H.F.R.I.
Hellenic Foundation for Research & Innovation

Description of the funded research project

2nd Call for H.F.R.I. Research Projects to Support Post-Doctoral Researchers

Title of the research project: Quantum measurement with cold atoms

Principal Investigator: Vasilakis Georgios

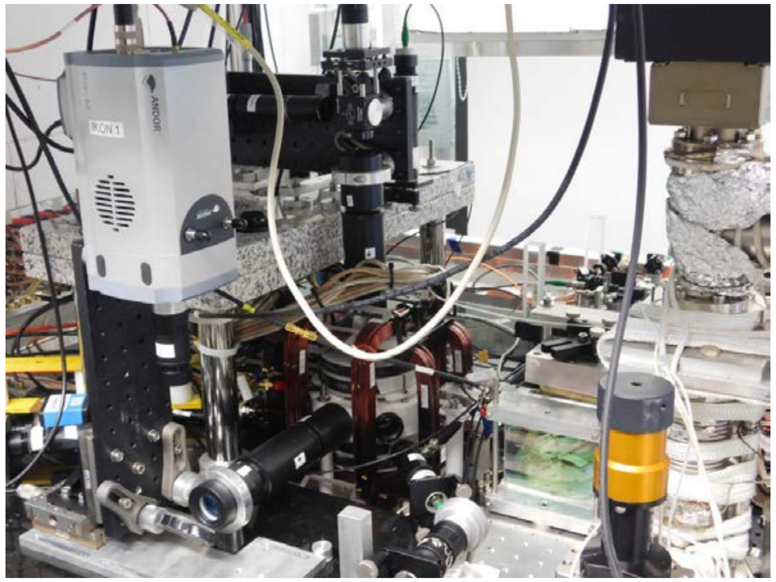
Reader-friendly title: QCAT

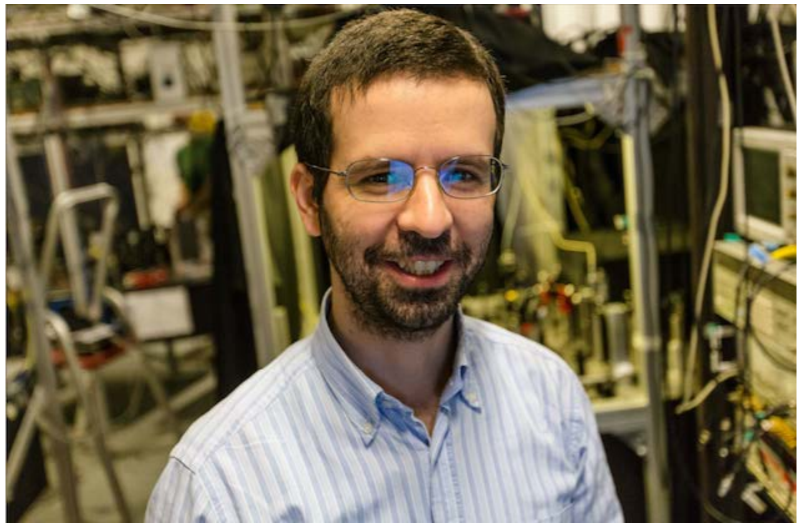
Scientific Area: Physical Sciences

Institution and Country: FORTH Greece

Host Institution: FORTH Greece

Collaborating Institution(s): -





Budget: 164000 euros

Duration: 36 months

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Research Project Synopsis

Ultracold atoms have demonstrated great prospects for both technological and fundamental science applications. In order to fully exploit their potential, a precise control of the atomic cloud that can manipulate the quantum features and harness quantum resources is required. The research aims to develop a robust method for measurement and control of the atom number in an ultracold atomic ensemble with precision better than the atom shot noise level. The measurement is based on the Faraday paramagnetic effect: off-resonant light, when traveling through a polarized atomic cloud, experiences optical rotation at an angle that is proportional to the number of atoms. The proposed measurement does not destroy quantum coherences and has an insignificant effect on the atomic temperature, so that it can be used to perform quantum-enhanced measurements and prepare the atomic state at the start of an interferometer sequence. Control of the atom number is realized by the unavoidable atom-loss that is introduced by the measurement, since even far off-resonant light has a non-zero probability for absorption. This atom-loss mechanism will be employed to shrink an initial ensemble to the targeted size. Measuring with sub-atom-shot noise resolution will lead to number squeezed states of Bose Einstein Condensates and will pave the way for squeezing and entanglement generation for spectroscopy and interferometry. The measurement sensitivity and the realized squeezing are fundamentally limited by the photon shot noise of the probe light. In order to overcome this limitation, we will use an optical resonator to enhance the signal from the ensemble. Applications of the research include atomic clocks, inertial sensors, quantum computing, quantum simulations and fundamental physics experiments such as gravitational detectors.

Project originality

The fundamental novelty of the project lies in the integration of a number of techniques from atomic-optical physics, quantum optics and precision measurements to address challenges in quantum measurements with cold-atoms. Specifically, QCAT advances for the first time a simple and robust scheme for precise characterization of the atom number in a minimally invasive way. A novel two-sensor scheme is introduced to suppress technical common mode noise. In addition, new measurement approach is implemented that encodes the useful information in a frequency component away from the noise-prone, near-DC spectrum, thus allowing for the introduction of lock-in techniques and stroboscopic probing. Furthermore, QCAT goes beyond the state of the art in cold-atom quantum technology by developing tools to overcome current limitations in the Faraday interaction between off-resonant light and atoms. For the first time in the context of large, cold atomic-ensembles, cavity-assisted probing will be employed in order to effectively increase the measurement strength and enhance the quantum advantage.

Expected results & Research Project Impact

The expected outcome of the project is a robust and simple method that will enable a precise measurement and control of the number of atoms in ultra-cold atomic ensembles, with minimal disturbance in the quantum state of the ensemble. This will have a disruptive effect in experiments with ultra-cold atoms, which are often limited by uncertainties in the atomic-ensemble size. A plethora of scientific and technological fields (including geoscience, astronomy, inertial navigation, time keeping) that can profit from cold atoms will benefit from the developments in QCAT. In addition, the proposed research aspires to implement quantum optics protocols and harness quantum resources (e.g. squeezing, Bose-Einstein Condensate). This way it will contribute to the development of quantum technology, which has a great potential to lead to revolutionary improvements in many aspects of technology, including sensing, communication and computation.

The importance of this funding

The project will foster the development of competencies that will help the Principal Investigator (PI) to secure a successful research career. Quantum sensing, the core of the project, is at the forefront of Europe's technological and innovation objectives. Given the explosive growth in quantum research, it is largely anticipated that in the near future quantum technology will have a large impact in people's everyday life. The need for quantum technology professionals is therefore high. The funding will consolidate the PI as one of the young leaders in this booming field of quantum metrology. Besides the scientific and technical expertise, the PI is expected to grow managerial and soft-skills. By the end of the project, the PI will have gained considerable experience in teaching and supervision of young researchers. Lastly, the PI will have the opportunity to become competent in budget management and accountability.

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