Low Temperature Ion Source for Focused Ion Beam Nanomachining Applications

A.V. Steele, B. Knuffman, A. Schwarzkopf
zeroK NanoTech, Gaithersburg, MD 20879 USA
adam@zerok.com

J. J. McClelland
Center for Nanoscale Science and Technology, National Institute of Standards and Technology, Gaithersburg, MD 20899 USA

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 previously demonstrated 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. We measured the brightness indirectly, determining the spatial current distribution via other ion source parameters and finding consistency with expected behavior. In our present work, we present progress toward the construction of an alpha tool, integrating our ion source with a commercial FIB column. We will make a direct measurement of the source brightness by measuring the current distribution in the focal spot. We present details of this measurement method, as well as data obtained to date.

We expect the measurements to be consistent with the values previously determined from our prototype system: measurements indicated that the prototype source has a brightness greater than 1×10^7 $Am^{-2}sr^{-1}eV^{-1}$ and an energy spread less than 0.34 eV.

The source consists of a laser-cooled atomic beam of cesium which is compressed and then photoionized within a volume of a few cubic micrometers [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 small energy spread 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.

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 at 1 pA. The source has also achieved total currents over 5 nA, albeit at a reduced brightness.

---

[1] B Knuffman, AV Steele, J Orloff, and JJ McClelland. *J. Appl. Phys.* **114**, 4 (2013).

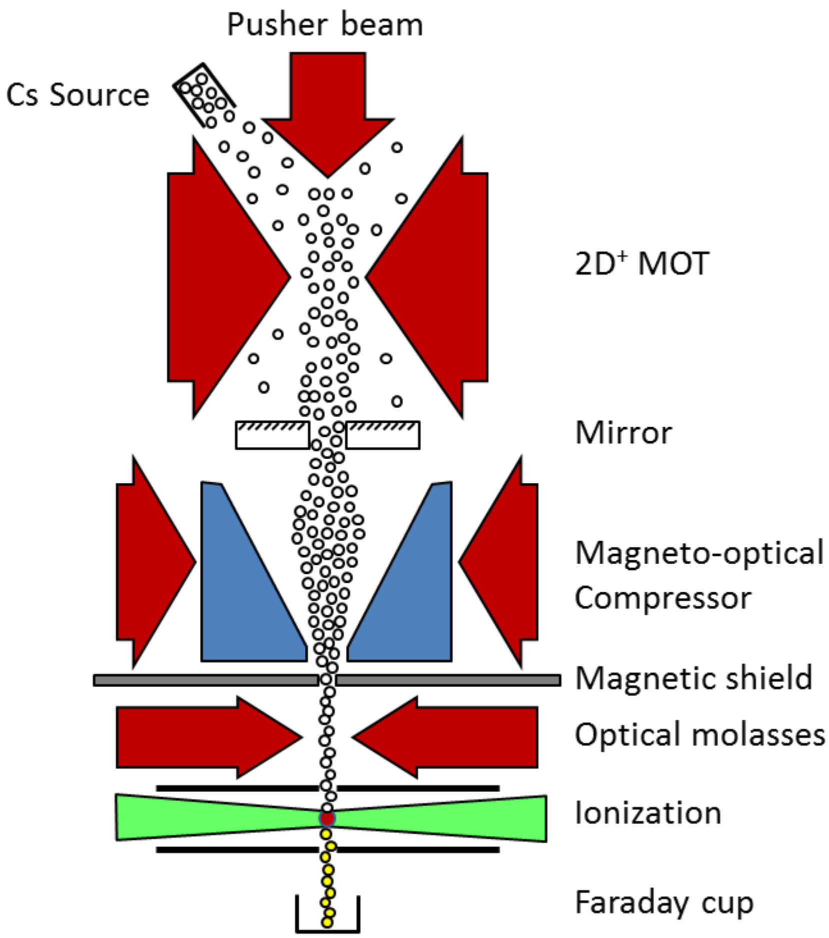

Figure 1. Schematic of the ion source, showing the four stages of ion beam production: 2D magneto-optical trap with pusher beam, magneto-optical compressor, optical molasses, and photoionization.