Dipolar Quantum Gases

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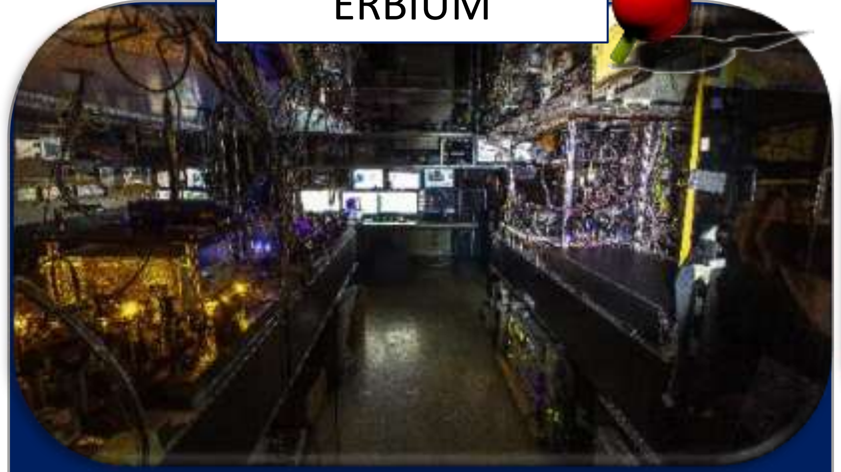
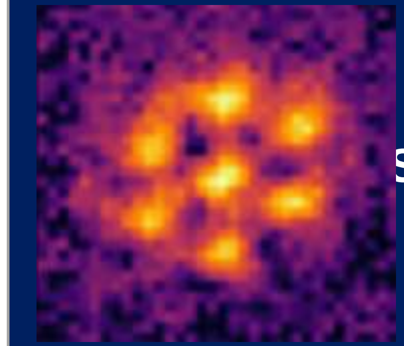
Institute for Experimental Physics and IQOQI

Theory · Experiments

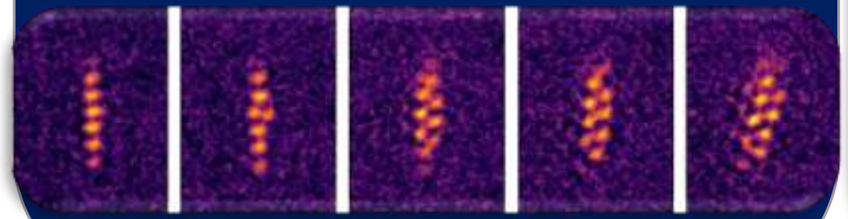
3 LABS and a THEORY TEAM

ERBIUM

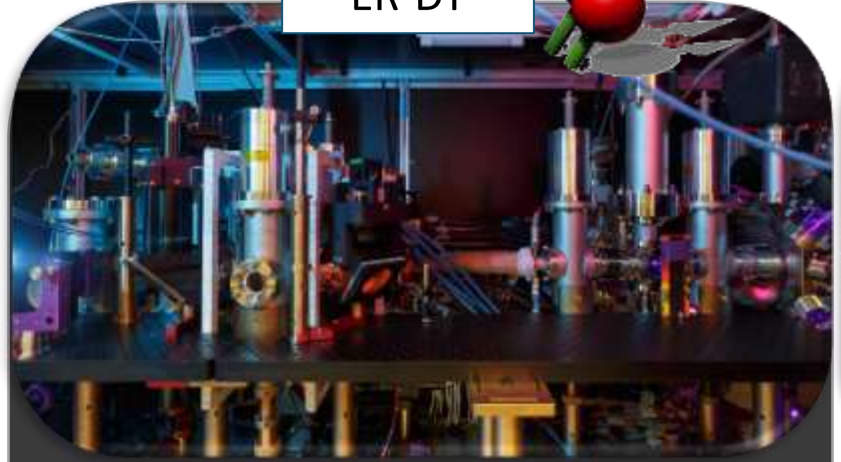


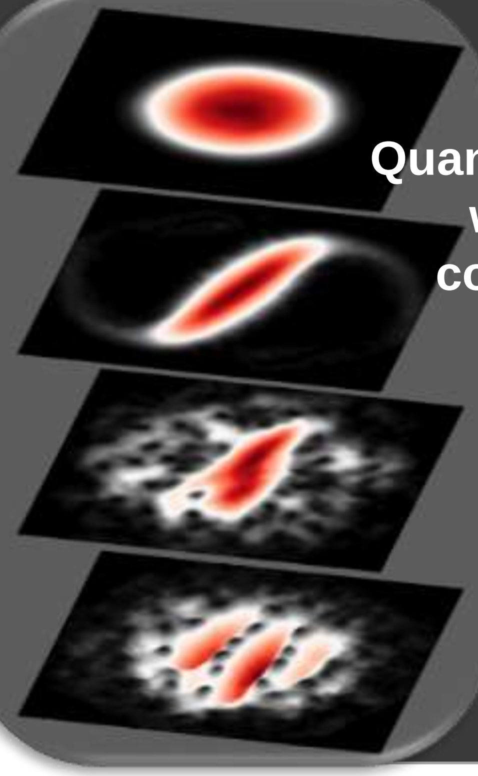


The discover of Supersolidity and Bloch Oscillations



ER-DY

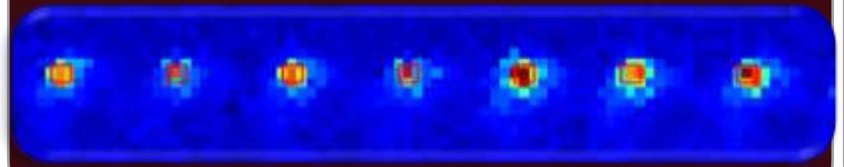




Quantum Vortices with high connectivity

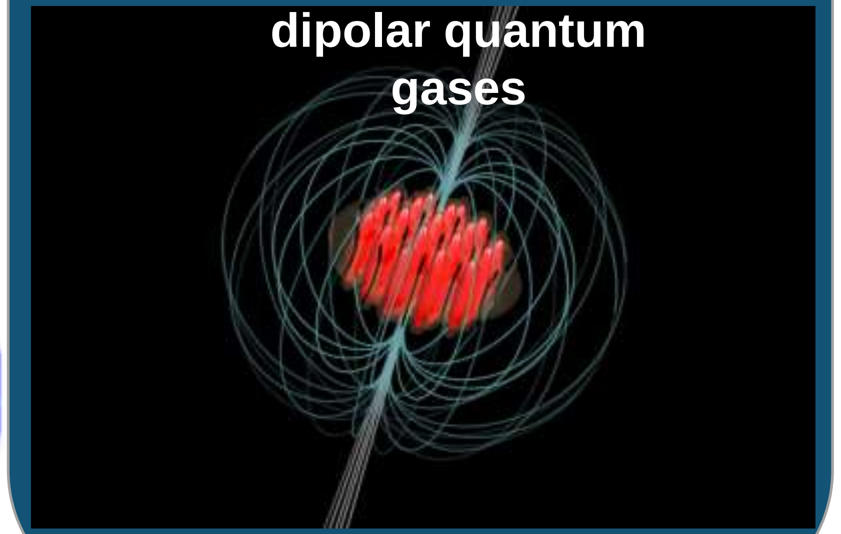
T-REQS

Single atomic magnet in an array of tweezers for quantum info



Theory

Simulation of the behavior of dipolar quantum gases



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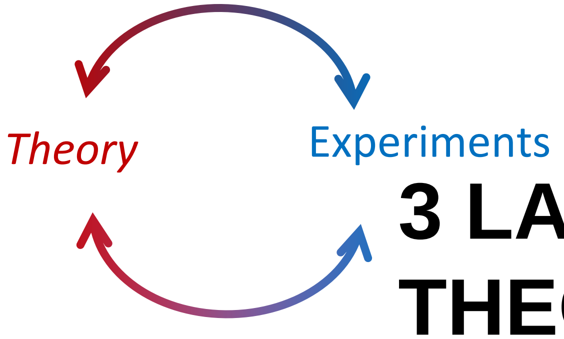
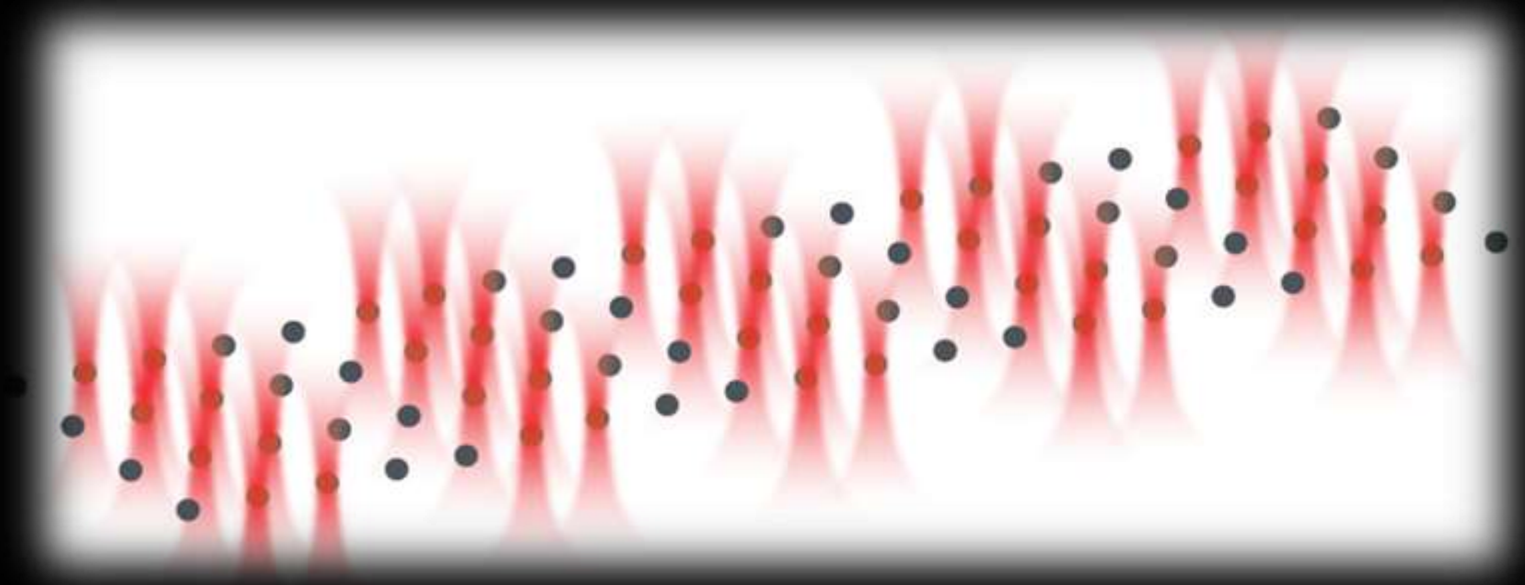


3 LABS and a THEORY TEAM

Bachelor Project

1. Quantum computing with neutral atoms in optical tweezers

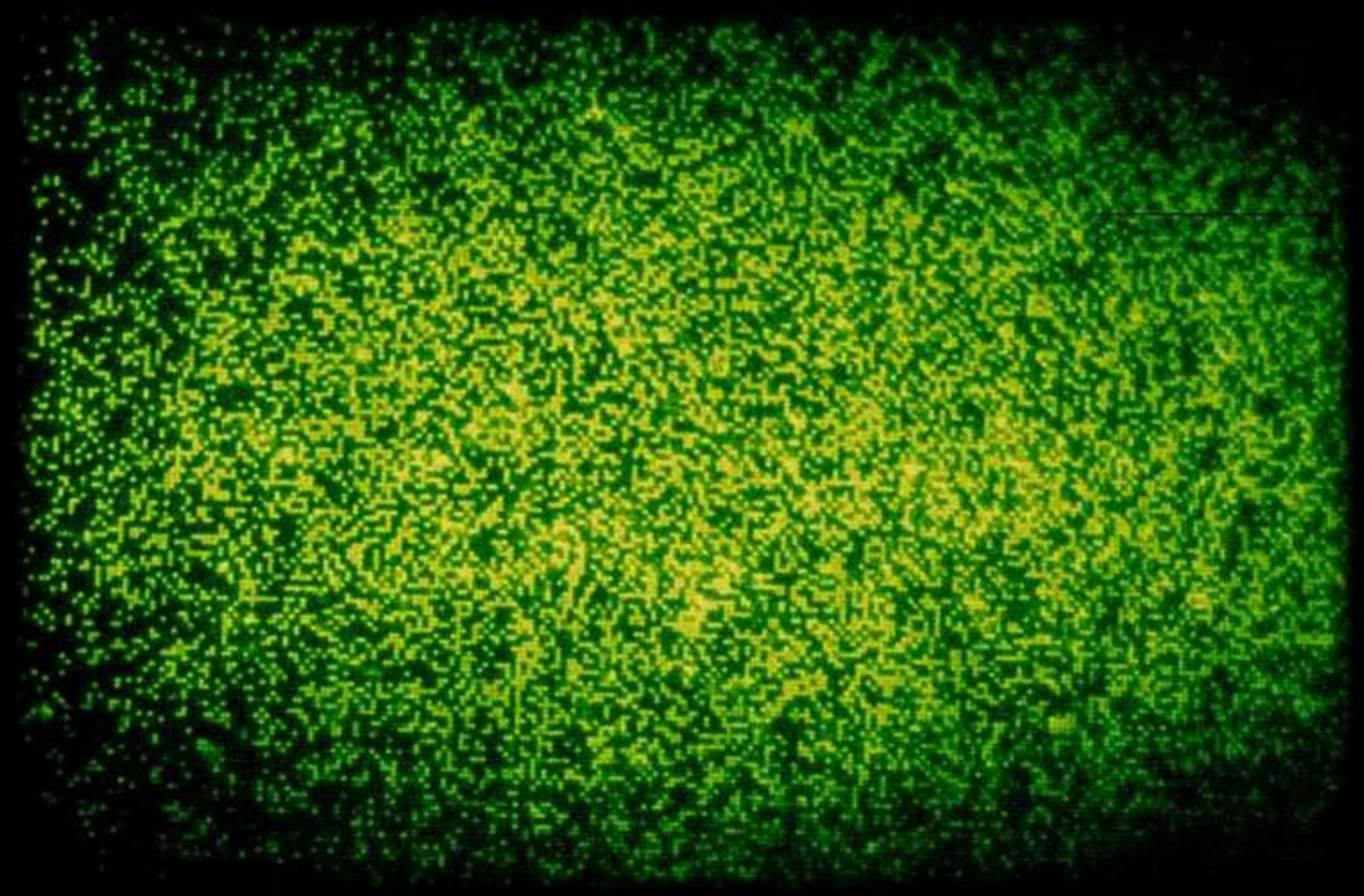
Quantum computing aims at solving computational problems that are intractable for classical processors, exploiting the quantum nature of atoms and of artificial systems with a similar internal energy structure. This project focuses on a specific platform, neutral atoms trapped in optical tweezers, and explores the implementation of qubits up to the state of the art achieved by recent experiments.



You will learn:

- What the building blocks of a quantum computer are, such as qubits, qubit gates, entangling gates and readout protocols.
- How sets of atoms can be trapped and controlled in single-atom traps arranged in arbitrary geometries.
- How the performance of a quantum computer can be quantified and benchmarked.

Bachelor Project



2. Observation methods in quantum gas experiments: from absorption to ultra-fast fluorescence

Keystone of progress in quantum gas experiments, observation methods extensively rely on the various atom-light interaction properties: a coherent source of light propagating through an atomic gas accumulates intensity and phase variations, and atoms scatter photons as being excited. Cutting-edge techniques are now developed to satisfy requirements of most advanced experiments, exceeding resolution limits and detecting single photons. The Bachelorarbeit will work out the basic principles of imaging techniques in quantum gas experiments: absorption, fluorescence, and phase contrast imaging. The Bachelorarbeit will also set-up and test the production of μs light pulses for the implementation of a novel ultra-fast imaging technique.

You will learn:

- How atom-light interactions are used for imaging purposes.
- How to image single atoms and what are the limits of resolution
- How to set up electronics in the laboratory for fast generation and control of optical pulses

Bachelor Project

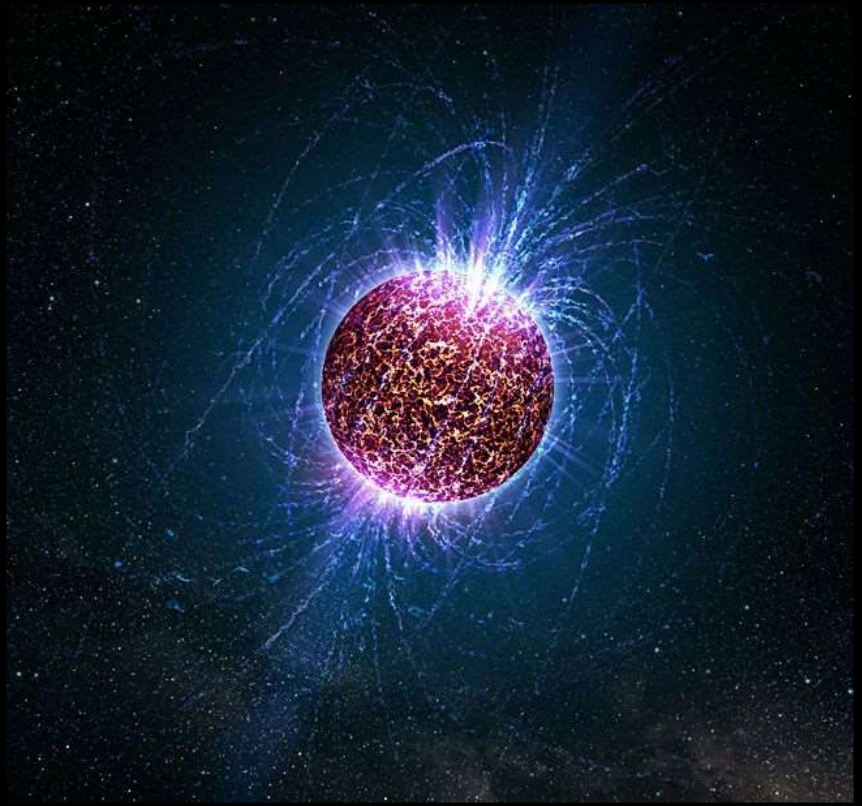
3. Glitches: from neutron stars to ultracold dipolar gases

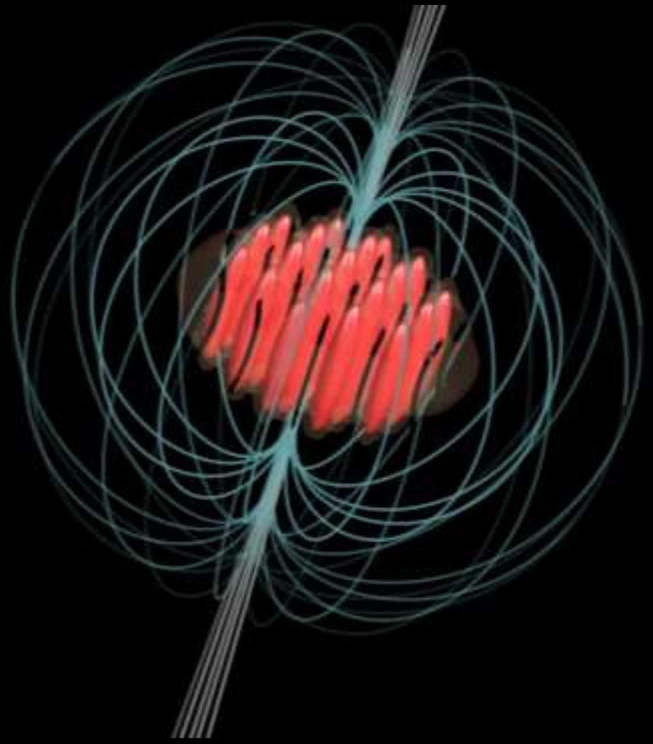
A particular flavor of neutron stars rapidly rotate in such a way that we can observe a pulsating flash of light each time the magnetic field poles point directly at Earth. Known as “pulsars”, the frequency of this flash is almost perfectly periodic, slowing down due to radiation emission. Once every 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. The project aims to explore the links between pulsar glitches and glitches in dipolar supersolid states.

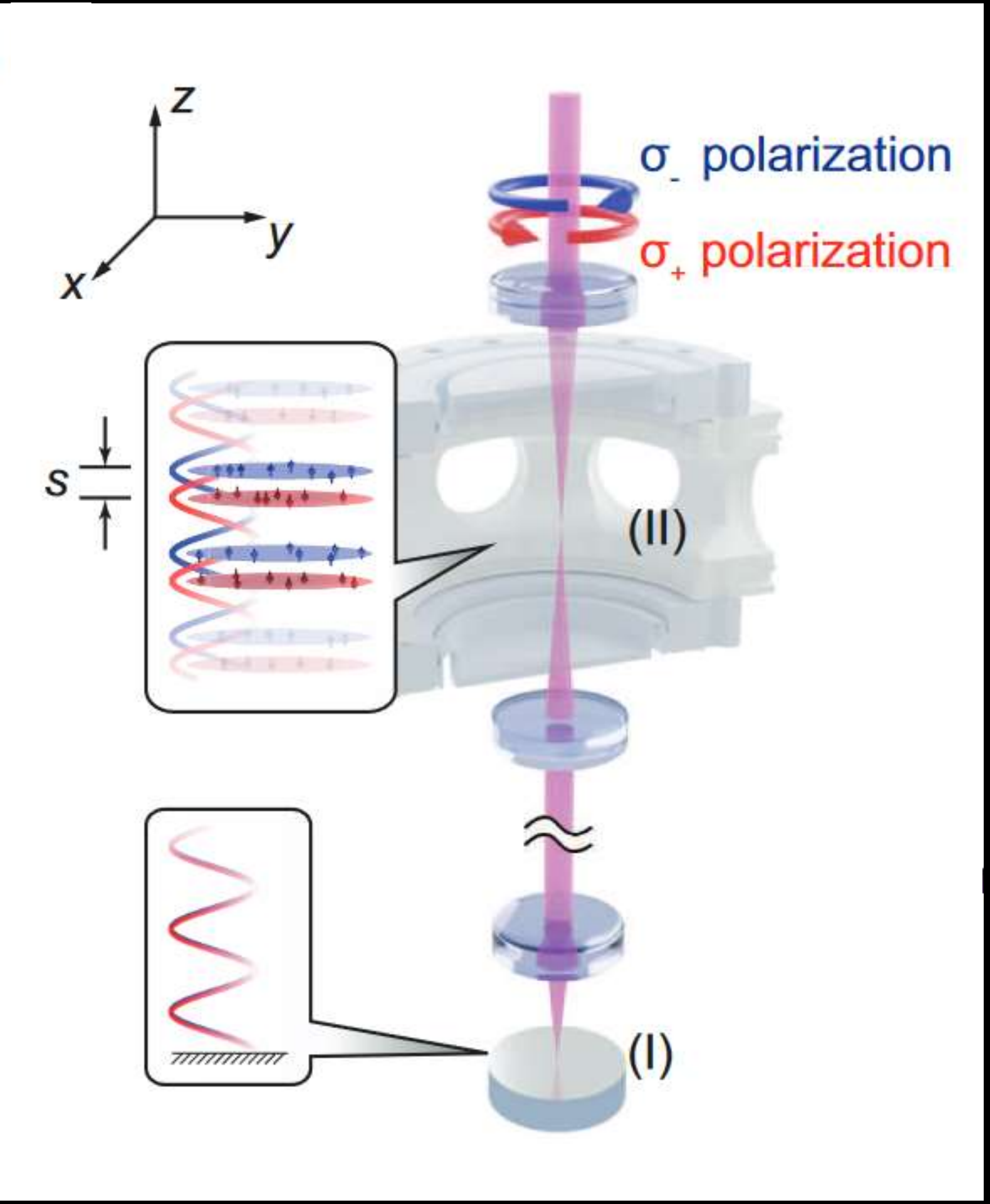
You will learn:

- How neutron stars form and why we believe their interiors are partly superfluid and supersolid.
- How using ultracold dipolar atoms we can create the supersolid phase here on Earth.
- How to numerically simulate the glitch mechanism using ultracold dipolar supersolids.





Bachelor Project



4. Sub-wavelength optical potentials for ultracold atom quantum simulators

Quantum simulation in ultracold systems aims to address problems that surpass the capabilities of classical computers by flexibly tuning the Hamiltonian of particles. These opportunities are further enhanced when atoms are confined within periodic potential configurations created by laser fields, known as optical lattices. One of the main challenges in such setups is to reduce the spacing between lattice sites relative to the laser wavelength, in order to enhance interactions between the atoms, thereby expanding the scope of quantum simulation applications. This project is dedicated to exploring the feasibility of implementing optical lattice potentials smaller than the wavelength within our erbium platform, building upon the state-of-the-art progress achieved in recent experiments.

You will learn how to:

- Trap and cool atoms using laser beams
- Design optical lattice geometries for building quantum simulators
- Utilize tools from the atomic physics and optics fields to implement non-conventional sub-wavelength optical lattices

Contact Us

francesca.ferlaino@uibk.ac.at

manfred.mark@uibk.ac.at

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