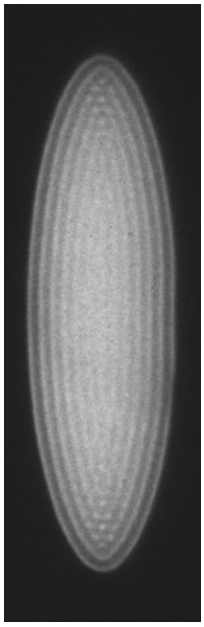
A laser-cooled trapped ion cloud for heavy particle detection

SUPERVISOR : CAROLINE CHAMPENOIS AND AURIKA JANULYTE
MAIL : CAROLINE.CHAMPENOIS@UNIV-AMU.FR
TEL : +33 413946413
LAB : PHYSIQUE DES INTERACTION IONIQUES ET MOLÉCULAIRES, MARSEILLE, CAMPUS DE SAINT-JÉRÔME[1]. (UMR7345)
WEB PAGE OF THE CIML GROUP : HTTPS://PIIM.UNIV-AMU.FR/EN/RESEARCH/SEVEN-TEAMS-AND-ONE-OPERATION/CIML-TEAM/

keywords : atom trapping and laser cooling, strongly correlated plasma, charged particles guiding



The CIML group has a strong expertise in laser cooling and ion trapping in radio-frequency trap. It is part of the European ion trapping network and one of the few groups trapping ions for fundamental physics purpose, in France. One of the experimental set-up of the group aims at the experimental investigation of the energy exchange between charged particles, sending a projectile onto a target. There, the target is a cold and dense trapped ion cloud which can be considered as a very non-conventional plasma, a one-component plasma (OCP). The projectile is a very heavy molecular ion and the perturbation that it induces in crossing the cloud of trapped ions can be used for its non-destructive detection, to demonstrate a prototype for mass spectrometer detector without mass limitation [1].

In practise, the target is a laser cooled Ca+ ion cloud (see picture). As they reach temperature lower than the kelvin, these ions bunch in the trapping potential and arrange in a stationary structure that minimise the trapping+Coulomb repulsion potential energy, to form what is called a Coulomb crystal. An example of these structures, formed by several hundreds of ions, is visible on the figure showing the image of the ion fluorescence on a CCD camera. The exploited signal is the laser induced fluorescence of the cloud. The interplay between the laser cooling efficiency and the non-linear dependence of the RF-heating with the cloud density and temperature turns the phase transition of the cloud as a signal amplifier for an efficient detection [2].

Objectives : We propose as a PhD project to demonstrate and quantify the energy exchange between charged heavy ions and laser cooled Ca+ OCP. It implies to develop a protocol to control the size and temperature of the trapped ions, the trajectory of the projectile and a diagnostic of the energy transferred to the ion cloud. The internship relies on an operational experimental set-up, where the detection will take place. It can also rely on a molecular dynamics simulation code that can be used to test the detection efficiency regarding the projectile characteristics, the trap and the laser-cooling parameters.

The **acquired skills** concern charged particle trapping and guiding, atom-laser interaction and laser cooling, tight laser control, data acquisition and processing.

REFERENCES :

[1] A. Poindron, *et al,* J. Chem. Phys. 154, 184203 (2021)
[2] A. Poindron, *et al,* PRA, 108, 013109 (2023)

[1] Saint-Jérome campus can be reached by public transportation from the city centre in less than 25 minutes. Our group benefits from a completely new technical environment with very good technical conditions.