Dipolar Quantum Gases

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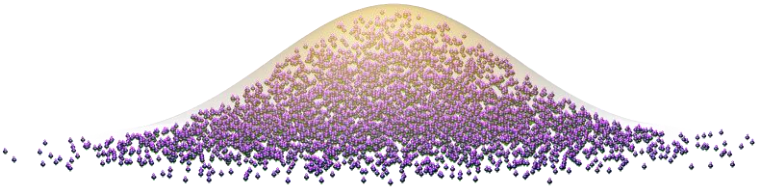
Institute for Experimental Physics and IQOQI

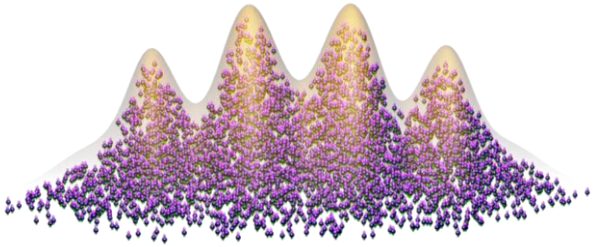
Some of our research questions

How do dipolar interactions change the many-body behavior of quantum particles in the bulk and crystal structures?

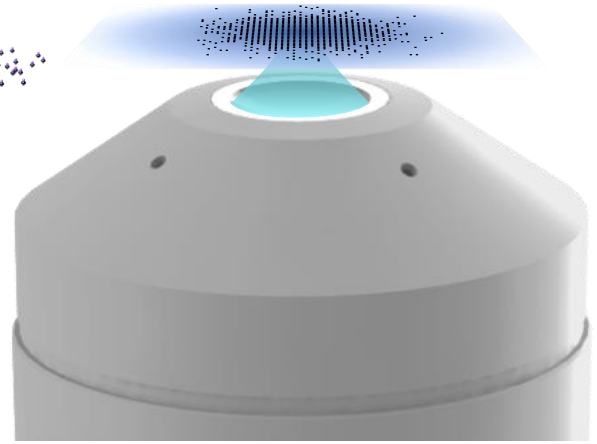
Dipolar BEC



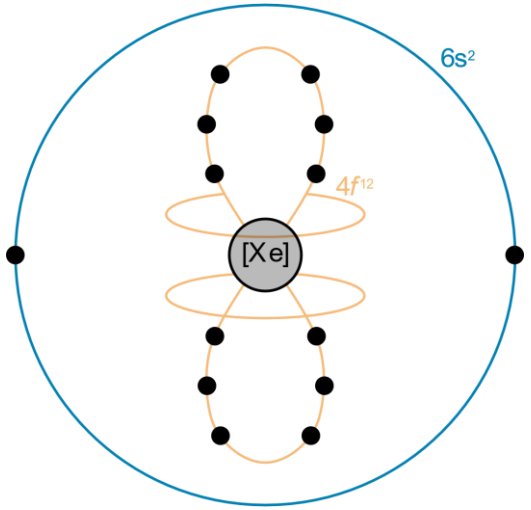
Dipolar Supersolid



Quantum gas microscope



How can we exploit the multi-electron nature of our quantum particles for advanced quantum simulation and quantum computation?



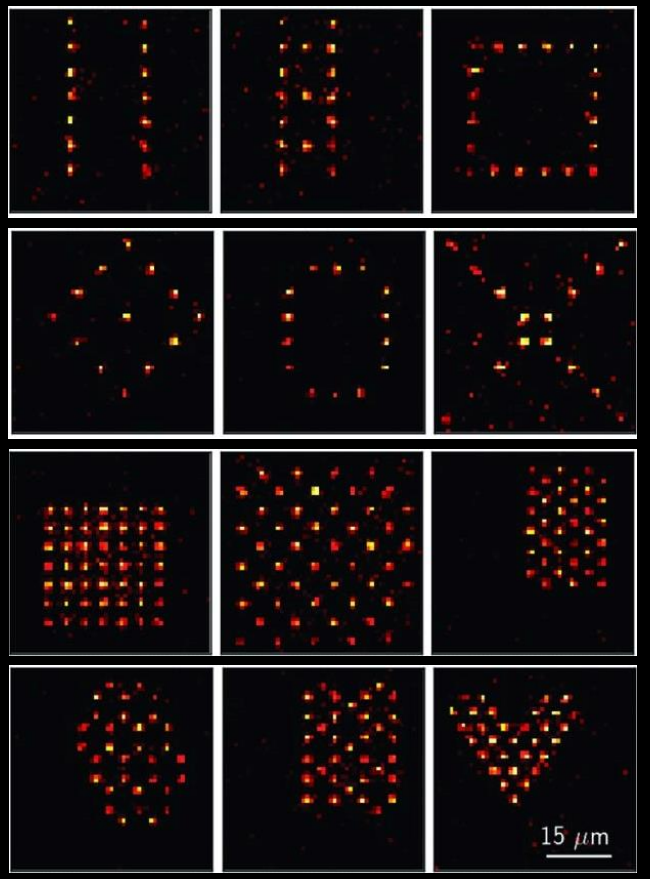
Bachelor Project

4. Controlling reconfigurable tweezer arrays

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. This project focuses on the techniques to create and control reconfigurable tweezer arrays in 1D, 2D and 3D. The goal is to learn and understand the current state-of-the-art methods for single atom control as well as their concrete implementations into experiments.

You will learn:

- The various methods to prepare optical microtrap arrays in 1D, 2D and 3D.
- How to load single atoms into such tweezer arrays.
- How to dynamically rearrange single atoms to create defect-free configurations.



Picture from Barredo et al. Science (2016)

Bachelor Project

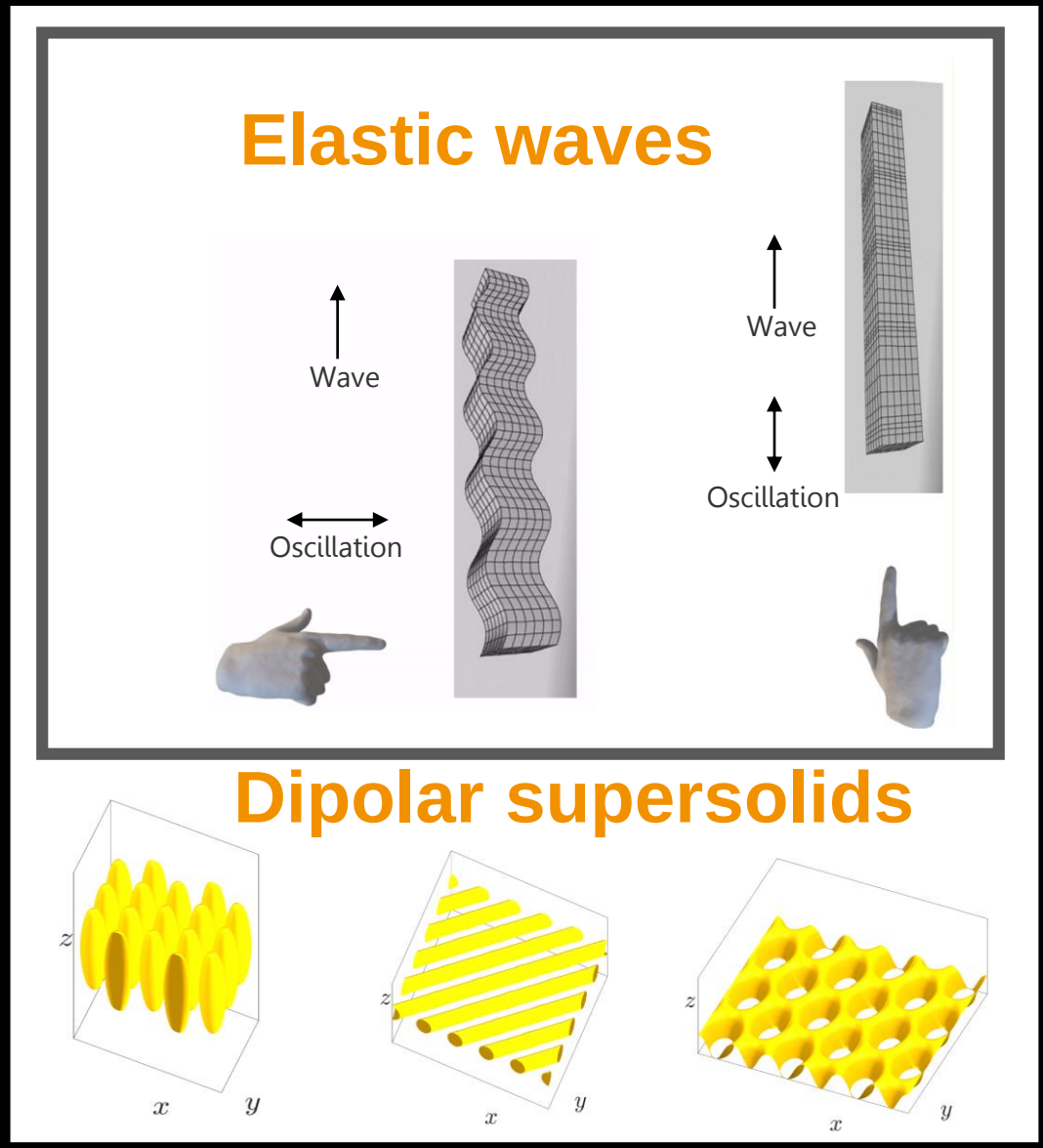
5. The dipolar supersolids: how solid are they?

Dipolar supersolids are quantum states of matter which have the frictionless flow of a superfluid while also behaving like a crystalline solid. These elusive states have had their superfluid nature rigorously tested, while its solid properties remain mostly unknown.

Classical solids can be characterized by their elastic moduli; quantities which measure the force required to elastically deform the solid. This project will explore the elastic moduli of the dipolar supersolids, and the associated elastic waves which propagate within them.

You will learn:

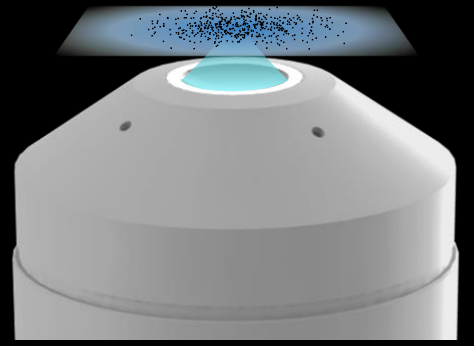
- How solids are defined, and the theory of elasticity used to characterize them.
- How supersolids differ from classical solids, and the equations which govern the behaviour of a supersolid.
- How to numerically simulate the propagation of elastic waves in ultracold dipolar supersolids.

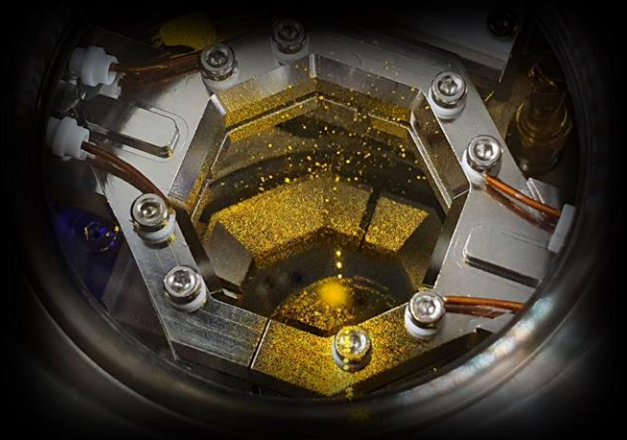


Possible Master Projects

How can we measure correlation functions of long-range interacting quantum particles in a crystal structure

The next generation of quantum gas experiments opens a new venue for the study of interacting quantum systems in unexplored regimes. The project focuses on the realization and measurement of an ensemble of strongly dipolar atoms in optical lattices in a quantum gas microscope experiment to detect non-trivial correlations as signatures for exotic quantum phases like topological superconductors.



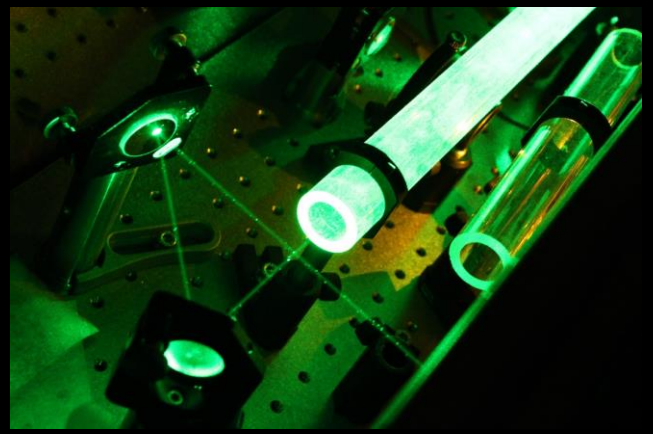


How can we create and use entanglement between tweezer-controlled single quantum particles in a high-dimensional space called qudits

Quantum computing using neutral atoms in optical tweezers is the newest technology in this rapidly growing field. This project aims at designing, implementing and characterizing experimental protocols for the initialization and manipulation of high-dimensional qudits. The qudits are stored in the large spin-manifold of tweezer-trapped erbium atoms, the entanglement is realized via Rydberg excitations.

How can we probe collective effects of ordered quantum emitters and their interplay with long-range interactions

Closely spaced light emitters can show collective behavior due to a photon-mediated coupling, leading to either an enhancement (superradiance) or suppression (subradiance) of spontaneous emission. The project focuses on the realization and measurement of those collective effects using strongly dipolar atoms regularly ordered in an optical lattices, realizing an ideal situation to investigate those effects.



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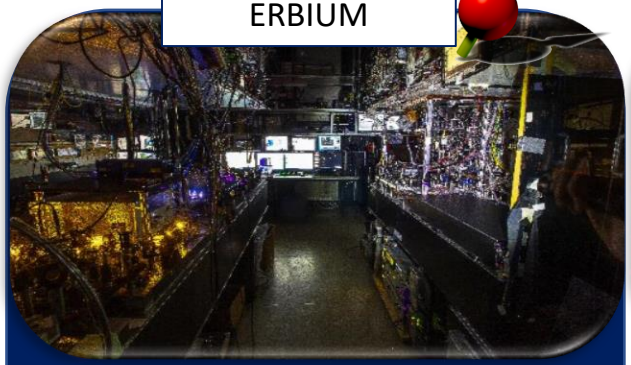
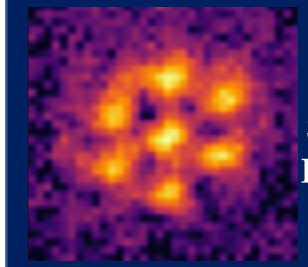
Theory ⇄ Experiments

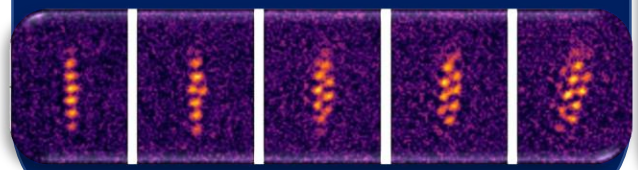
3 LABS and a THEORY TEAM

ERBIUM

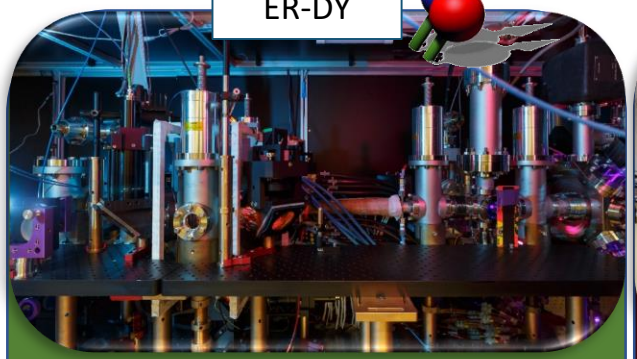


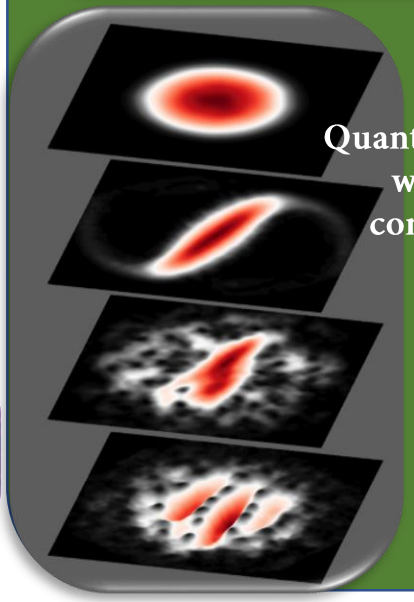


The discover of Supersolidity and Bloch Oscillations



ER-DY

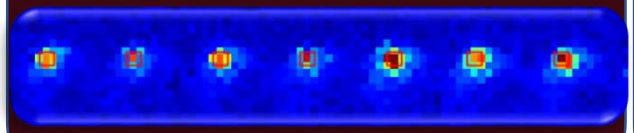




Quantum Vortices with high connectivity

T-REQS

Single atomic magnet in an array of tweezers for quantum info



Theory

Simulation of the behavior of dipolar quantum gases