# A point source of energetic helium atoms for proximity lithography

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## ABSTRACT

A concept for a point source of energetic neutral particles, Fig. 1, has been previously described[1] where helium ions are extracted from a multi-cusp ion source, accelerated, and focused to a cross-over at earth potential. As current increases, however, space charge near the point of minimum cross-section may significantly modify the current distribution in the beam.[2] Ions are neutralized by charge transfer scattering in a differentially pumped high pressure cell near the beam waist and an electrostatic deflector removes the residual ions to form a pure beam of energetic neutral particles. There is very little change in the direction (<0.5 mr) or energy (<5eV) of the parent ions during the neutralization process. The neutral particle beam then appears to emanate from a Gaussian *virtual* source. The critical source parameters for proximity lithography are the diameter, which controls penumbra, and brightness, which determines throughput. The goal of this study is to optimize a neutral particle source with respect to these parameters.

Preliminary experiments were carried out using a multi-cusp ion source, 3.175 cm in diameter with a filament-supported, 200 W helium discharge. The beam energy was 30 keV and the extraction potential was 3 kV. A scanning Faraday cup, positioned 4.44 m from the final electrode in Fig. 1, was used to measure both ion and neutral particle flux. For neutral particles, the cup was biased to measure secondary electron current and calibrated against the ion dose required for negative-tone exposures of Poly(methylmethacrylate) resist. The apparent position, diameter, and brightness of the virtual source were determined by profiling the beam formed by an aperture 2.92 m from the measurement plane. The apparent position of the virtual ion source was 78 cm from the final lens electrode; its diameter ($2\sigma$) and brightness were 88 μm and 420 A/m$^2$-sr-V, respectively. (we note that another common definition would result in a brightness twice this high). Thus, the beam waist was well beyond the cell. As a result, the 1 mm entrance aperture of the charge transfer cell severely limits the beam size. While not optimal for lithography, this configuration clearly elucidates the important space charge effect.

Figure 2 shows the neutral beam profile for several values of cell pressure. The beam has a Gaussian shape with $\sigma$ =2.5 mm; by comparison the ion beam is broad and nearly uniform over a disc 1 cm in diameter. Moreover, the position of the virtual source is 22 cm from the final lens for neutral particles compared to 78 cm for the ions while the diameter ($2\sigma$) of the virtual source for neutrals is 308 μm at all cell pressures but just 88 μm for ions. Because of the very small scattering angle, the neutral particle source represents the cross-over of the ion beam without space charge. Thus, space charge shifts the position of the virtual ion source away from the lens, broadens the beam, and apparently (to be confirmed by direct measurement) demagnifies the cross-over. The brightness of the virtual neutral source is shown in figure 3 as a function of cell pressure. Ninety percent of the ions are neutralized at 100 mtorr. These results imply that it may be possible to achieve a much smaller virtual source and a more uniform beam by neutralizing the ions downstream of the beam waist. A detailed study of the effect of operating parameters and physical configuration on neutral particle source performance will be presented at the conference.

Research supported by NSF awards DMI-0521523 and ECS-0404308, Center for Nanoscale Materials at the Argonne National Laboratory, and the Texas Center for Superconductivity at the University of Houston.

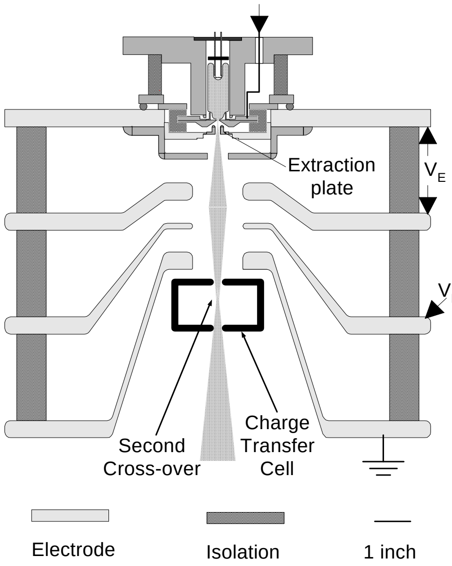

Figure 1: A point source of energetic neutral particles where ions are neutralized by charge transfer scattering in a differentially pumped high pressure cell near the beam waist. An electrostatic deflector downstream of the cell removes residual ions from the beam.

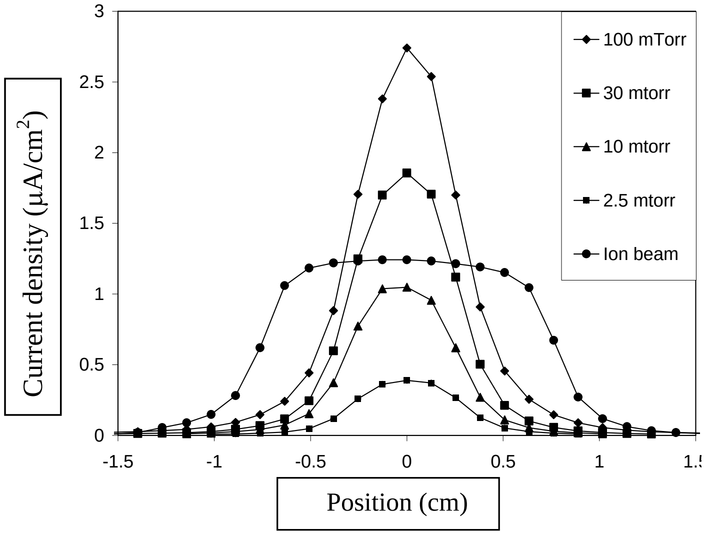

Figure 2: Neutral beam profile as a function of charge transfer cell pressure at a distance of 4.44 m from the grounded electrode of Figure 1. The profile of the parent ion beam at the same distance is shown for comparison. The ion beam is broader and less intense due to space charge repulsion at the cross-over.

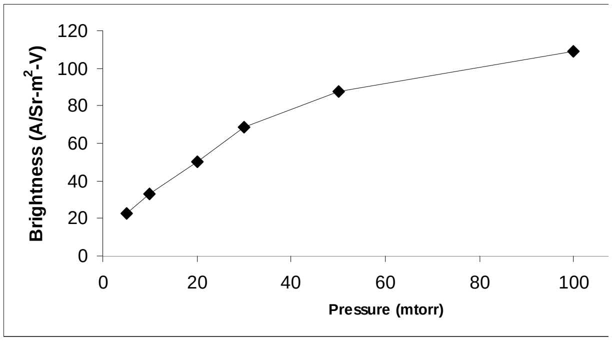

Figure 3. Brightness of the neutral particle cross-over as a function of cell pressure. The diameter ($2\sigma$) and brightness of the 30 keV parent ion source are 88 μm and 420 A/m$^2$-sr-V, respectively. The diameter of the neutral particle cross-over is 308 μm, independent of cell pressure.

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[1] Hong-jie Guo, Barry Craver, Jackson Reynolds, and John C. Wolfe , "Design studies for a high brightness, energetic neutral atom source for proximity lithography," J. Vac. Sci. Technol. B 25(6), 2188-2191 (2007).

[2] H. Moss, Narrow angle electron guns and cathode ray tubes, Academic Press, NY, 1968.