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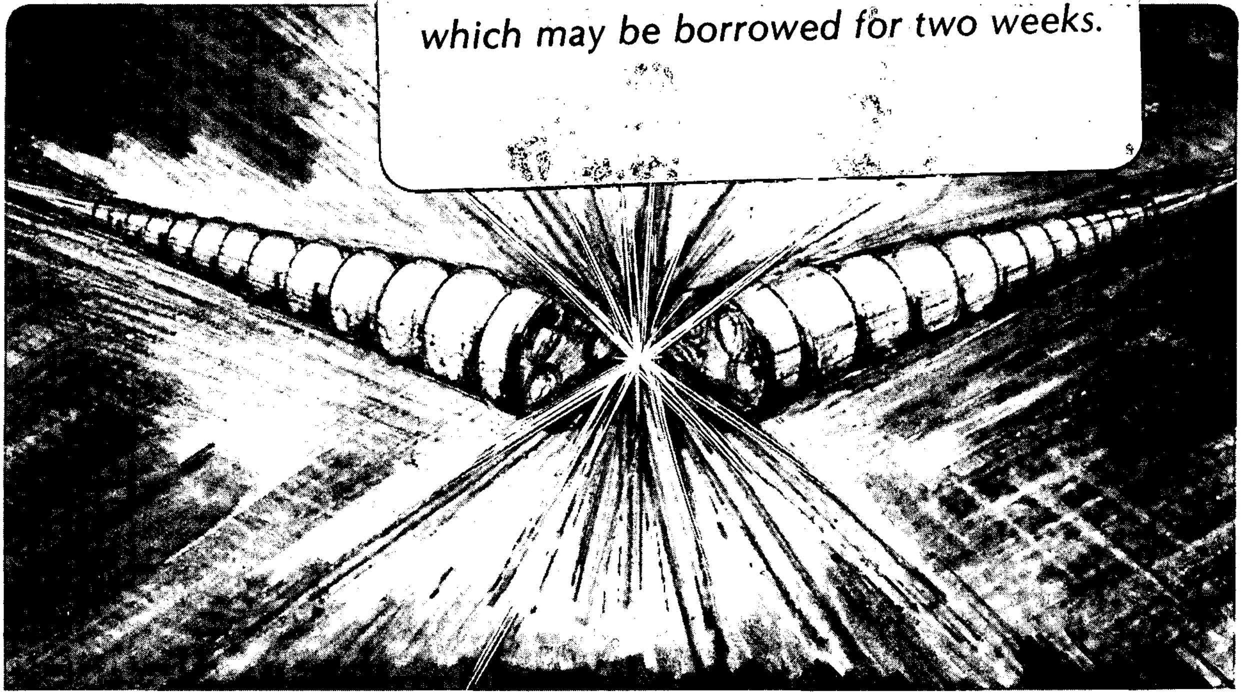

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VOLUME PRODUCTION OF Li^- IN A SMALL MULTICUSP ION SOURCE*

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Abstract

Negative lithium ions, generated by volume processes, have been extracted from a small magnetically filtered multicusp ion source. Current densities of 1.9 mA/cm^2 have been obtained with a discharge voltage of 40V and discharge current of 4A.

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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 molecules,[7] a process very similar to the production of H^- ions.[8]

$$e + Li_2(v,J) \Rightarrow Li + Li^- \qquad (1)$$

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 dissociative attachment cross-section of Li_2 has been studied, and is shown to increase as a function of vibrational state[9,10] in a manner similar to H_2.[8] Efficient volume production of H^- has been demonstrated by Leung et. al.[11] using a filtered multicusp ion source. The filter provides a narrow region of B-field which is strong enough to confine the primary ionizing electrons. However, the plasma can go through the filter and reach the extraction region where the electron temperature is always low ($T_e < 1eV$), which is favorable for the formation of H^- ions by the dissociative attachment process. The low T_e also helps to reduce the stripping loss of H^- by electrons. As a result, the use of the magnetic filter substantially increases the negative ion yield.[11,12] In this experiment a similar source geometry was employed to extract a beam of Li^- ions.

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. 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. The use of 16 columns of magnets, as opposed to a smaller number, allows a larger 'field-free' region ($B < 10$ gauss) where the filament is placed and primary electrons are emitted. The magnet columns on the cylindrical wall are connected at the end flange by two rows of samarium cobalt magnets that are also in a line-cusp configuration.

A samarium cobalt magnetic filter[11] near the plane of extraction divides the chamber into an arc discharge and an extraction region. The filter magnets provide a transverse magnetic field ($B = 100$ gauss at the center) which serves to prevent energetic primary electrons from reaching the extraction region. However, positive ions, negative ions, and low energy electrons can diffuse across the filter into the extraction region to form a plasma.

Inside the source chamber is a heat shield constructed of molybdenum sheet metal (7.6×10^{-3} cm thick). A solid sample of lithium metal is placed in the heat shield and evaporates during operation due to discharge heating. In this manner, a substantial vapor pressure of lithium is obtained, at which time the flow of argon support gas can be turned off and a self-sustained lithium plasma is produced.

A two-electrode acceleration system is attached to the open end of the chamber. The extraction aperture is 1mm in diameter giving an extraction area of 7.85×10^{-3} cm^2. The source and the first or plasma electrode are biased negative for negative ion extraction and positive for positive ion extraction. The second electrode is electrically grounded. A plasma is produced by primary electrons emitted by a 0.5-mm-diameter hairpin tungsten filament. The chamber wall, heat shield and plasma electrode serve as the anode for the discharge.

Located downstream from the second electrode is a compact magnetic deflection spectrometer[13] for measurement of the negative or positive ion species in the extracted beam. In order to measure the negative ion current, the electrons in the extracted beam are removed with a permanent magnet mass separator[11] which generates a B-field strong enough to remove the electrons but does not perturb the ion trajectories significantly. The electrons are collected on ridged graphite plates in the mass separator and the current is measured. The remaining beam, composed solely of negative ions, is collected on a Faraday cup. This arrangement, schematically represented in Fig. 1, provides the total negative ion current and the ratio of extracted electrons to ions.

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 $^{6}Li^{+}$, $^{7}Li^{+}$, and Li_2^{+} are present in the extracted ion beam with $^{7}Li^{+}$ composing 80% of the beam. A small peak shows the presence of ions at mass 13. Presumably these are Li_2^{+} ions formed by the combination of ^{6}Li and ^{7}Li 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 $^{6}Li^{-}$ and $^{7}Li^{-}$) were detected. Under normal operation no H^{-} or O^{-} impurities were detected. Hence the negative ion current measured by the Faraday cup consists mainly of Li^{-} ions.

As previously stated, measurements of the extracted negative ion current and the ratio of extracted electrons to ions were made with a permanent magnet mass separator and a Faraday cup. The maximum negative ion current measured was 14.9μA (corresponding to a current density of 1.9 mA/cm^{2}) for a discharge voltage of 40V and discharge current of 4A. Actual current densities could be higher since no effort was made to improve the ion optics. 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. This ratio can presumably be improved when the magnetic filter geometry is optimized.[14]

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. Results show that substantial Li^- current can be obtained by volume processes. Future work is directed at eliminating the problem of lithium condensation on the extraction electrodes and controlling lithium vapor pressure more directly with an external oven. We also plan to optimize the filter geometry and the bias potential on the first extraction electrode to maximize the Li^- output and the Li^- ion-to-electron ratio. Results of these investigations will be reported in the near future.

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Figure Captions

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).

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

References

1. D. M. Thomas, W. P. West, and S. Zheng, Bull. Am. Phys. Soc., 31(9), 1574, (1986).
2. M. M. Menon, IEEE Proc., 69(8), 1012, (1981).
3. J. R. Mowat, E. E. Fisch, A. S. Schlachter, J. W. Stearns, and Y. K. Bae, Phys. Rev. A, 31(5), 2893, (1985).
4. J. W. Stearns, R. V. Pyle, and F. Tehranian, J. Vac. Sci. Technol. A, 4(3), (1986).
5. E. H. A. Granneman et. al., Proc. 3rd Int. Symp. on the Production and Neutralization of Negative Ions and Beams, p. 206, Brookhaven National Laboratory, (1983).
6. M. W. McGeoch and R. E. Schlier, Phys. Rev. A, 33(3), 1708, (1983); and J. Appl. Phys. to be published June (1987).
7. J. M. Wadehra and H. H. Michels, Chem. Phys. Lett., 114(4), 380, (1985).
8. J. M. Wadehra and J. N. Bardsley, Phys. Rev. Lett., 41,1795, (1978).
9. M. W. McGeoch and R. E. Schlier, Bull Am. Phys. Soc., 30(2), 148, (1985).
10. H. H. Michels and J. M. Wadehra, Bull Am. Phys. Soc., 30(2), 129, (1985).
11. K. N. Leung, K. W. Ehlers, and M. Bacal, Rev. Sci. Instrum., 54, 56, (1983).
12. J. R. Hiskes, Proc. 4th Int. Symp. on the Production and Neutralization of Negative Ions and Beams, Brookhaven National Laboratory, (1986).
13. K. W. Ehlers, K. N. Leung, and M. D. Williams, Rev. Sci. Instrum., 50, 1031, (1979).
14. K. N. Leung, K. W. Ehlers, and R. V. Pyle, Rev. Sci. Instrum., 56, 321, (1985).

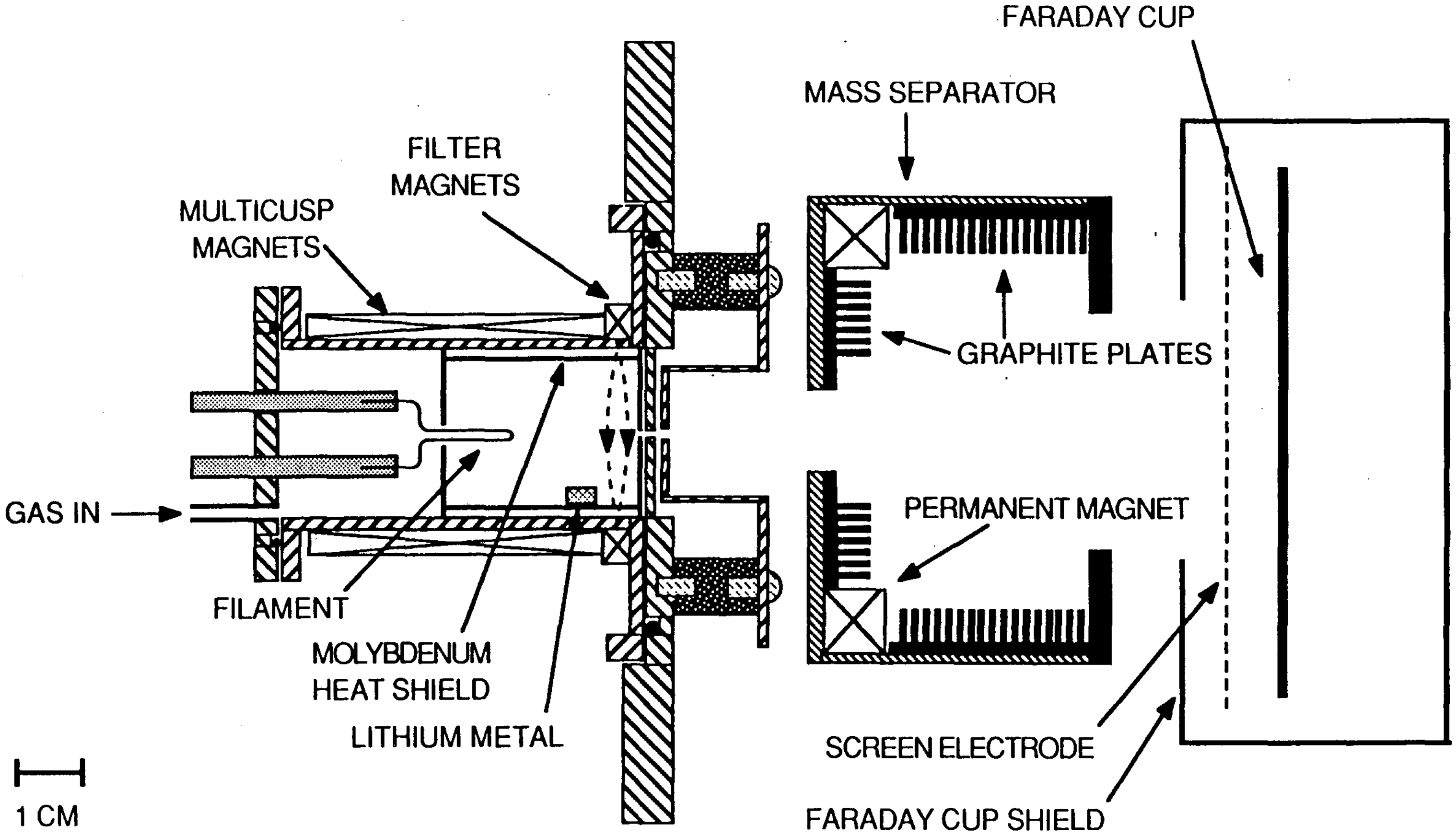

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Fig. 1

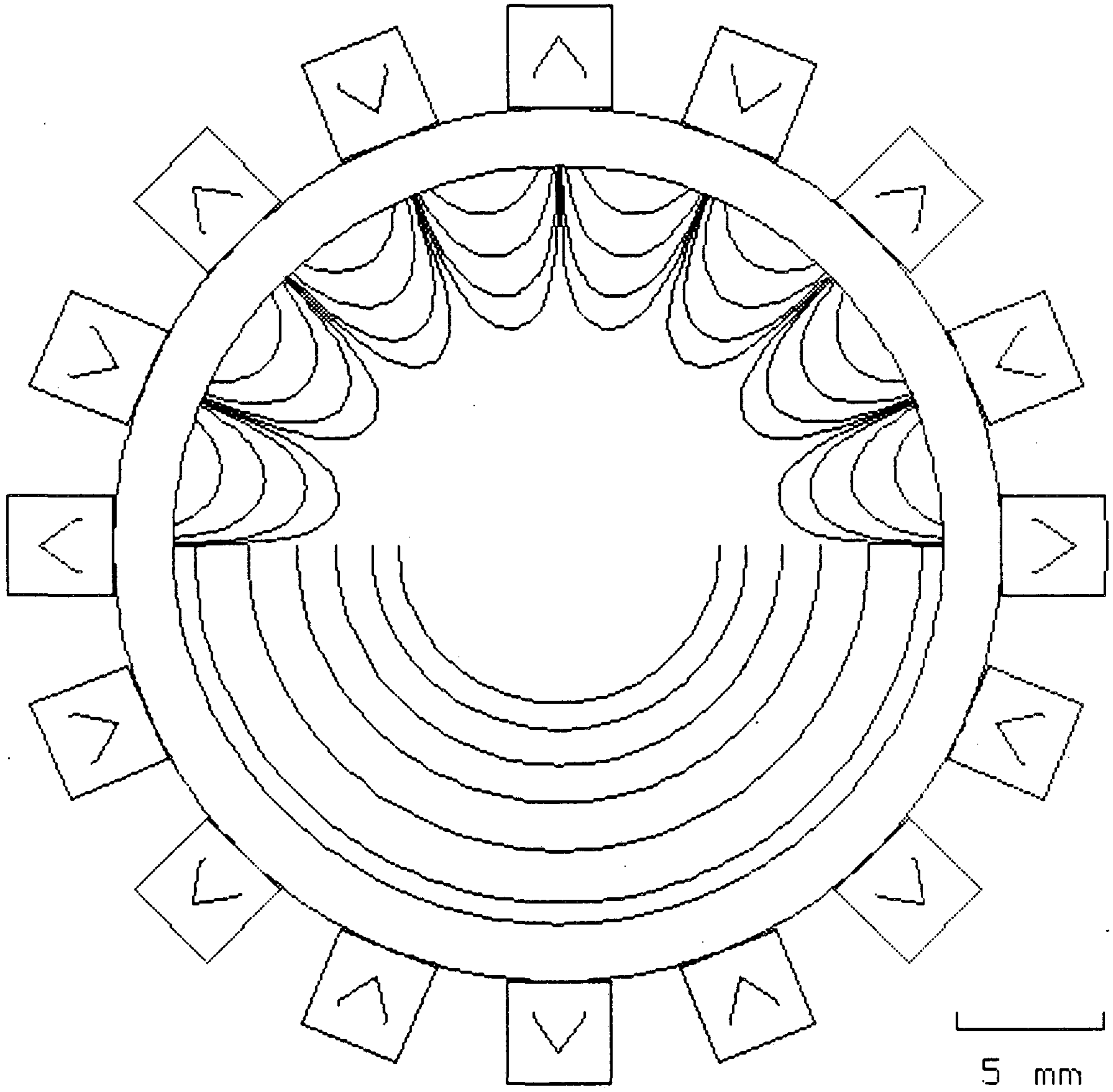

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Fig. 2

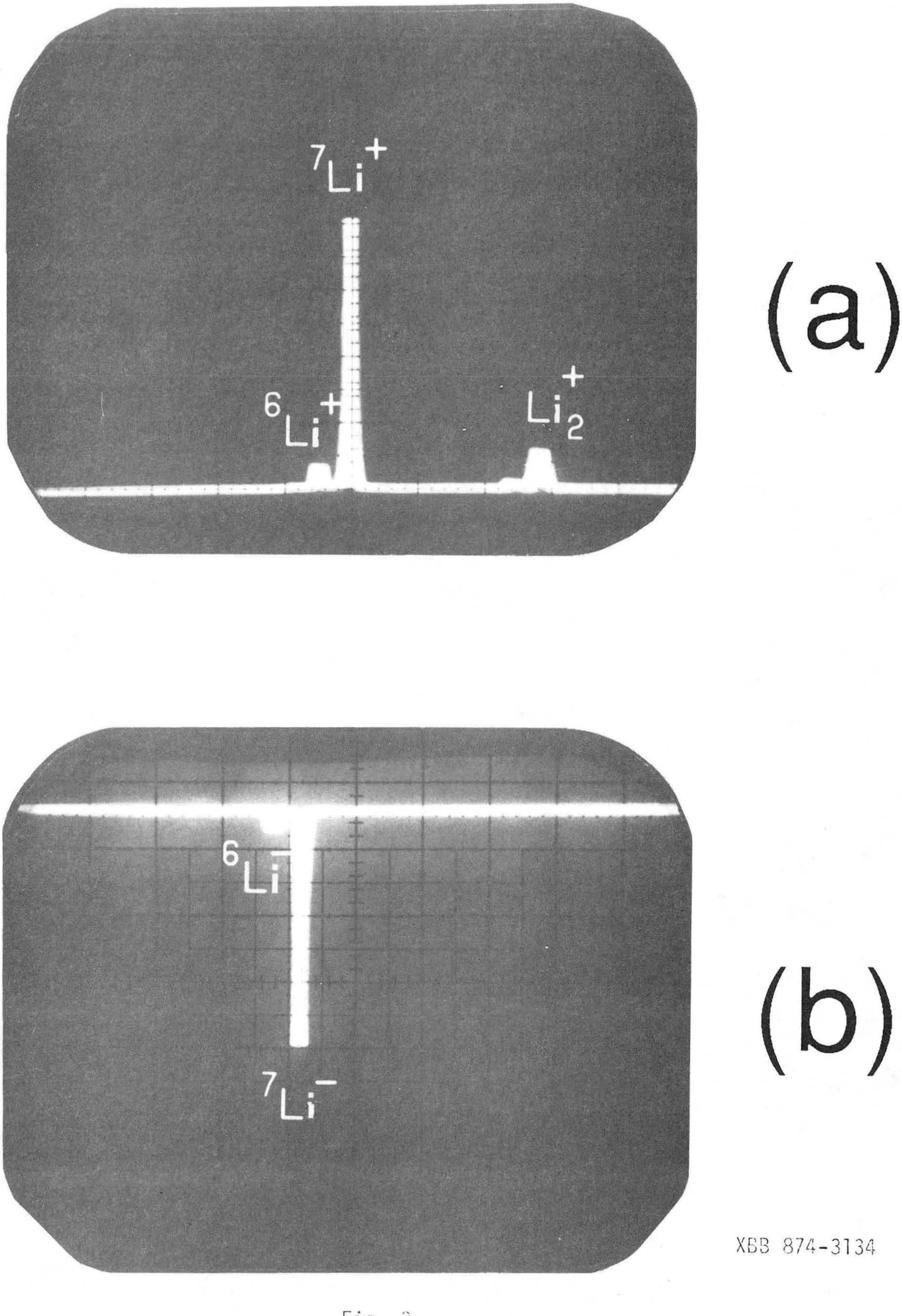

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Fig. 3