD Thesis Defense GIORGIO COLANGELO 'Quantum Measurements with Cold Atomic Ensembles'

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December 16, 2016

Friday, December 16, 2016, 11:00. ICFO Auditorium

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Quantum Information with Cold Atoms and Non-classical Light

ICFO-The Institute of Photonic Sciences

This thesis describes quantum measurements of an ensemble of cold rubidium-87 atoms.

We extend the covariance matrix formalism to spin-1 systems, including effects of de-coherence, losses due to probing and atom number fluctuations.

We show that the model can reproduce experimental results of both the mean and variance of a Faraday rotation measurement of the free induction decay signal of a coherent spin state precessing in an inhomogeneous magnetic field.

We derive linearization procedures for Faraday measurements with high rotation angles and develop a fast differential photodetector that allows high dynamic range detection. We also study how to experimentally calibrate the reference quantum noise level under inhomogeneous light-atom interaction. We show that two non-commuting collective spin observables describing the atomic ensemble can be simultaneously known with sensitivity beyond classical limits, producing a planar quantum squeezed state. We theoretically study this state's metrological advantages and we find optimal conditions for its realization.

Finally, using quantum non-demolition (QND) measurements of an atomic coherent state precessing under an orthogonal magnetic field, we track the radial and the angular component of the collective spin of the atomic ensemble below Poisson statistics and below the projection noise level by 7.0 dB and 2.9 dB respectively.

The final topic of this thesis is the investigation of measurement back action as a genuine quantum signature through the violation of Leggett-Garg inequalities. The use of QND measurements, which does not perturb the measured quantity, provide a way to certify such violations as due to true quantum effects rather than other possible classical disturbance caused by the measurement. The use of Gaussian states described by covariance matrix calculations indicates these techniques can be applied to truly macroscopic systems.

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Thesis Director: Prof . Dr. Morgan Mitchell

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