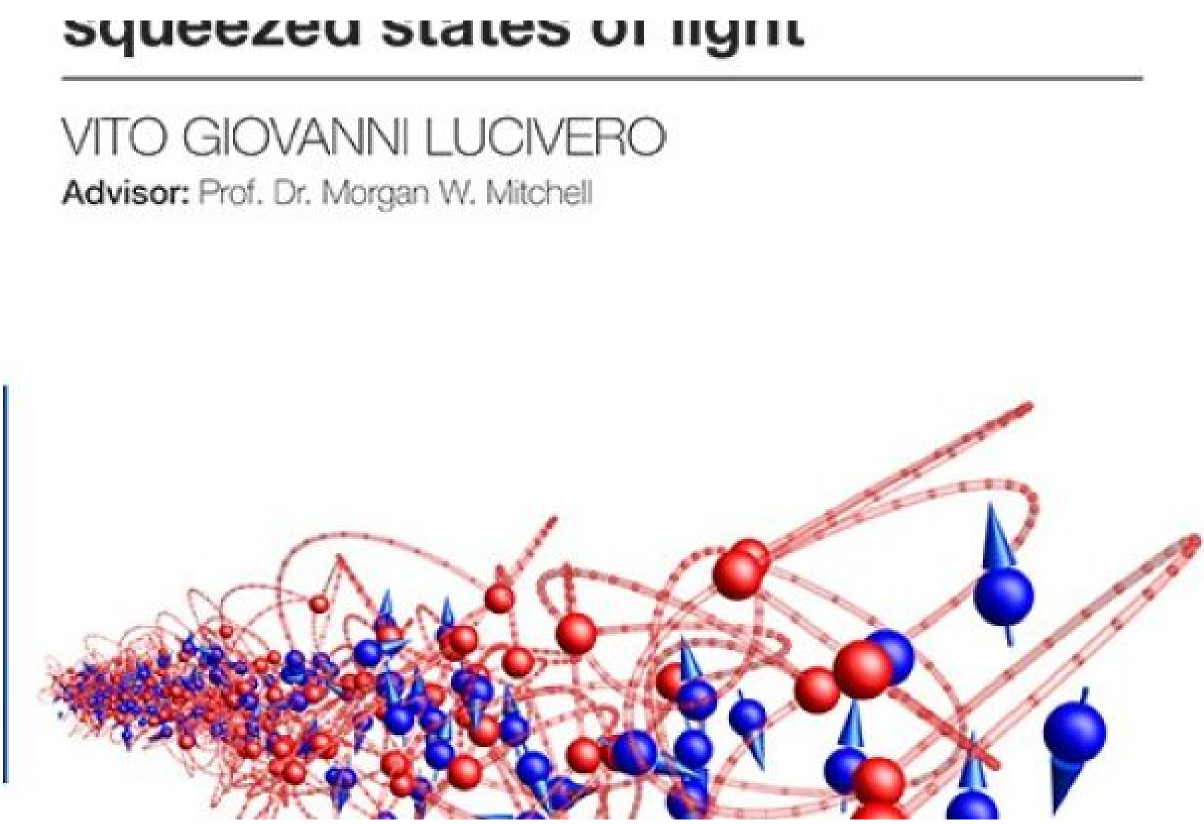

PhD Thesis Defense VITO GIOVANNI LUCIVERO 'Quantum Metrology with High-Density Atomic Vapors and Squeezed States of Light'

VITO GIOVANNI LUCIVERO

October 14, 2016

Friday, October 14, 16:00. ICFO Auditorium

VITO GIOVANNI LUCIVERO

Quantum information with cold-atoms and non-classical light

ICFO-The Institute of Photonic Sciences

Nowadays there is a considerable progress in optical magnetometry and spin noise spectroscopy, which use magnetically-sensitive atomic ensembles and optical read-out, approaching the limits set by quantum mechanics. In recent years optical magnetometers have become the most sensitive instruments for measuring low-frequency magnetic fields, achieving sub-femtotesla sensitivity and surpassing the competitive superconducting quantum interference devices (SQUIDs), and have found applications in biomedicine, geophysics, space science as well as in tests of fundamental physics. Another emerging technique is spin noise spectroscopy (SNS), which allows one to determine physical properties of an unperturbed spin system from its power noise spectrum. In the last decade technological advances like real-time spectrum analyzers and shot-noise-limited detectors have allowed improvements in the sensitivity of spin noise detection leading to a broad range of applications in both atomic and solid state physics.

The main goal of this thesis is to address a major outstanding question: whether squeezed light can improve the sensitivity of atomic sensors under optimal sensitivity conditions, typically in a high-density regime due to the statistical advantage of using more atoms. Firstly, we describe the design, construction and characterization of a new versatile experimental apparatus for the study of squeezed-light atomic spectroscopy within a high-density regime (n=¿10¿^12 ¿cm¿^(-3)) and low-noise (¿pT/vHz) magnetic environ ent. The new experimental system is combined with an existing source of polarization squ ezed light based on spontaneous parametric down conversion (SPDC) in a nonlinear crystal, hich is the active medium of an optical parametric oscill tor. Secondly, we report the first experimental demonstration of quantum-enhanced spin oise spectroscopy of natural abundance Rb via polarization squeezing of the probe bea . We found that input squeezing of 3.0 dB improves the signal-to-noise ratio by 1.5 dB to 2 6 dB over the combined (power¿number density) ranges (0.5 mW to 4.0 mW) ¿ (1.5 × ?10¿^12 ¿cm¿^(-3) to 1.3 ×¿10¿^13 ¿cm¿^(-3)), covering the ranges used in opt mized spin noise spectroscopy experiments. We also show that squeezing improves the rade-off between statistical sensitivity and bro dening effects. Next, we introduce a novel theoretical model by defining a standard quantu limit (SQL) for optically-detected noise spectroscopy, identified as a bound to the ovariance of the parameters estimated by fitting power noise spectra. We test the mod l for spin noise spectroscopy of natural abundance Rb and we demonstrate experiment l performance of SNS at the SQL for a coherent probe and below the SQL for a polarizatio squeezed probe. Finally, we report an optical magnetometer based on amplitude modulated optical rotation (AMOR), using a 85Rb vapor cell, that achieves room temperature sensitivity f 70 fT/vHz at 7.6 T and we demonstrate its photon shot-noise-limited (SNL) behaviour f om 5 T to 75 T. While no quantum resources of light were used in this second experim nt, the combination of best sensitivity, in the class of room-temperature scalar ma netometers, and SNL operation makes the system a promising candidate for application of queezed light to an optimized optical magnetometer with best-i

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