OPERATION OF A SHORT PULSE NEGATIVE ION SOURCE

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Abstract

A magnetically filtered multicusp negative hydrogen ion source has been tested on the RFQ-1 preinjector at CERN in anticipation of injection of H^- beams into the LEAR machine. Although the source is remarkably simple in concept, its operation in the short pulse mode (> 10 μs) has proved to be somewhat more complicated due to a long formation time of the negative ions. For a 150 μs long discharge of 230 A, a maximum of 5 mA of H^- has been accelerated to 520 keV in unoptimised conditions.

Introduction

At CERN, a negative ion beam is being developed for a very specific experimental purpose where the accelerator use is only of secondary importance. One of the options retained for the LEAR (Low Energy Antiproton Ring) machine was a co-rotating $\bar{p}/H^-$ mode for the production of the proton/antiproton bound state[1] in flight with Linac 1 acting as a source of the necessary H^- beam. Beams of between 5-10 mA, 0.5-5 μs long would be required.

Self extraction negative ion sources based on surface generation of H^- ions on caeseated surfaces have been used with success by a number of laboratories[2] in particle accelerator applications, but in general, these sources suffer from the disadvantages of low gas efficiency and the presence of caesium vapour. The latter was felt to be a major problem in a multiparticle test accelerator such as Linac 1. Current developments in negative ion source technology have come from attempts to produce clean, gas economic, reliable multimegawatt neutral beam injectors for fusion research. The yield of negative ions directly extracted from large volume low density discharges can be significantly improved by the addition of a magnetic filter. The bias on the plasma electrode (PE) can also influence the yield whilst reducing the extracted electron component[3].

This absence of caesium and a reasonable gas efficiency indicated that a volume production multipole source seemed well suited to the conditions existing in Linac 1. The results presented in this paper will show that, whereas the volume source has given encouraging results, its operation as a pulsed source still requires study.

Early investigations

Some years ago, tests with the 520 kV Cockcroft-Walton preaccelerator using a hollow discharge duoplasmatron (based on the Brookhaven work[4])gave promising results. These tests were repeated when Linac 1 was converted to RFQ preacceleration[5]. The outcome was very disappointing as this preaccelerator was less tolerant of gas consumption and extracted electron current. It was believed at the time that the electron load could be tolerated for short pulses. During these tests it was remarked that the accelerated currents were very unstable and narrow compared with the discharge length (1 μs beam for 10 μs discharge) and data to be presented later point to an explanation.

Experimental Layout

An initial design of the source and extraction geometry was calculated using the program BEAM and is shown as installed in the preinjector in Fig. 1. The overall arrangement of the RFQ injector has already been described[5].

The stainless steel ion source chamber (100 mm Ø and 200 mm long), surrounded by a steel backed permanent magnet decapole, is divided in a ratio of approximately 2:1 by a small permanent magnet dipole. The larger arc chamber contains a standard CERN manufactured oxide cathode[6]. Hydrogen is introduced into this chamber by a commercial flow controller. The front of the smaller extraction chamber is closed by an insulated PE with an extraction aperture of 14 mm. Two permanent magnets are installed close to the aperture to reduce electron drain. The initial 8 mm thick extraction electrode held at +3 kV relative to the source was 3 mm from the PE. The final accelerating gap was 17 mm and the source was held at 50 kV relative to ground. Beam monitoring points were after the preinjector and the RFQ. No further diagnostics could be mounted on the beam line.

Experimental Observations

Initial tests in the laboratory had established discharge current and gas flow parameters similar to those of a proton multipole source. However, the negative ion parameters proved more difficult to find.

During the very first tests, about 1 mA of a narrow unstable beam was detected at the end of the RFQ (520 keV). Little could be done to improve this beam, although it did establish a need for very high discharge currents and a relatively underheated cathode (compared to proton operation). The beam length was independent of the discharge length and not reproduceable.

After the reconfiguration of Linac 1 in 1985 (same RFQ layout), a much longer period allowed a more profound study of the source. The problems noted above again manifested themselves but with reduced beam output. Attempts were made to reduce the PE dipole field but this only increased the electron load. Modification of the extraction geometry to increase the initial extraction field also had little effect.

In the absence of an absolute pressure gauge, the pressure in the plasma chamber could only be estimated from a knowledge of the gas flow and calculated conductances which are temperature dependent. It is known that if the pressure in the plasma chamber is too low, the negative ion yield drops whilst the electron load increases. Reducing the extraction aperture to 5 mm Ø with a thin plate produced a dramatic change in source characteristics. 1.5 mA at 520 keV were measured at the exit of the RFQ for 230 A discharge current (equipment limit) and a gas flow of 3.5 cc/min. Whereas the gas flow and the PE bias had little effect on the accelerated beam, the cathode heating proved to be a very sensitive control of beam intensity. Measurements at the source showed that the optimum cathode conditions gave arc voltages (after the initial peak) in the range 120-150 V (Fig. 2). More remarkably, the beam length corresponded to the discharge length but with long risetime. The current was eventually optimised to 3.5 mA.

The extraction aperture was then increased to 8 mm and with a gas flow scaled to the increased aperture, 5 mA could be obtained at 520 keV for a beam length of

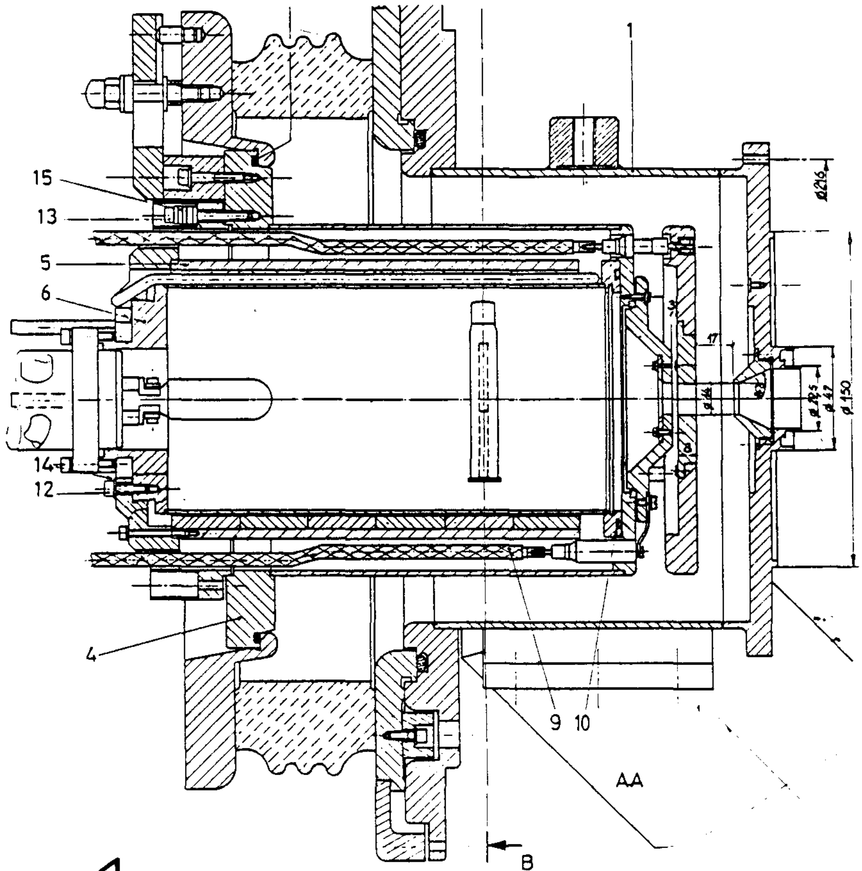

Fig. 1 : Ion source installed in preinjector

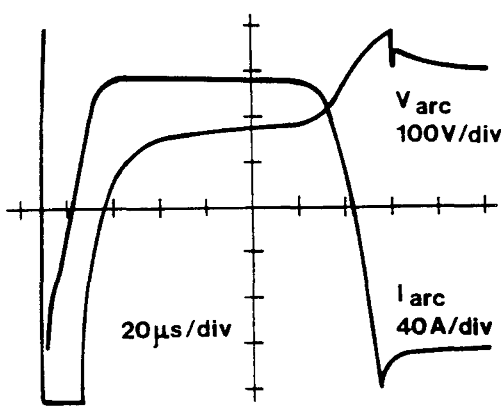

Fig. 2 : Arc voltage and current under optimal conditions.

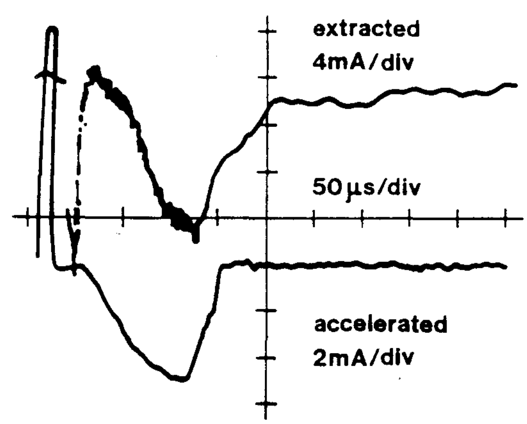

Fig. 3 : Typical beam extracted at 50 kV showing initial electron peak and beam accelerated by the RFQ.

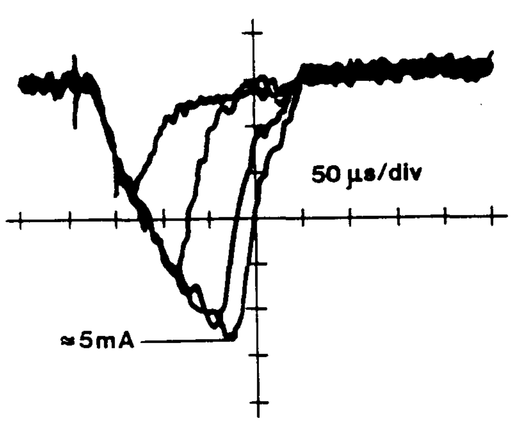

Fig. 4 : Accelerated beam for discharge lengths of 50, 100, 150, 175 uS. Source parameters constant.

125 μs. Under these conditions approximately 12 mA was extracted and accelerated from the source. Fig. 3 shows the extracted beams. Of special note in the extracted beam is the large initial peak which is probably hot electrons generated during the initial turn-on transient whilst the arc voltage falls from around 2.2 kV at ignition to around 200 V at the end of the discharge. The bias on the PE could be either positive or negative over a range of 5 V without noticeable effects on the beam. Under these conditions the total drain on the HT supply was of the order of 200 mA.

With the ion source settings fixed, the amplitude of the extracted and accelerated beam was found to be dependent on the length of the discharge. Fig. 4 shows the accelerated beam for discharges varying from 50 - 175 μs long. It was not possible with the pulser available to investigate if a true plateau had been reached or whether the amplitude would start to decrease. Bad acceleration optics prevented any notable increase in discharge current. Increasing the cathode heating towards proton values caused a progressive loss of ion current whilst reducing the arc voltage towards 80 V.

Conclusions

A volume production multipole negative hydrogen ion source has been made to operate in an accelerator environment as a short pulse source. However, its operation has proved to be much more complicated when compared with a dc source. To date, from a total extracted current of 12 mA, 5 mA have been accelerated to 520 keV. If the extracted current is assumed to be only ions, the electron/ion ratio would be around 16:1. Further investigations will be needed to optimise the filter and to discover its actual location (intended or at the PE magnets). The formation time phenomena will also need study to establish whether this is due to the real formation time of negative ions or due to the decay of hot electrons generated during the source turn-on transient. Equally, both could be present. Better extraction optics will also be needed to improve the transmission from source to RFQ.

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