Low Temperature Ion Source for Focused Ion Beam Nanomachining Applications

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The focal spot size of most focused ion beams (FIBs) has been limited by the intrinsic brightness and energy spread of the gallium liquid metal ion source (LMIS). Recognizing the demand for better performance, we present a prototype Cs^+ ion source whose high brightness and low energy spread may make it an ideal replacement for the LMIS in high-resolution nanomachining FIB applications. The source may also offer additional analytical capabilities by improving the performance of site-specific secondary ion mass spectrometry (SIMS).

The source is comprised of a laser-cooled atomic beam of neutral cesium which is compressed and then photoionized within a volume of a few cubic microns [1]. A uniform electric field is applied to form an ion beam. A schematic of the prototype apparatus is shown in Fig. 1. The micro-kelvin temperature of the neutral atoms results in a Cs^+ beam with a low intrinsic transverse velocity spread, yielding low emittance. The energy spread is also very small; it is determined in this source by the finite spatial extent over which ions are created in a uniform electric field of approximately 10^5 V/m.

Measurements of the source's brightness and energy spread will be presented. Monte-Carlo simulations will be included to demonstrate the extent to which Coulomb interactions affect the source brightness [2]. To date, our measurements indicate that the prototype source has a brightness greater than 1×10^7 $Am^{-2}sr^{-}eV^{-1}$ and an energy spread less than 0.34 eV. This brightness and energy spread imply that, when coupled to an optimized ion acceleration and focusing column, a d_{50} spot size less than 1 nm should be achievable. The source has also achieved total currents over 5 nA, albeit at a reduced brightness.

With further refinement and a proper acceleration and focusing column design, this source may provide a versatile solution for FIB nanomachining and analysis.

[1] B. Knuffman, A. V. Steele, and J. J. McClelland. *J. Appl. Phys*. **114**, 044303 (2013).
[2] A. V. Steele, B. Knuffman, J. J. McClelland. *J. Appl. Phys.* **109**, 104308 (2011).

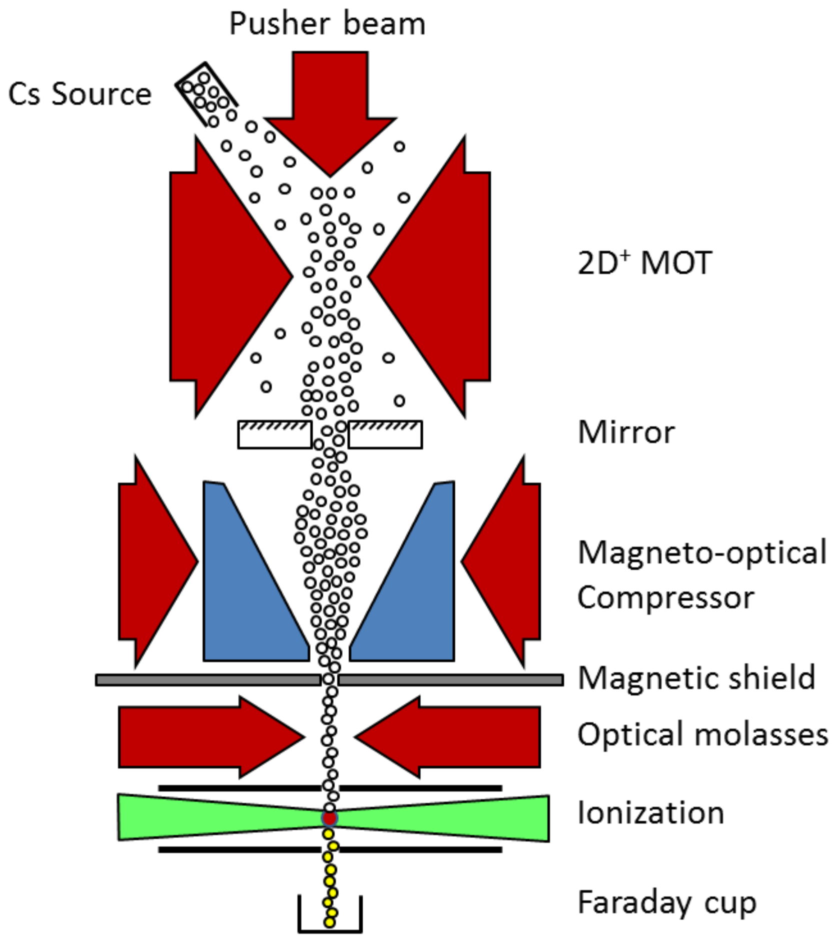

Figure 1. Schematic of the ion source, showing the four stages of ion beam production: 2D magneto-optical trap with pusher beam (2D$^+$ MOT), magneto-optical compressor, optical molasses, and photoionization.