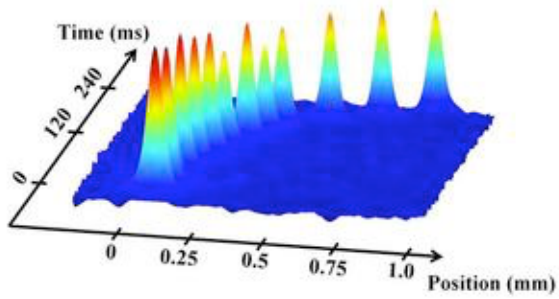
M2/thesis in Experimental Quantum Physics
Ultracold atoms at Institut d'Optique

Bose-Einstein condensates in arbitrary potentials

Our group is experienced in controlling interaction in potassium 39 condensates, in reduced dimensionalities (1D and 2D) and in introducing disorder. We can thus probe the properties of a variety of interacting quantum systems. Our apparatus allows for the production of Bose-Einstein condensates in a few seconds, and for highly sensitive imaging. Magnetic field sweeps permit to accurately and quickly change the scattering length that is the only parameter characterizing interaction at low temperatures. This ability is clearly demonstrated in the production of bright solitons, i.e. one-dimensional self-trapping condensates that do not diffuse in the absence of any trap because of attractive interaction (see figure).

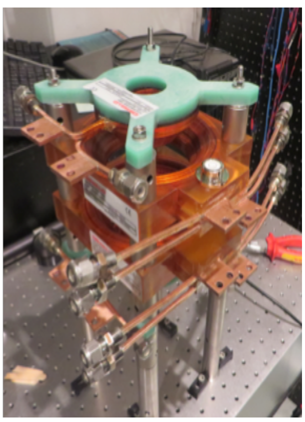


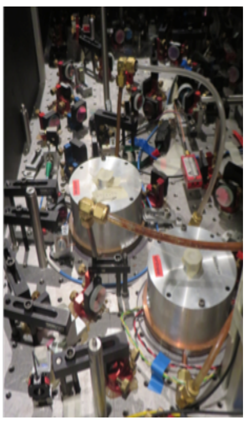
Non-dispersive propagation of a 39K bright soliton.
S. Lepoutre et al., PRA 94, 053626 (2016)

We now focus our activities on the study of quantum mixtures of Bose-Einstein condensates in two different spin-states. In particular, Potassium 39 allows for specific configurations with attractive interspecies and repulsive intraspecies interaction. In this situation, the usually dominant two-body mean-field interaction can be almost cancelled, such that the small higher order terms such that the ones originating from quantum fluctuations become important and may change the physics. One can for example create quantum droplets, a new self-trapped gaseous state of matter exhibiting liquid like behavior, i.e. a flat density profile. These systems offer perspectives for quantitative studies of beyond-mean-field effects in dilute Bose gases. In addition, they are also higher order mean-field effects such that effective three-body interactions in coupled Bose-Einstein condensate mixtures.

During the internship, we will develop a new tool: the ability to impose arbitrary potentials on the atoms and therefore to modify the trapping geometry. This can be done by using a digital micro-mirror device (DMD), a matrix composed of mirrors that can be individually addressed. The intern will characterize the new setup, that is currently being installed on the experiment. Tests will include the production of box traps as well as point-like disorder potentials, which will be useful in the context of our research.

The internship will open the path to a PhD thesis on the same setup. The main topics will be the study of quantum mixtures with and without coupling between two spin states of Potassium in various trapping geometries. Specific objectives are the production of new types of quantum droplets, with coupling and/or in reduced dimension. In 1D, quantum droplets are for example predicted to have counterintuitive properties. On the longer term, the study of transport in disordered Bose gases with variable interaction is also an option.





The intern will devote most of his work on the development and tests of the DMD system. He will also get to know the fascinating world of an ultracold atom experiment in which we can control the two-body interaction.

Please contact Thomas Bourdel for more information
E-mail : Thomas.bourdel@institutoptique.fr
Tel : 01 64 53 33 35
Institut d'optique, 2 av. A. Fresnel, 91120 Palaiseau