MULTICUSP H$^-$ ION SOURCE AT KEK

Akira TAKAGI, Yoshiharu MORI, Kiyoshi IKEGAMI, Zen-ei IGARASHI
Chikashi KUBOTA and Sadayoshi FUKUMOTO
National Laboratory for High Energy Physics
Oho-machi, Tsukuba-gun, Ibaraki-ken, 305, Japan

ABSTRACT

A multicusp H$^-$ ion source was built for the charge-exchange multiturn injection project in KEK 500 MeV booster proton synchrotron. More than 20 mA H$^-$ ion beam was extracted from the ion source, 18 mA was injected into the linac and 8.5 mA was accelerated up to 20 MeV. Some results from lifetime test of the ion source are presented.

INTRODUCTION

In order to increase beam intensity of proton synchrotron reducing beam loss at injection, a charge-exchange multiturn injection scheme has been currently used in the various laboratories[1] and at KEK it was also proposed for the 500 MeV booster synchrotron.

For this purpose, a multicusp H$^-$ ionsource[2] has been developed. The ion source was directly installed in the accelerating column of 750 keV preaccelerator just like a duoplasmatron. In the high voltage dome, it is not necessary to use analysing magnet because the components other than the H$^-$ ions included in the beam, electrons are main , are the same order of H$^-$ ion current and beam loading due to the Cockcroft-Walton preaccelerator.

A beam acceleration test was performed in September 1983 and the H$^-$ beam was successfully injected in the booster synchrotron[3,4]. For the long period routine operation of accelerator use, the lifetime test has been carried out to define the failure of this multicusp source.

H$^-$ ION SOURCE

A schematic view of the multicusp H$^-$ ion soruce is shown in Fig. 1. It consists of a cylindrical plasma chamber, a molybdenum converter and a couple of tungsten filament cathode. The plasma chamber is surrounded by 22 pieces of Alnico-9 permanent magnet to confine a plasma efficiently. Each magnet and the converter are cooled by water. H$^-$ ions are produced on the surface of the converter covered with cesium atoms. The surface of the converter is concave to focus the beam in the anode hole. A negative voltage of $- 300 \sim - 500$ V is supplied to it. Cesium is supplied through a small (6 mmϕ) heated stainless steel pipe from a reservoir which is placed at outside of the chamber. The operating temperature of the reservoir is 160 $\sim$ 190°C. We observed some decrease of O$^-$ ions from the source after 5 or 6 hours hydrogen mode conditioning without introducing cesium vapor. By this procedure, the various contaminations in the source, especially attached on the converter surface might be effectively removed.

Typical operating conditions are follows; arc current and voltage are 60 $\sim$ 80 A and 90 $\sim$ 150 V. The pulse duration of the arc is 200 μsec and the repetition rate is 20 Hz at the maximum. Operating hydrogen gas pressure is $3 \sim 7 \times 10^{-4}$ Torr and the gas consumption rate is about 1 atm·cc/min, almost one tenth of that of the duoplasmatron.

The extracted H$^-$ beam current depended largely on the converter voltage and the arc current. Figure 2 shows the variation of the H$^-$ beam current as a function of the converter voltage. The beam current was saturated over the converter voltage of 350 V. The maximum beam current was defined by both of the arc current and the cesium oven temperature for the optimum converter voltage. Figure 3 shows the arc voltage and the H$^-$ beam current as a function of the arc current. The beam current increases linearlly by increasing of the arc current. The maximum value of the H$^-$ ion current was obtained by using of the temperature limited region of the filament cathode emission. The H$^-$ beam current of 25 mA was obtained by the optimum source parameters at the test stand as shown in Fig. 4.

To obain further more intense H$^-$ beam current, we constructed an another multicusp source with Sm-Co permanent magnets. The Sm-Co magnets were prepared to confine a more dense plasma. This source is now being operated at the test stand and the measurement of H$^-$ beam currents and beam emittances will be carried out.

BEAM ACCELERATION

The ion source was directly mounted in the 750 kV accelerating column. The H$^-$ ion beam was accelerated up to 750 keV by a three electrode system, whose total

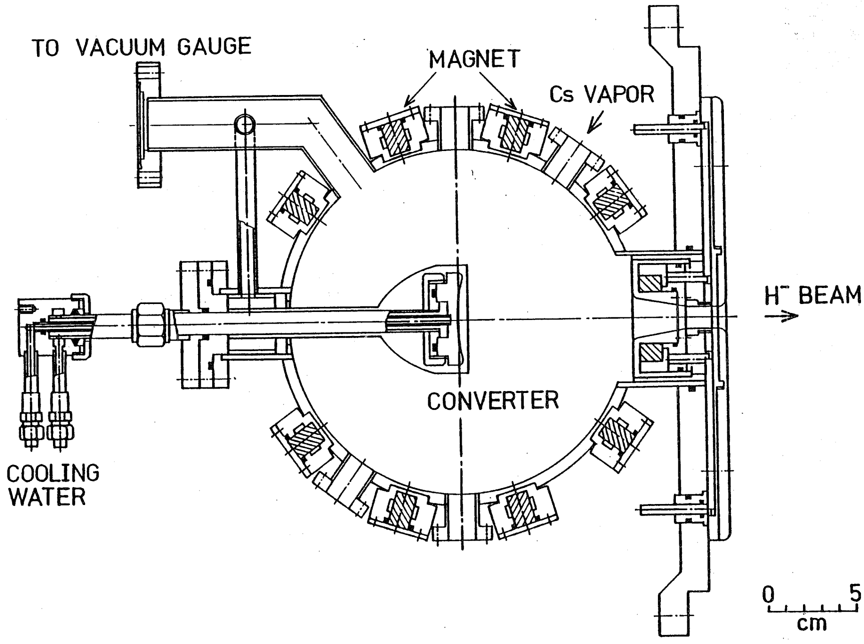

Fig. 1 Schematic view of multicusp H$^-$ ion source.

gap length is 76 cm, focused by quadrupole magnets and injected into the 20 MeV linac. It was hard to measure the H^- beam current just after the acceleration of 750 keV because of the electrons in the beam. However, after passing through four quadrupole magnets, the measured beam was about 20 mA, so it was conceived that more than 20 mA H^- ion beam was extracted from the ion source. The beam emittances were measured at the entrance of the linac. A typical emittance configuration, when the beam current was 11 mA, is shown in Fig. 5. The normalized (= phase space area × $\beta\gamma/\pi$) 95 % emittance was 0.17 cm·mrad. After acceleration by the linac, we have obtained 8.5 mA H^- ion current at the maximum so far. The emittance of 20 MeV beam was almost same as that of 750 keV beam[4]. By changing the duty factor, the beam current changed slightly, however, the operational condition did not change drastically. A new intensity record of the booster beam of 7.13×10^{11} ppp was achieved, whereas the previous one was 6.8×10^{11} ppp.

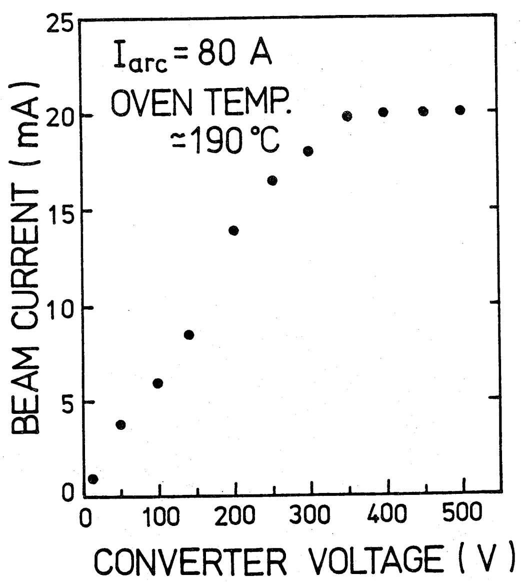

Fig. 2 Variation of converter voltage as a function of arc voltage.

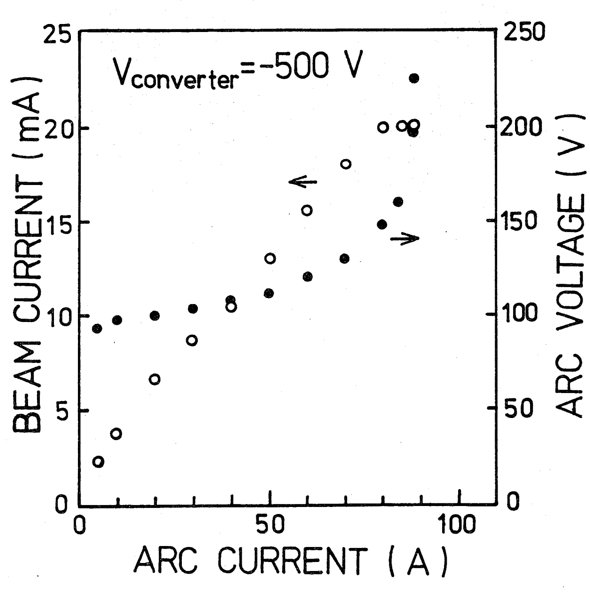

Fig. 3 H^- current and arc voltage as a function of arc current.

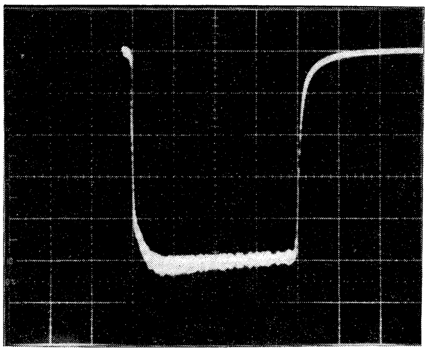

Fig. 4 30 keV H^- ion beam at test stand.
V: 5 mA/div., H: 50 μsec/div.

Typical operating parameters of H^- ion source during the acceleration test ar shown in Table 1.

LIFETIME TESTS

During first acceleration test, the failures of the ion source occurred and were caused by the breaking of a filament wire as shown in Fig. 6. The filaments were made of pure tungsten or thoriated tungsten. The lifetime of the filament was short and beams were not stable for 50 Hz ac heating. The lives of the 1 mm diameter filament were 30 hours or less when heated by the ac current of 55 A whereas the 1.2 mm diameter one lasted more than 100 hours and was not broken during the test run when heated by the dc current of 78 A. The H^- ion current was stable when the filament cathode was heated by dc current.

At the test stand, some tests were carried out to decide the filament lifetime for the long period routine operation.

Two test stands were prepared, one is simple and the ion source is directly mounted to a vacuum vessed on a turbomolecular pump (Fig. 7). The beam current is measured by a Faraday cup. The other is ordinary, equipped with a Faraday cup, a profile monitor and an emittance monitor. The source is in a high voltage dome.

Some tests have been carried out to develop long life cathode of the ion source. The KEK proton synchrotron runs for ten days in routine operation. As the cathode works in temperature-limited condition, directly heated tungsten filaments were tested. They are strong against ion bombardment. The lives were 120 and 190 hours of 1.2 mm in diameter pure tungsten filaments, 70, 76 and 430 hours of 1.5 mm pure tungsten filaments and 150 and 240 hours of 1.6 mm thoriated tungsten filaments. The maximum life of 430 hours was obtained with a lower arc current of 40 A, about a half of the above mentioned typical current. As the arc current is limited by temperature of the filament, a shorter life results from a higher arc current. The scatter of the data are partly due to differencies in operating conditions. These lives are, however, insufficient for routine operation of the KEK synchrotron.

There might be some possibilities to improve the cathode life. One is to use a larger diameter tungsten filament, although it needs more power. The next candidate is a LaB_6 cathode. It is strong against ion bombardment too, so that it can be used in temperature-limited condition. It seems best at present and a test cathode of LaB_6 is being designed. A hollow cathode is also being examined. The arc voltage is supported at the exit of the cathode so that field gradient of the electron emission surface is not high. It might be possible to use a material which is not strong enough against ion bombardment.

The cesium oven with an ampoule of 5 g, has been operated more than 700 hours with supplying cesium.

CONCLUSION

A multicusp H^- ion source was made and mounted to the 750 kV Cockcroft preinjector. It yielded a 750 keV H^- beam of more than 20 mA. Its cathode is made of tungsten filaments and life test is being done on test stands. Although a change from ac heating to dc heating improved its life significantly, lives of test filaments seem somewhat insufficient for routine operation of the KEK synchrotron. Further improvement is being continued.

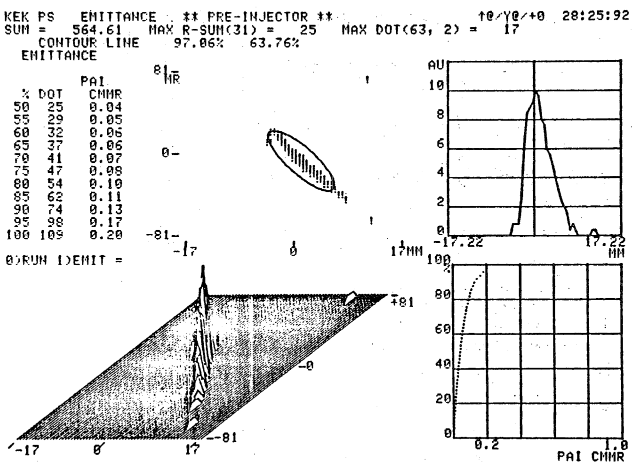

Fig. 5 Emittance of 750 keV H^- ion beam.

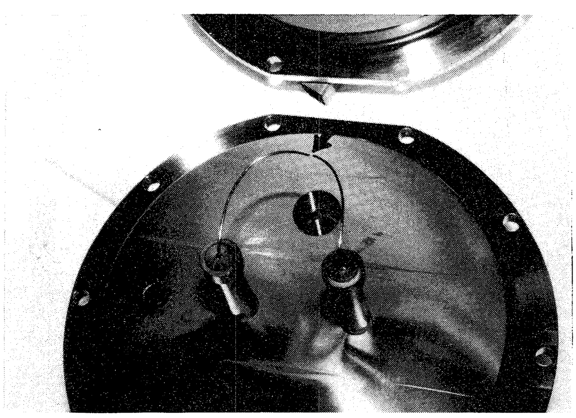

Fig. 6 Filament flange removed after failure. Arrow indicates the point of breaking.

Table 1

Typical operating parameters of multicusp H^- ion soruce

Beam current/energy	20 mA/750 keV
Pulse length	150 μsec
Repetition rate	20 Hz
Extraction voltage	375 kV
Total accelerating gap	76 cm
Length in column	
Arc current/voltage	80-100 A/90-110 V
Filament current/power	155 A/1.4 kW
Hydrogen pressure	3-5 × 10^{-4} Torr
Exit diameter	1.3 cm
Cesium oven temperature	190 °C
Converter voltage	-300 V

18 Oct. 1983

REFERENCES

1) S. Fukumoto, Proc.Int'l Ion Engineering Congress-ISAT'83 & IPAT'83, Kyoto, 663 (1983).
2) R.L. York and Ralph R. Stevens, Jr., IEEE Trans., NS-30, 2705 (1982).
3) A. Takagi et al., AIP Conf. Proc. No.111, 520 (1984).
4) T. Kawakubo et al., KEK Report 84-6.

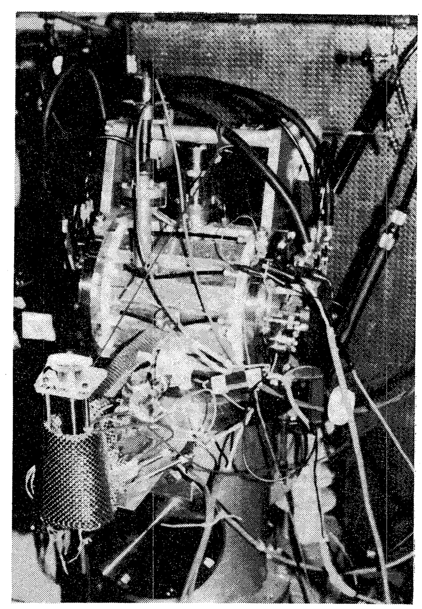

Fig. 7 Multicusp H^- ion source mounted on the simple test stand for its cathode life test.