A large laser cooling experiment for ultra-cold plasma studies

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We describe an experimental device, aimed for ultra-cold plasma studies. It is based on a large MOT (magneto-optical trap), where Rubidium atoms are cooled down and trapped by a system of laser beams and a static magnetic field configuration.

The radiative transition used for laser cooling couples the $5^2S_{1/2}$ and $5^2P_{3/2}$ energy states, at a wavelength of 780 nm. This experimental device is able to confine a large number of ^{87}Rb atoms, around 10^{10} atoms, in a sphere of 1 cm diameter, at a temperature of 100 micro-Kelvin. The confining magnetic field is provided by two main coils in anti-Helmholtz configuration, complemented by two couples of smaller compensation coils.

The atomic density profiles have been studied, in order to characterize the experiment and more importantly, to determine the equation of state of the ultra-cold gas. Collective processes associated with the atomic effective charge in the neutral phase have close similarities with those occurring in plasmas [1, 2]. Static and dynamical properties of the confined gas are under investigation.

The neutral cooled gas can be ionized using the second harmonic of an additional Nd:Yag pulse laser. We can then produce a strongly correlated ultra-cold plasma, with ion temperatures bellow 1 K, and electron temperatures between 1 and 10 K. After a fast rearranging process, the plasma attains a quasi-steady state, which can be described by a Thomas-Fermi equilibrium model [3]. The plasma is slightly non-neutral due to the escape of the energetic electrons and expands on a millisecond timescale. Our experimental program will be mainly focused on plasma instabilities and confinement regimes.

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[2] J.D. Rodrigues, J.T. Mendonça and J.A. Rodrigues, Satellite rings and normal modes in rotating clouds of ultra cold atoms, http://arxiv.org/abs/1406.6098 (2014).

[3] J.T. Mendonça and H. Terças, *Physics of Ultra-cold Matter*, Springer, N.Y. (2013).