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Improvement of Gas
Efficiency of Negative
Ion Sources

J. H. Whealton

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FUSION ENERGY DIVISION

IMPROVEMENT OF GAS EFFICIENCY OF NEGATIVE ION SOURCES

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ABSTRACT

A modification of the currently operating Calutron, magnetron, and modified duoPIGatron negative ion source is proposed. The modification should improve gas efficiency by more than an order of magnitude in the Calutron, by a factor of 5 in the magnetron, and by a factor of 2 in the duoPIGatron.

Negative ion sources are preferred for high velocity neutral beams, since the neutralization of negative ion beams is more readily obtained at these speeds than at those of positive ion beams. Unfortunately, such negative ion sources are in a primitive state of development and have as a dominant, potentially fatal flaw the fact that the flux of gas emanating from the source is around two orders of magnitude greater than the flux of negative ions. For positive ion sources the flux of gas emanating is about equal to the flux of ions; even for positive ion sources the pumping and beam line length problems are not deemed entirely trivial. Therefore, a more gas efficient negative ion source is called for.

A major improvement in the gas efficiency of negative ion sources of the Calutron [1-3] or magnetron [4-6] type was made, and tests on the magnetron [7] type showed an improvement of a factor of 3, from 2% to 6%. Gas efficiency was obtained with a preliminary version, and even higher gas efficiency is presumably obtainable. These two ion sources are similar in that negative ions of both are generated by a cesium-like surface from plasma ion bombardment. These negative ions are accelerated by a sheath in a direction normal to the cesium-like surface, and they exit from a slit aperture after recrossing the plasma, as shown in Fig. 1. This design fails to utilize all the negative ions generated on the cesium surface, allows an abundance of un-ionized gas to escape, and does not significantly hinder source plasma electrons from presenting themselves at the extraction aperture for acceleration (a feature deleterious to the power efficiency of the source). The major improvement [8] as evidenced in Fig. 2(b) is a curved surface that, because of the source plasma sheath acceleration, aims the negative ions produced at this surface toward the slit, producing two dramatic effects. First, all of the surface-produced negative ions can now be utilized. Second, the abundance of negative ions focused at the aperture inhibits, to some extent, the availability of plasma electrons at the extraction region for deleterious acceleration.

The improvement we suggest to this design is shown in Fig. 2(c), in which the slot groove shape shown in Fig. 2(b) is replaced by cylinder-like dents and the slot extraction electrode is replaced by an electrode

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Fig. 1. Conventional extraction for a multislot Calutron or magnetron negative ion source before the invention of Ref. [8].

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Fig. 2. Extraction for a multislotted Calutron or magnetron negative ion source using the invention of Ref. [8] [Fig. 2(b)] and using the present proposal [Fig. 2(c)].

with circular apertures. The improvement is two-fold while still retaining the improvement of Ref. [8] with respect to total negative ion utilization. First, the electrons are repulsed even more strongly at the extraction aperture since the negative ions are even more focused because of the extra focusing dimension. Second, in this case the gas is inhibited from traversing the aperture since the transparency of the extraction electrode is less (without, however, diminishing the passing negative ion current). The gas efficiency could improve by a factor of 16 over that of the flat emitter surface and by a factor of 4 over the cylindrical emitter.

The shape and size of the dents with respect to the apertures will be determined by the magnetic field and the plasma potential with respect to the cesium surface potential.

Another utilization of this improvement obtains for the modified duoPIGatron source [9-11]; the cesium-like surface is shown in Fig. 3. The proposed model for ion evolution from positive to negative does not account for the acceleration of the negative ions through the sheath presented by the plasma surface interface. For an electrode that accounts for this acceleration, inhibits electrons from the potential extraction region, and inhibits gas from the extraction region, we offer the design of Fig. 4, which could improve gas efficiency by a factor of 4 from the flat cesium emitter surface.

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Fig. 3. Cesium surface configuration of the modified duoPIGatron ion source; the ions are imagined to follow a course as illustrated in order to appear as negative ions available for acceleration.

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Fig. 4. Proposed cesium surface configuration of a duoPIGatron negative ion source.

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