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# VOLUME PRODUCTION OF $Li^-$ IN A MULTICUSP ION SOURCE*

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High energy beams of neutral lithium atoms have applications in neutral beam heating of fusion plasmas and plasma diagnostics. Specifically, a neutral 100kev Li beam has been used as a diagnostic tool for determining current, plasma density, and magnetic pitch angle on the Texas EXperimental Tokamak (TEXT).[1] Scale up of this diagnostic for the Tokomak Fusion Test Reactor (TFTR) would require use of a $Li^-$ beam because of the inefficiency of neutralizing $Li^+$ at the high energies required.[2] Previous efforts to generate $Li^-$ beams have focused on electron capture in a gas[3] or production on a low work function surface in a plasma.[4,5] Volume $Li^-$ production by dissociative attachment of optically pumped lithium molecules has also been studied.[6] In this paper we report the first volume production of a $Li^-$ ion beam from a plasma discharge. In the volume of a plasma, $Li^-$ ions are presumed to be formed via dissociative attachment to vibrationally and rotationally excited $Li_2$

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molecules,[7] a process very similar to the production of $H^-$ ions.[8] $Li_2$ molecules are first formed by evaporation or by three body recombination of Li atoms; subsequent electron impact excitation provides a population of vibrationally and rotationally excited $Li_2$ molecules.

The ion source uses a cylindrical water cooled copper chamber (2.5 cm diameter by 5 cm long) with the open end enclosed by a two grid ion extraction system. Inside the source chamber is a heat shield constructed of molybdenum sheet metal ($7.6 \times 10^{-3}$ cm thick). A solid sample of lithium metal is placed in the heat shield and evaporates during operation due to discharge heating. A schematic diagram of the ion source is shown in Fig. 1. The source chamber is surrounded externally by 16 columns of ceramic magnets to form a longitudinal line-cusp configuration for primary electron and plasma confinement. Fig. 2 shows a computer plot of the magnetic field produced by the longitudinal line-cusp magnets.

In this experiment, argon was used as a supporting gas to initiate the discharge. Typical discharge parameters are: an arc voltage of 40V and an arc current of 4A. The mass spectrometer output signal in Fig. 3(a) shows that $^6Li^+$, $^7Li^+$, and $Li_2^+$ are present in the extracted ion beam with $^7Li^+$ composing 80% of the beam. A small peak shows the presence of ions at mass 13. These are $Li_2^+$ ions formed by the combination of $^6Li$ and $^7Li$ atoms. $Ar^+$ ions are present in the extracted beam but the signal is too small to be seen on the same scale. Figure 3(b) shows a mass spectrometer trace of the negative ion species extracted from the source plasma. Only $Li^-$ ions (both $^6Li^-$ and $^7Li^-$) were detected.

The maximum negative ion current measured was 14.9uA (corresponding to a current density of 1.9 mA/cm$^2$) for a discharge voltage of 40V and discharge current of 4A. The extracted electron current measured by the mass separator was 3.75 mA which gives an electron to ion ratio of 250 to 1 for the extracted beam. The ion source was capable of steady-state operation. However, due to the condensation of lithium vapor on the water cooled extraction plates, the source could be operated for only a short period of time (~ 2-3 min.) before the extraction apertures were clogged with lithium. This observation indicates that a "hot" extraction electrode system is needed for steady-state operation. As far as we are aware, these are the first measurements of volume produced $Li^-$ current density and electron-to-ion ratio.

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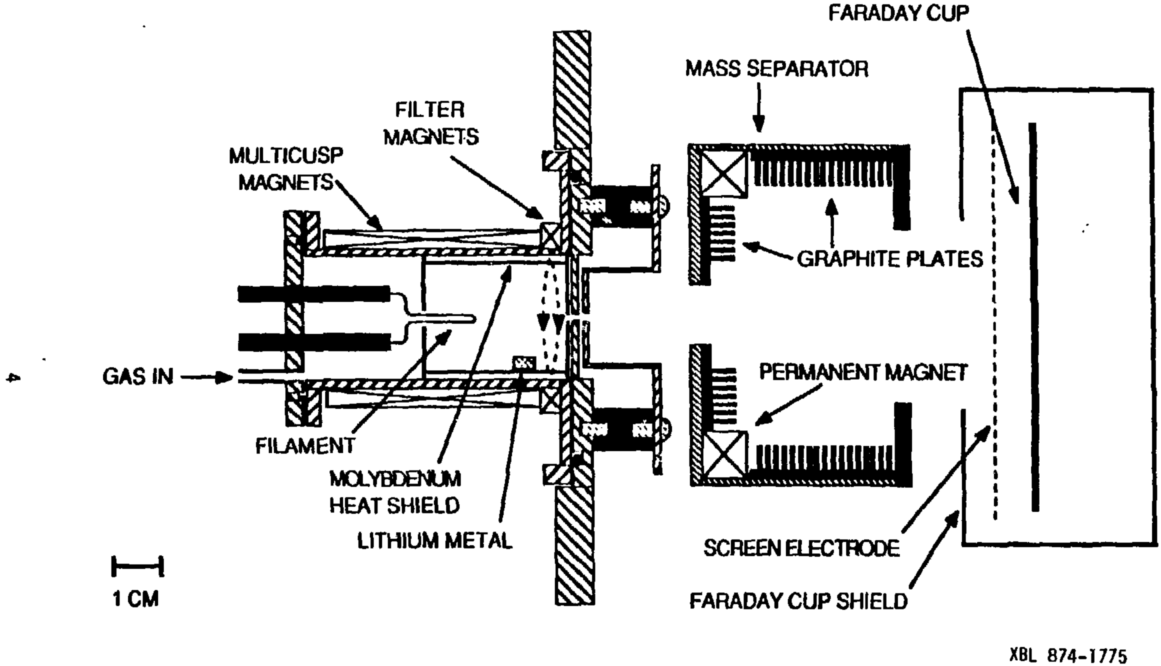



Figure 1 A schematic drawing of the ion source and apparatus for measuring negative ion and electron currents.

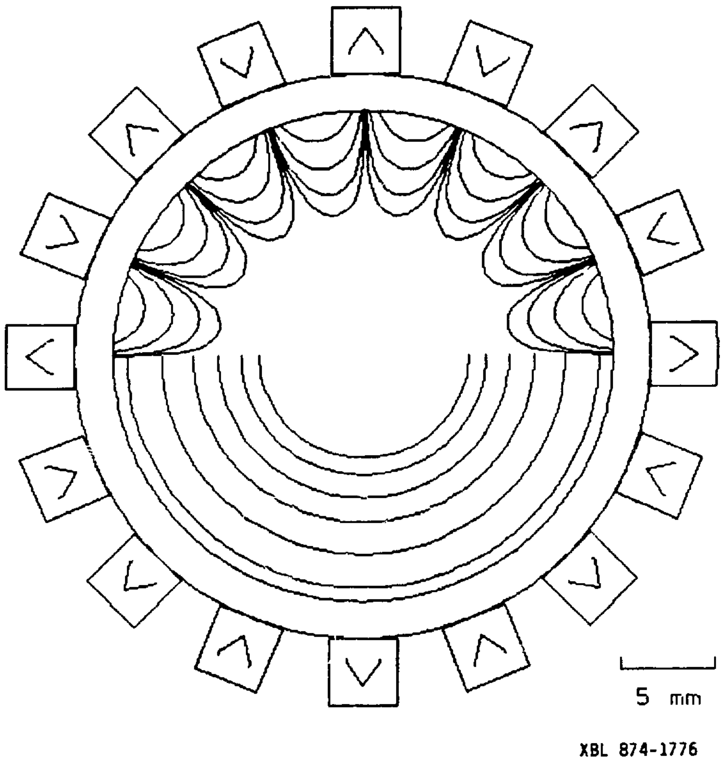
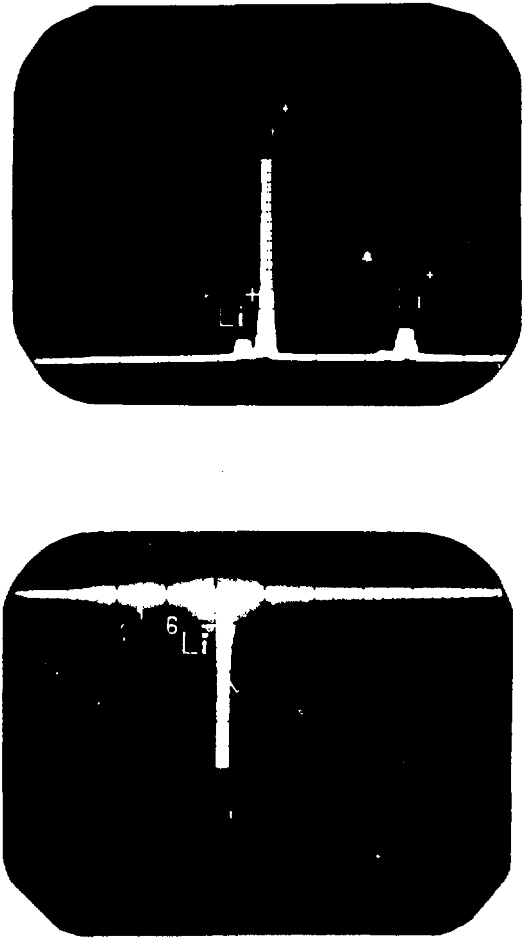



Figure 2 A computer plot of the magnetic field produced by the multicusp magnets surrounding the ion source. The upper half plot shows the field lines (1,3,10,30 gauss–cm), and the lower half plot shows the field intensity contours (1,3,10,30,100,300 gauss).




(a)

(b)

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Figure 3. Mass spectrometer output signals showing (a) the positive ion species and (b) the negative ion species in the extracted ion beam.