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

Bose-Einstein condensates with tunable interactions

Our group has expertise in producing potassium-39 Bose–Einstein condensates within a few seconds and in controlling two-body interactions via magnetically tunable scattering resonances. Interestingly, in potassium, nearby scattering resonances exist for different atomic internal spin states. In this context, preparing the condensate in a coherent superposition of two spin states coupled by a radio-frequency (RF) field or a two-photon Raman process not only allows us to control two-body interactions but also uniquely introduces effective three-body interactions (PRL 128, 083401 (2022); PRA 111, 053319 (2025)). With competing attractive and repulsive interactions between the two spin states, three-body interactions can even dominate the condensate dynamics. They may, for example, lead to the formation of quantum droplets, self-bound ensembles of atoms originating from attractive two-body interactions and repulsive higher-order effects.

More recently, we have also used the atomic spin degree of freedom to rapidly transfer condensed atoms from a weakly interacting state to a strongly interacting one, close to a scattering resonance. We then study the development of out-of-equilibrium correlations in this complex many-body system.

During an M2 internship, you will implement and test an imaging method based on fluorescence imaging using two pulsed, counter-propagating resonant optical beams. Such a method has previously been demonstrated for imaging single atoms in optical tweezers, and we would like to extend it to atomic ensembles. You will therefore build a new optical setup, learn how to operate our experimental apparatus, perform the necessary tests, and compare the results with our existing imaging capabilities. You may also contribute to our ongoing scientific projects on condensate dynamics with tunable interactions in spin mixtures. This internship could then continue as a PhD thesis, starting in October 2027.

Please contact Thomas Bourdel for more information
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