Focused Ion Beam Milling with Cold Rubidium

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Charged particle sources based on ionization of laser-cooled atoms promise important advances in our understanding of charged particle dynamics[1] and applications in electron[2] and ion microscopy and nanofabrication. Enhanced beam brightness due to the low temperature of the generated electrons and ions enables higher resolution imaging and milling. More than 30 elements can be cooled, allowing for high brightness sources for many new ion species.

A focused ion beam (FIB) apparatus using laser-cooled rubidium atoms has been developed for use in nanofabrication and imaging. Our rubidium FIB aims to achieve a higher beam brightness and a smaller focus spot size than existing state of the art gallium FIB systems. The ion source is designed to achieve brightness in excess of $10^7\ \mathrm{A\,m^{-2}\,sr^{-1}\,eV^{-1}}$, with sufficient beam current for both milling and microscopy.

We present the design and preliminary results from our cold atom ion source. We generate a neutral cold atomic beam from a vapour loaded 2D magneto-optical trap (MOT)[3]. The transversely cooled atoms are pushed out of the 2D MOT along the longitudinal dimension, are further cooled in a polarization gradient cooling stage, and are then photoionized. We use a two-step photoionization process, allowing control over the ionization volume and beam energy,[4] maximising beam brightness. This ionization scheme can be adapted to allow for unique capabilities including: coincident electron/ion detection and feedback for high-fidelity heralding of ions[5]; Rydberg exceptional state field ionization for reducing beam energy spread and chromatic aberration; and Rydberg blockade for isolating single ions.

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