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Author
Leung, K.N.

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Lawrence Berkeley Laboratory
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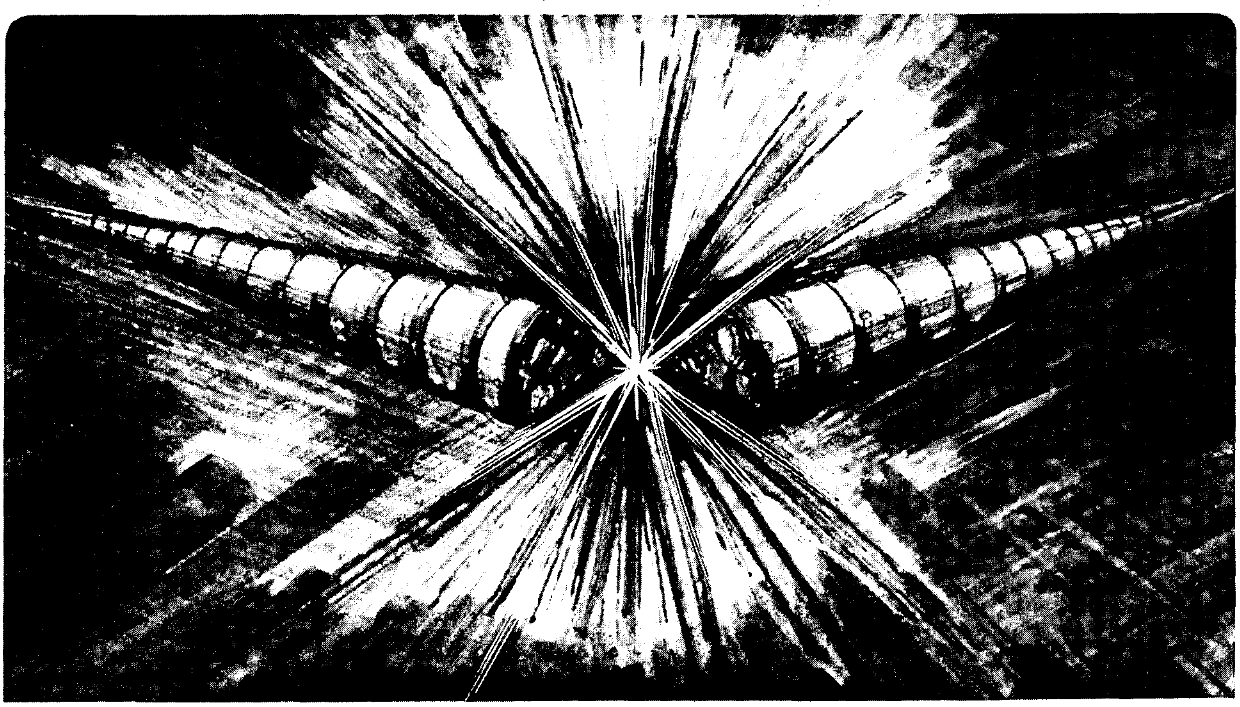

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Large Area Ion Source for Fusion*

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Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

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Neutral beam injection has proved to be a successful heating method for tokamaks as well as for mirror confinement systems.[1,2] Major fusion devices such as the Tokamak Fusion Test Reactor (TFTR), Doublet III, and the Mirror Fusion Test Facility (MFTF-B) in the U. S.; the Joint European Tokamak (JET) in Europe; and the JAERI Torus (JT-60) in Japan will all use high power neutral beams with multisecond pulse durations to heat the reactor plasma. For this purpose, the ion source for the injector should be capable of producing a dense, uniform and quiescent plasma with a high percentage of atomic species. The permanent magnet plasma generator[3] (also known as the multicusp or bucket source) is able to fulfill most of these requirements, and it has been recently developed by various laboratories throughout the world to be used as ion sources for neutral beam injection systems.[4-7]

In this type of source, the surface magnetic field generated by the samarium-cobalt magnets can confine the primary ionizing electrons very efficiently.[8] As a result, the arc and gas efficiencies of these sources are high and hydrogen or dueterium ion beams with atomic species content 75% can be extracted from the source.

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To increase plasma penetration by a neutral beam, a high percentage of H^+ or D^+ is desire. It has been found that atomic species higher than 90% can be obtained if a magnetic filter is incorporated into the multicusp ion source.[9-12] This filter, generated either by inserting small magnets into the source chamber or by installing a pair of dipole magnets on the external surface of the source chamber, provides a limited region of transverse B-field which is strong enough to prevent the primary electrons from reaching the extraction region but is weak enough to allow the plasma to leak through. The absence of energetic electrons will prevent the formation of H_2^+ or D_2^+ in the extraction region and thus enhance the atomic ion species percentage in the extracted beam.

In all fusion experiments, neutral beam injections at multimegawatt power levels will be employed. In order to meet this requirement, almost all the multicusp sources are operated with current densities greater than 200 mA/cm^2 at the extraction plane. To produce such dense plasmas, the tungsten filaments in these sources have limited hours of operation. For the purpose of long pulse or dc operations, new types of cathodes such as directly heated LaB_6 filaments are now being developed.[13] The use of rf plasma generators in advanced neutral beam injection systems is also being explored.[14]

In order to heat plasmas in future fusion reactors and for current drive in tokamaks, multiamperes of very high energy neutral beams will be required.[15] The high neutralization efficiency (60%) of H^- or D^- ions enables them to form atomic beams with energies in excess of 150 keV.[16]

There are different approaches for producing H^- or D^- ions. A large self-extraction H^- source based on surface conversion of positive ions has already been operated successfully to generate a steady-state H^- ion beam current greater than 1 A.[17] Several experiments are now in progress to extract H^- ions directly from a hydrogen discharge plasma.[18-20] This technique of generating H^- ions has the advantage over surface production process in that it requires no cesium and it uses presently developed positive ion sources. Recent experimental results demonstrate that good quality H^- beams with current densities as high as 40 mA/cm^2 can be obtained from a magnetically filtered multicusp source.[21] Extraction systems are now being developed in various laboratories to achieve the best electron suppression with no degeneration of ion optics. Should this succeed, one could operate a large area plasma source to provide H^- ions in much the same manner as is now done to provide positive hydrogen ions for neutral beam systems.

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