Dipolar Quantum Gases

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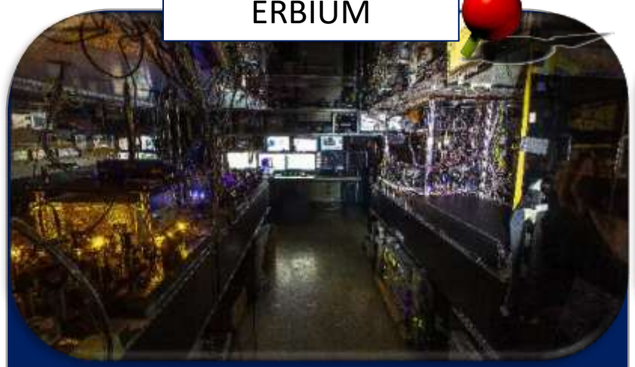
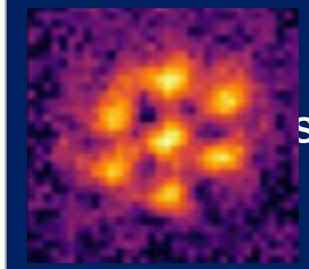
Institute for Experimental Physics and IQOQI

Theory Experiments

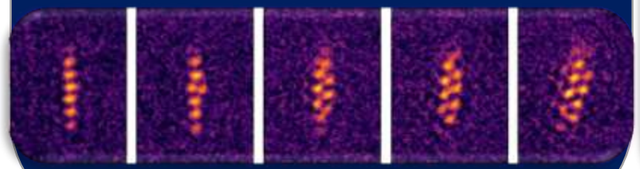
3 LABS and a THEORY TEAM

ERBIUM

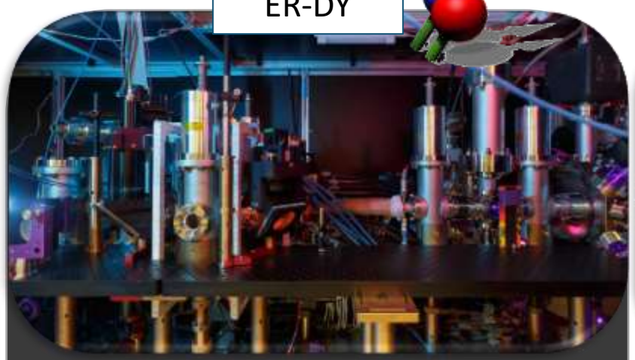


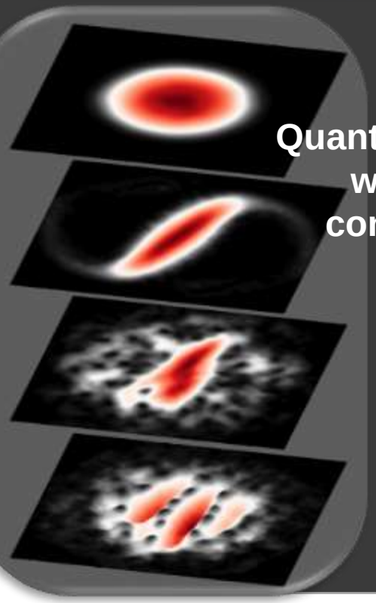


The discover of Supersolidity and Bloch Oscillations



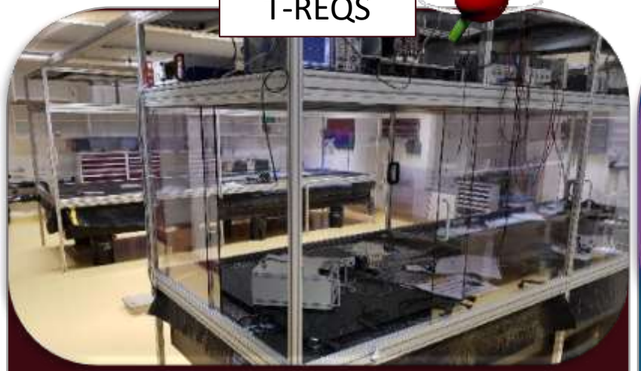
ER-DY



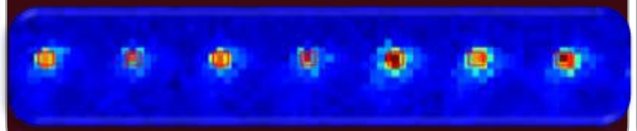


Quantum Vortices with high connectivity

T-REQS

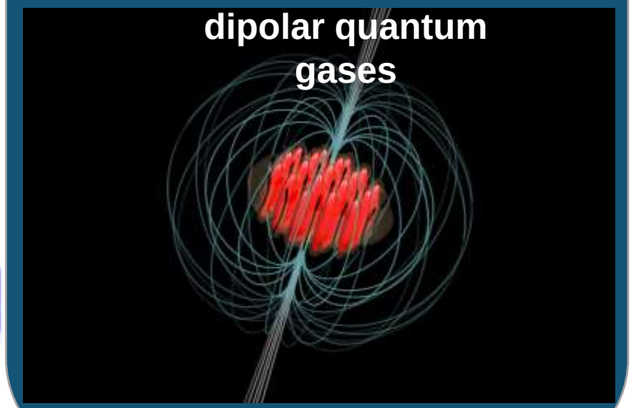


Single atomic magnet in an array of tweezers for quantum info



Theory

Simulation of the behavior of dipolar quantum gases



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Group Leader:
Univ. Prof. Francesca Ferlaino

Master Project

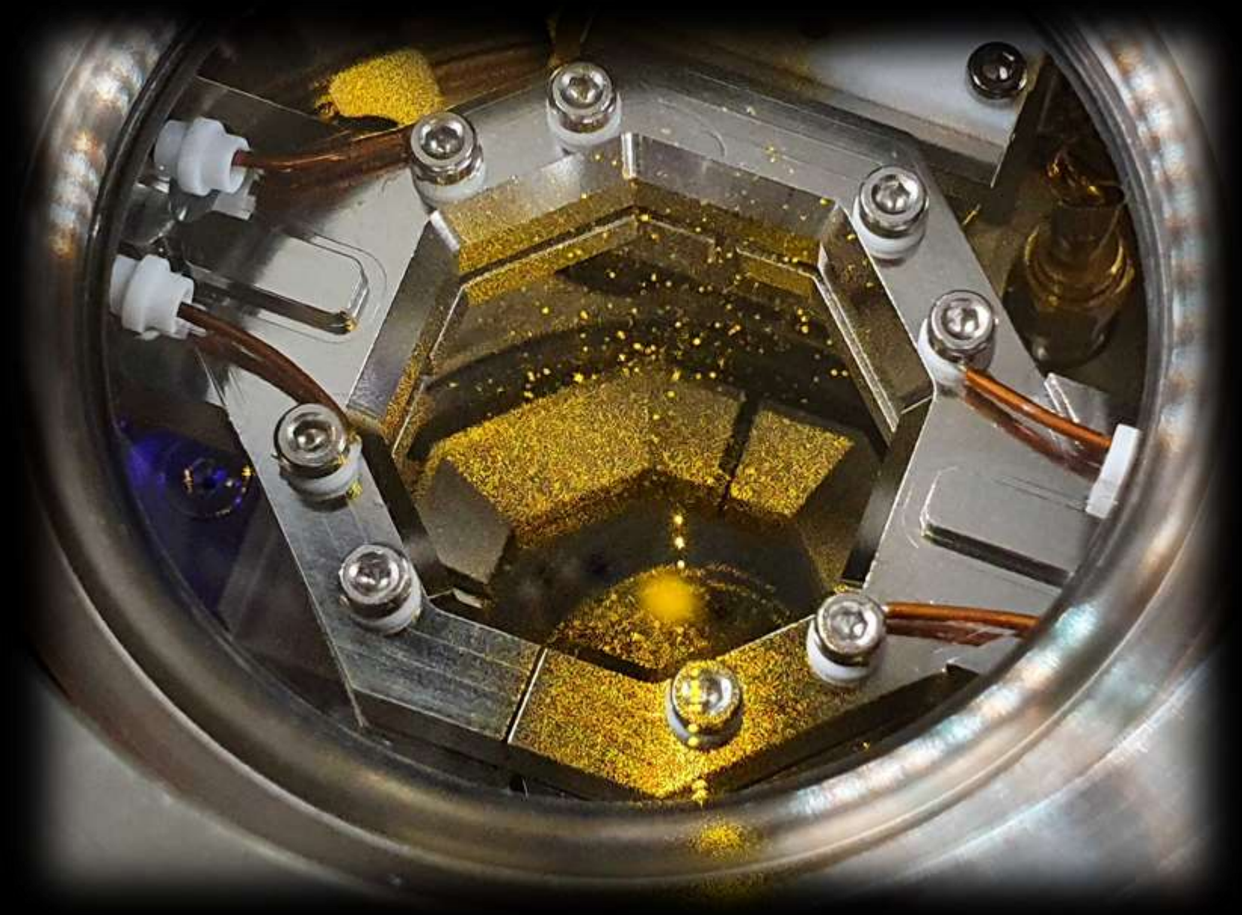
1. Algorithms and software development for optical tweezers manipulation

Tightly focused beams of light, known as optical tweezers, have fast become a leading method for trapping and moving single atoms, with broad applications in particular in the fields of quantum computing and simulation. In this project, you will develop a control software to automatically re-arrange the positions of a set of optical traps to achieve arbitrary geometries of ordered arrays of atoms .

You will:

- Programmatically interface with advanced instrumentation.
- Design and implement efficient algorithms for tweezer fast manipulation.
- Develop high-performance code in a low-level programming language

Master Project



2. Design of protocols for the implementation of qudits in neutral atoms in optical tweezers

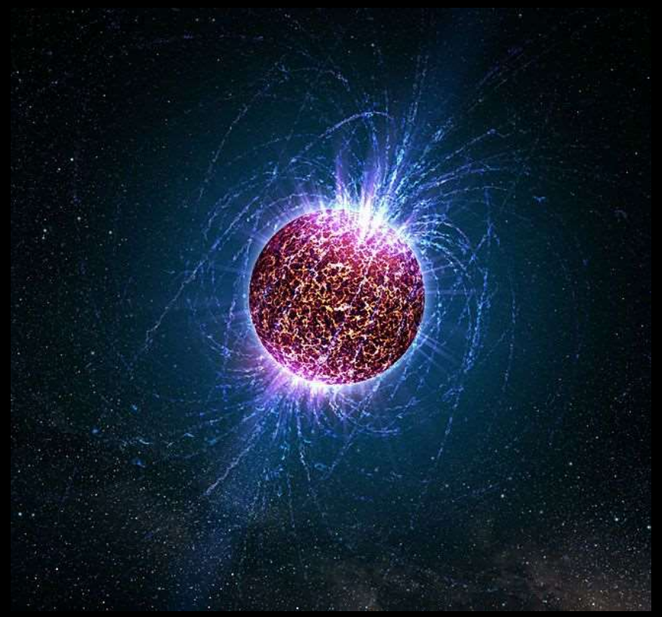
Quantum computing is a quickly developing technology exploiting the properties of quantum states to solve computational problems that are intractable for classical processors. This project aims at designing and implementing experimental protocols for the initialization, manipulation and entanglement of quantum bits of information in a high-dimensional space (qudits), using the vast state space offered by erbium atoms trapped in optical tweezers.

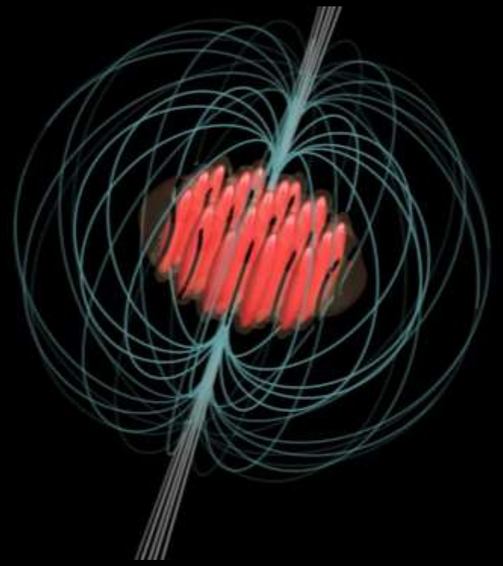
You will learn:

- How atoms can be manipulated with laser light to encode and process quantum information.
- How to design protocols for the initialization of qudits and implementation of single and multi-qudits gates.
- How to set up electronics in the laboratory for fast generation and control of optical pulses

Master Project

3. Glitches: from neutron stars to ultracold dipolar gases



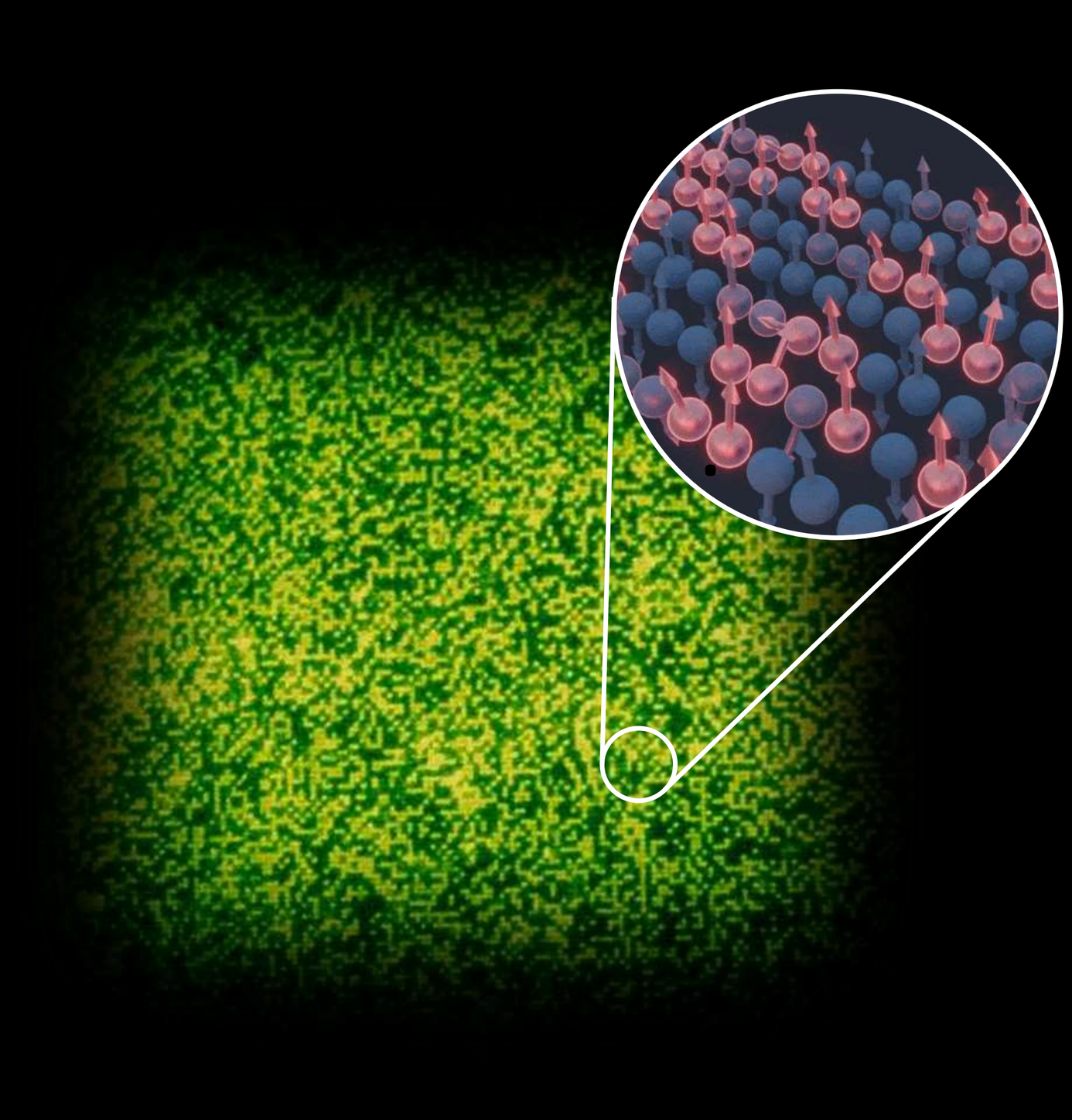


A particular flavor of neutron stars rapidly rotate in such a way that we can observe a pulsating flash of light each time the magnetic field poles point directly at Earth. Known as “pulsars”, the frequency of this flash is almost perfectly periodic, slowing down due to radiation emission. Once every few years, however, the star speeds up, in a process known as a glitch.

The reason for a glitch is unknown, but expected to be related to the partly superfluid nature of neutron stars. This project aims to tie our understanding of pulsar glitches and glitches in dipolar supersolid states.

You will learn:

- How to perform numerical simulations with the extended Gross-Pitaevskii equation, emulating neutron star dynamics.
- Physics of quantum vortices in a dipolar supersolid.
- How to use High Performance Computers (supercomputers)



Master Project

4. Spin manipulation in optical lattices

Ultracold atoms offer an exceptional platform for quantum simulation, enabling flexible control over many-body interactions. In this regard, the optical manipulation of spin states and their interactions in erbium experiments paves the way for the simulation of many exotic phases of condensed matter. This project focuses on manipulating and imaging the spins of atoms at the single-site level within optical lattice systems. This achievement will represent a major step towards realizing unconventional states of matter within our ultracold atom platform.

You will learn how to:

- Manipulate atoms using light
- Engineer laser beams using light modulation tools
- Build a stable optical setup for atomic lattices applications

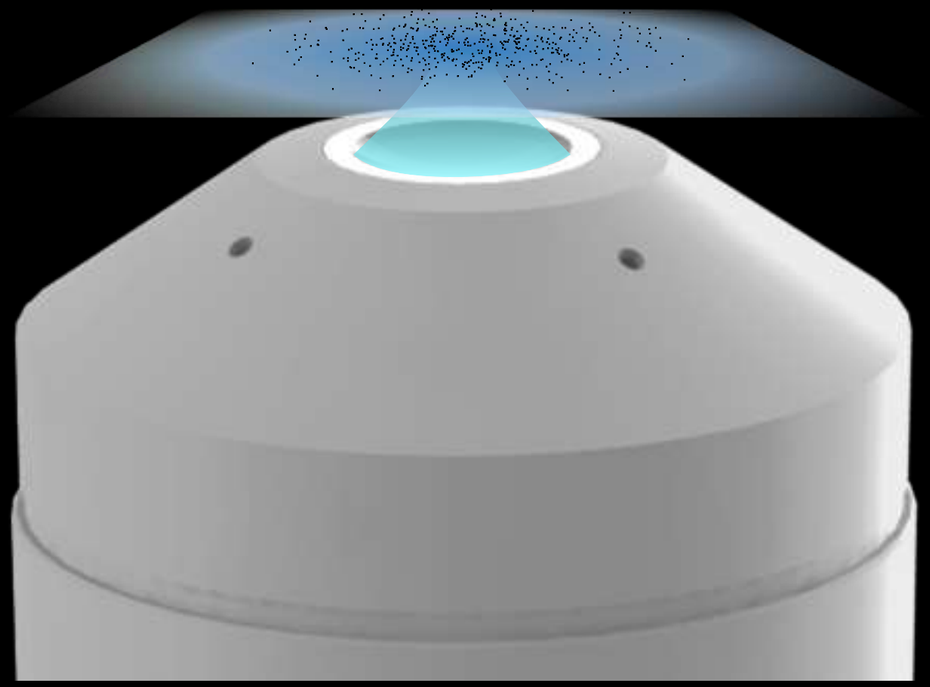
Master Project

5. Quantum gas microscope for strongly dipolar atoms

With the recent technological progress in observation and detection methods, the next generation of quantum gas experiments opens a new venue for the study of interacting quantum systems in unexplored regimes with acquired sub-wavelength spatial resolution and single photon sensitivity. The student will participate to the implementation of the various systems required for the realization of an ensemble of strongly dipolar atoms in optical lattices in a quantum gas microscope experiment.

You will learn:

- Lattice physics with dipolar atoms
- How to build and implement various optical traps, from opto-mechanics to electronics and computer control
- Fluorescence imaging with a quantum gas microscope



Contact Us

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Bachelor Projects

1. Quantum computing with neutral atoms in optical tweezers
2. Observation methods in quantum gas experiments: from absorption to ultra-fast fluorescence
3. Glitches: from neutron stars to ultracold dipolar gases
4. Sub-wavelength optical potentials for ultracold atom quantum simulators

Master Projects

1. Algorithms and software development for optical tweezers manipulation
2. Design of protocols for the implementation of qudits in neutral atoms in optical tweezers
3. Glitches: from neutron stars to ultracold dipolar gases
4. Spin manipulation in optical lattices
5. Quantum gas microscope for strongly dipolar atoms