High-resolution Focussed Ion Beam by laser cooling and compression of a thermal atomic beam

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In order to improve the resolution of nano-fabrication using Focused Ion Beams (FIBs) we are developing an ultra-cold ion source based on photo-ionization of a laser-intensified atomic beam. Initial calculations have shown that an ion beam with a brightness of 10^7 A/m^2 sr eV and a longitudinal energy spread of less than 1 eV can be achieved at a current up to 10 pA. Combined with high performance focusing optics, this would lead to a nanometer-sized spot at which sample manipulation can be performed.

The starting point is a high-flux atom source which consists of a Knudsen cell connected to a collimating tube. The brightness of the atomic beam is increased by laser cooling and compression in the transverse direction by means of a magneto-optical compressor. The resulting cold beam of atoms is photo-ionized inside an electric field to suppress disorder-induced heating caused by the non-uniform Coulomb interactions between the ions. The ion beam is then focussed to a nanometer-sized spot by means of a an electrostatic lens column.

Numerical calculations have been performed on the magneto-optical compressor in order to find an optimal set of parameters. These reveal that a length of only 60 mm is sufficient for cooling and compressing the atomic beam to a brightness higher than 10^7 A/m^2 sr eV at an equivalent flux up to 1 nA. Furthermore, a model was set up to describe the effect of both the disorder-induced heating of the ions and of the lens aberrations on the final spot size. This was verified using particle tracking simulations incorporating a realistic ionization and acceleration structure. It was shown that spot sizes smaller than 1 nm can be achieved at currents up to a few pA or 5 nm at currents up to 20 pA which is better than the state of the art Liquid Metal Ion Source based FIBs.

We will report on simulations and on the experimental realization of the high-flux Knudsen cell with collimation tube and the magneto-optical compressor.

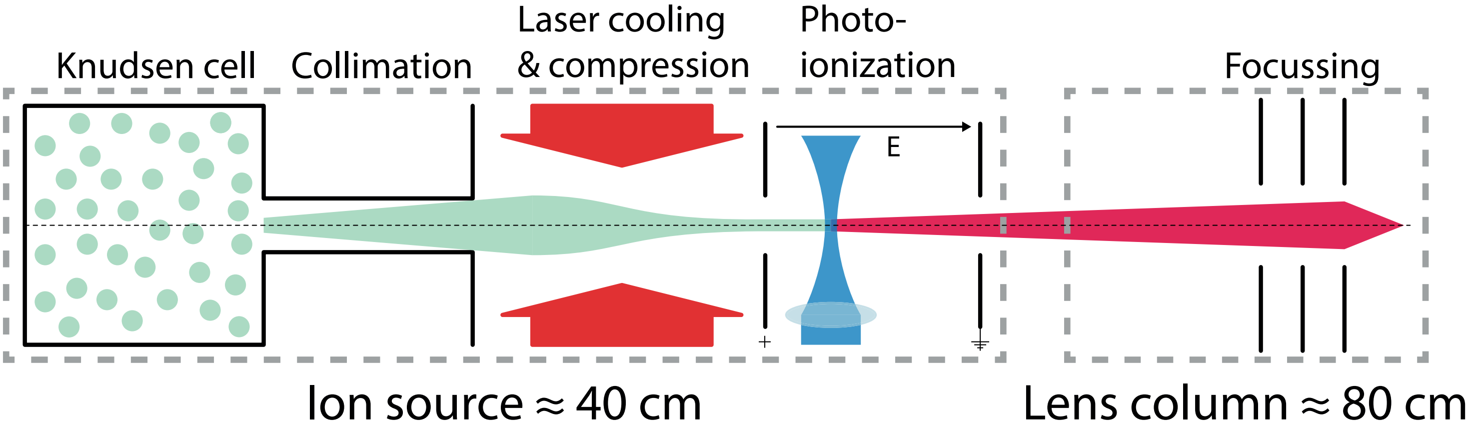

Figure 1: *Schematic drawing of the Atomic Beam Laser-cooled Ion Source.*

References