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ACCELERATION OF NEGATIVE DEUTERON IONS AND BEAM EXTRACTION IN A CLASSICAL CYCLOTRON

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The acceleration of negative ions provides a very convenient way of beam extraction.

First suggested in 1957[1] and first achieved in 1962[2], it has been since successfully used on several accelerators, such as the machines at UCLA, University of Manitoba, and University of Milan. The 600-MeV TRIUMF cyclotron under construction in Vancouver (Canada) will use both positive and negative ion beams. Along the lines of the work published in the literature we have performed negative deuteron ion operation in the 16-MeV cyclotron of the »Ruđer Bošković« Institute and have extracted the beam by stripping electrons in a thin metallic foil.

The positive ions thus created move in the reversal of curvature of the orbit which brings them out of the magnetic field.

To achieve this goal, we have made several modifications in the cyclotron.

Modification of the ion source. The ion source was developed from the Livingston type. The chimney is made of copper and differs from the one used for positive ions inasmuch that the exit slit is placed not tangentially to the arc column but recessed 1 mm from it. The reason for this modification is the fact that Bohm et al. suggested that negative ions are formed mostly outside the arc column by plasma electrons that have diffused out of the arc column[3]. Test made at the University of Milan cyclotron confirm that (private communication). The hot filament cathode is a 4-mm-diameter tantalum rod, which is thinned in its central part to a $1.5 \cdot 4$ mm strip. The top part of the anode consists of a graphite block, as seen in Fig. 1.

Stopper. The difference in mass between D^+ and D^- ions is only $\frac{2}{1800}$ a. m. u. Resonant conditions for positive and negative ions are, therefore, very close, and it is imperative to stop as much as possible positive ions in

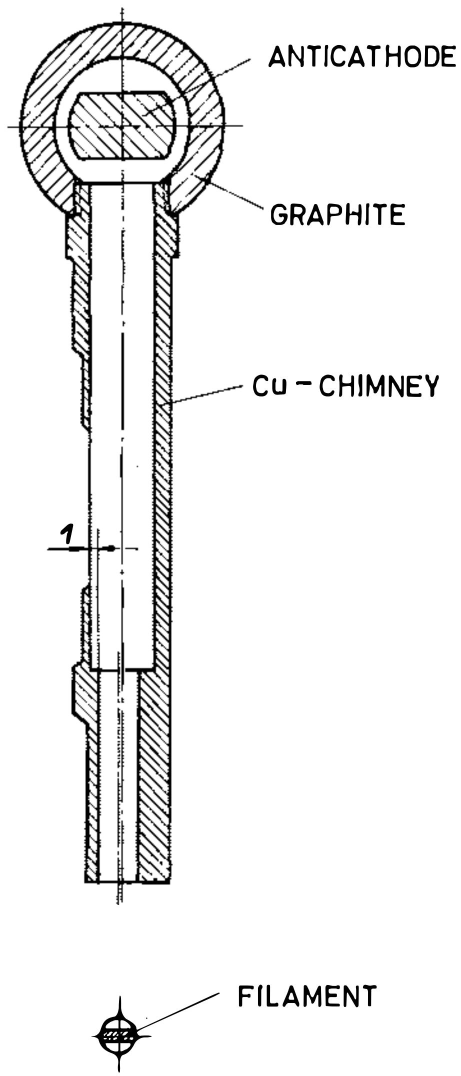

Fig. 1.

the vicinity of the ion source to avoid the burning of the stripper foil. Fig. 2 shows the first few orbits for positive and negative ions for different dee voltages. The position of the graphite stopper is indicated, its length being sufficient to stop positive ions at a dee-to-ground voltage of 85 kV. Fig. 2

depicts theoretical calculations not taking into account the exact electrical field in the vicinity of the ion source. However, calculations are in reasonable agreement with experimental results.

Stripper foil. A 2.5 μm nickel foil was placed at the radius corresponding to 13-MeV deuterons. The foil was 5 mm large, mounted on a Cu holder. A further protection from positive ions which had escaped the stopper was achieved by shielding the target holder with a graphite block on the side of positive ions.

Good vacuum is essential to negative ion operation, since the negative ion recombination rate in poor vacuum rises tremendously. The vacuum in our accelerating chamber was — 10^{-5} mm Hg. Such a vacuum is to be considered

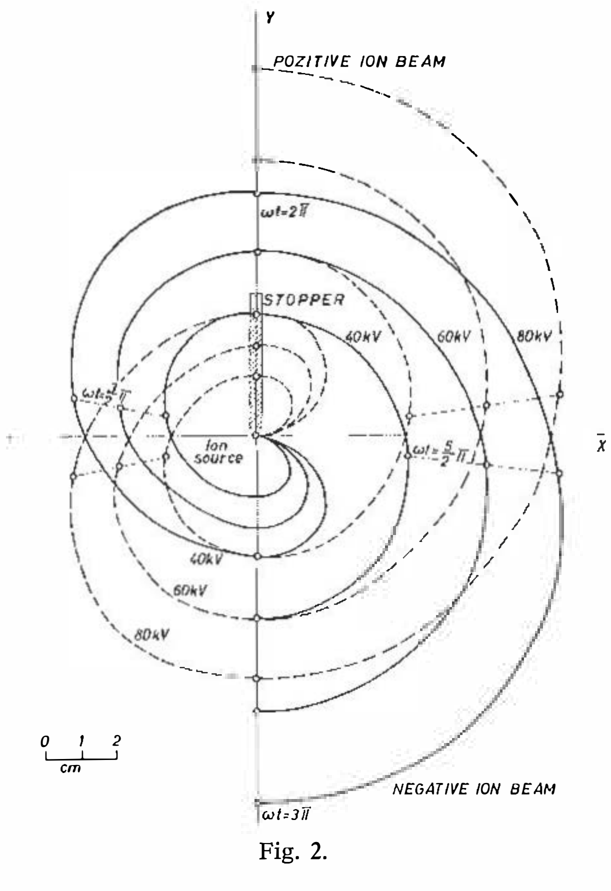

Fig. 2.

bad from the point of view of negative ion operation. It is obvious that the beam current will depend critically upon the dee voltage applied. The higher the voltage the shorter the path the ion travels during acceleration, thus decreasing the probability of recombination. Plans are to place a refrigerated trap on the pumping system, thereby eliminating part of oil and water vapour, which presently enhance the recombination rate.

Deuterium gas was obtained either by electrolysis of heavy water or by using reagent-grade deuterium gas supplied by Carl Roth OHG Karlsruhe, West Germany.

The experiment performed shows that the latter gas is more adequate. It should be mentioned that the use of a palladium leak on the gas line decreases the extractable beam current by a factor of ~ 20.

Using a dee-to-ground voltage of 85 kV we have so far succeeded in extracting a maximum current of 0.7 μA through a lateral window. This current of 0.7 μA was measured by stopping a beam in a block of aluminium outside of the cyclotron chamber. Since this arrangement is not a properly constructed Faraday cup, obviously this reading of 0.7 μA is only a qualitative estimate. However, the actual beam is different by definitely not more than a factor of two.

Acknowledgement

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