Master 2 “Photonics, Complex and Quantum Systems (PhoCQS)”: Research Training 2023-2024

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Topic: Cold Atoms

Quantum simulations with a Bose-Einstein condensate experiment with controllable interactions

The physics of interacting quantum systems (or many-body quantum physics) is extremely complex and difficult to model theoretically and numerically, because of the size of the state space – which grows exponentially with the number of particles in the system – and of the presence of non-classical properties such as entanglement or quantum correlations.

To tackle this fundamental complexity of the quantum world, one way for studying interacting quantum systems, imagined by Feynman, is to experimentally produce what we today call “quantum simulators”, which are model systems, very flexible and which obey controllable Hamiltonians. Thanks to recent technical and scientific advances in the field of quantum, it is becoming possible to build such 'quantum simulators' in the laboratory - particularly with ultracold atoms - in order to study quantum phenomena that are still poorly understood, such as high-temperature superconductivity, quantum magnetism, etc.

It is nowaday possible to experimentally produce samples of ultracold atoms, with temperatures of only a few nano Kelvins – very close to absolute zero. At these temperatures, quantum behavior becomes dominant even at the scale of ‘macroscopic’ sets of atoms. This leads, for example, to the appearance of new states of matter, such as Bose-Einstein condensates.

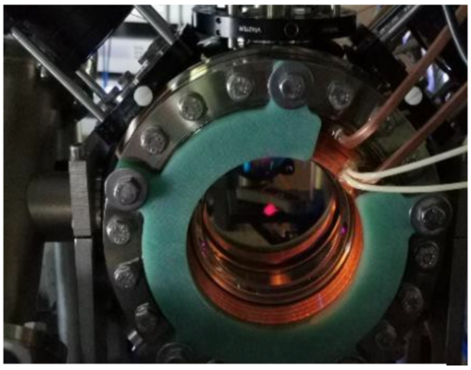

Figure 1: Photo of a cloud of Potassium atoms cooled down to T=15 μK (experiment at the PhLAM laboratory)