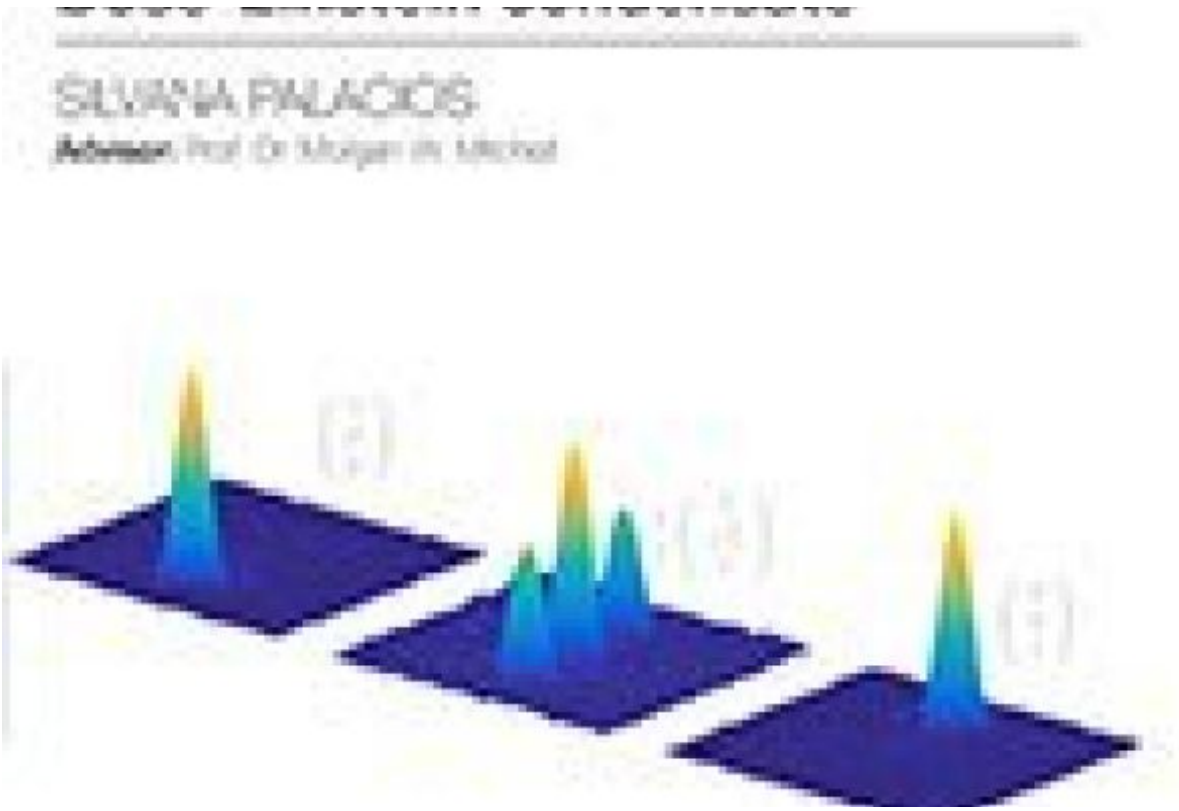

PhD Thesis Defense SILVANA PALACIOS 'Single Domain Spinor Bose-Einstein Condensate'

SILVANA PALACIOS

July 31, 2017

Monday, July 31, 11:00. ICFO Auditorium

SILVANA PALACIOS

Quantum Information With Cold Atoms and Non-classical Light

ICFO-The Institute of Photonic Sciences

This work reports on the construction of a new-generation system capable to create single-mode spinor Bose-Einstein condensates of 87Rb, and non-destructively probe them using optical Faraday rotation. This system brings together many of the stateof-the-art technologies in ultra-cold physics in a minimalist design which was possible due to the prolific advances in the field respect to the pioneering experiments (Cornell?s, Ketterle?s,

and Chapman?s groups). There is rich phenomena that can be potentially studied in this system from the study of predicted novel quantum phases and topologies to entanglement and spin squeezing which are useful for quantum information and interferometry. The potential of this system make it suitable to answer fundamental questions on the phase transition to a condensed and ferromagnetic state.
In particular, this work describes theoretically and experimentally, the atomic spin coherence, which is relevant for applications like coherent sensing of magnetic fields. In this direction, our findings demonstrate the characteristics of our system make it a sensor with the best predicted energy resolution per unit bandwidth (~10^-2 ?) among all the different technologies applied to magnetometry.

The thesis is structured as follows: Part I is dedicated to the mathematical description of the relevant interactions. First, the interaction of optical polarization and atomic spin polarization is reviewed, with special attention to ac-Stark shifts, which are used to generate a conservative trapping potential and Faraday rotation effects that are used for non-destructive spin detection. Second, the interaction of the atoms with a magnetic field is presented. And finally, the mean-filed theory of spinor Bose-Einstein condensation is summarized. The dynamics of a spin-1system in this picture is described by a three-component Gross-Pitaevskii equation.

Part II contains three chapters describing the implemented technologies and techniques used in the experiment to create and characterize a spinor condensate. The first chapter describes the ultrahigh vacuum, magnetic fields, lasers, spectroscopy and imaging needed to create a magneto optical trap (MOT) and transfer those atoms into an optical dipole trap (ODT). We implemented a non-standard loading technique based on the semicompensation of the strong differential lightshift induced by the ODT which profits from the effective dark-MOT created at the trap position. In the second chapter we detail, theoretically and experimentally, the all-optical evaporation process employed to achieve condensation in less than five second after the loading. In the final chapter the spin manipulation and read-out techniques are presented. Because there is no observable associated to the spin angle, we exploit the Faraday rotation effect and Stern-Gerlach imaging in order to retrieve information about the spin dynamics.

Finally in Part III, we consider the potential of a spinor BEC as a magnetic sensor. The measurement of fundamental properties defining the sensitivity of the sensor are detailed. Those properties are the volume, the temporal coherence and the readout

noise. We present a model of the magnetic field environment and its repercussion on the noise of the magnetometer. In the last chapter we present our perspectives to the possible applications of our system.

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Thesis Director: Prof. Dr. Morgan Mitchell