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KEK MULTICUSP NEGATIVE HYDROGEN ION SOURCE

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Summary

A surface plasma type multicusp H^- ion source has been developed at KEK. Directly heated lanthan hexaboride (LaB_6) filaments have been tested recently. Any serious damages have not been seen after the operation for more than 1,000 hours at the arc current of 20 - 25 A and during the experiment, the H^- ion beam of about 20 mA has been stably extracted. Increasing the arc current to 45 A - 50 A with using large size LaB_6 filaments, we could obtain the H^- beam current of 40 mA.

Introduction

In KEK, a routine operation of charge exchanged multi-turn injection with H^- ion beam for the 500 MeV booster of the 12 GeV proton synchrotron (PS) will start from this June after one year shutdown for the tunneling of TRISTAN ring. A preliminary test for this new injection scheme has been already tried in 1983[1] and a new intensity record of the 500 MeV booster synchrotron has been achieved.

As for H^- ion source, a surface plasma type of multicusp H^- ion source has been used[2,3] and it was mounted directly into the acceleration column of the 750 kV Cockcroft preinjector. The extracted beam was very quiet and stable without any significant plasma oscillations. The normalized 90 % emittance (ε = phase space area × $\beta\gamma/\pi$) of the H^- ion beam, which was measured at the entrance of the linac, was 0.13 cm·mrad. However, there was a problem for the filament lifetime in this ion source and it has to be overcome for long period operation. We have used tungsten filaments whose diameters were 1.2 mm or 1.5 mm so far and they could last only for 200 - 300 hours at the arc current of 30 - 40 A. The 12 GeV PS is used to be operated continuously for ten days and this short lifetime of the tungsten filament is not enough for routine operation.

In LBL, K. Leung et al. have applied lanthan hexaboride (LaB_6) as a material of directly heated filaments for a PIG H^- ion source and a volume extracted multicusp H^+ ion source[4]. They found the

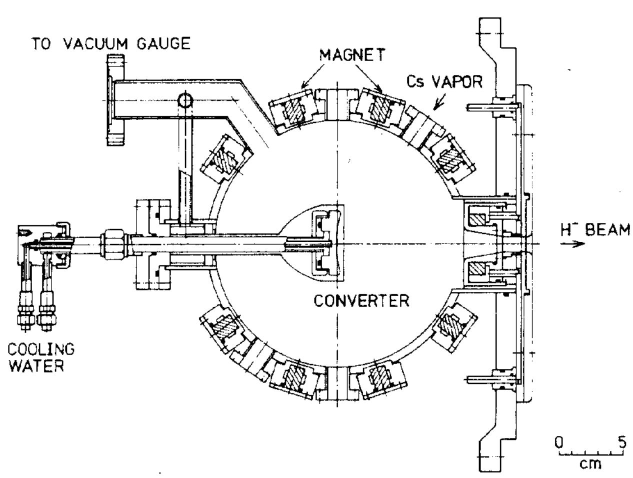

Fig. 1 Schematic setup of multicusp H^- ion source.

LaB_6 filaments had an excellent performance for the operation of these ion sources at high arc current. The work function of LaB_6 is 2.66 eV. This low work function provides a high arc current at a relatively low operating temperature. The normal operaitng temperature of the LaB_6 filaments is about 1500°C, which is almost 1000°C lower than that of the tungsten filaments. This relatively low temperature makes evaporation rate smaller and a long lifetime would be expected. Thus, the filament made of LaB_6 seems to be also very useful for our H^- ion source. We have made a life test of the LaB_6 filament and in a series of experiments, LaB_6 showed very good performance as a filament material of our multicusp H^- ion source.

Ion Source

A schematic setup of the multicusp H^- ion soruce is shown in Fig. 1. The ion source consists of a cylindrical plasma chamber, a molybdenum converter and a couple of filaments. The plasma chamber is made of stainless steel and surrounded by 22 pieces of Alnico-9 permanent magnets. H^- ions are mainly produced at

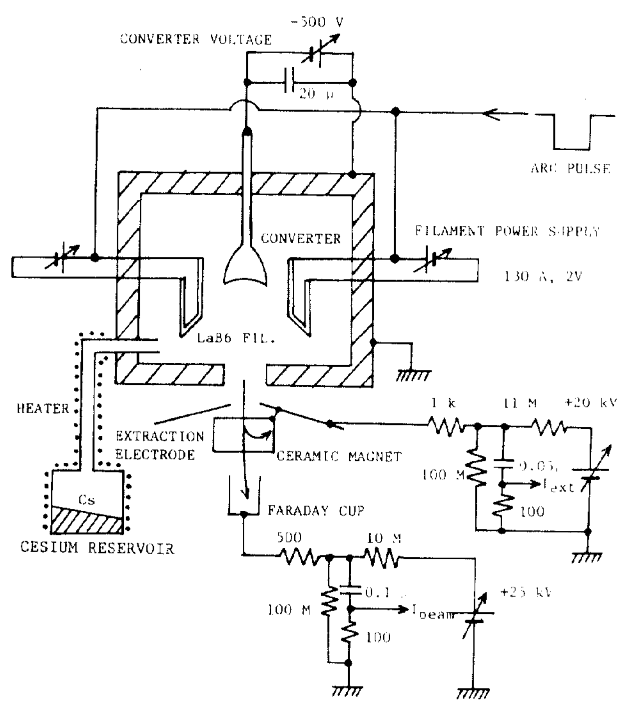

Fig. 2 Schematic diagram of the experimental setup for life test of LaB_6 filament.

the surface of the converter covered with cesium atoms and a negative voltage of - 300 - 500 V is applied to it. Cesium is fed through a heated stainless steel pipe and valve from the reservoir. The ion source is operated in pulse mode. The pulse duration and the repetition rate are 200 μsec. and 20 Hz, respectively. The operating hydrogen gas pressure is about 0.1 Pa and the gas consumption rate is 3 - 5 atm.cc/min.

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Life Test of LaB_6 Filaments

The experiment was performed at a test stand. The multicusp ion source was mounted on the vacuum chamber in which there were a beam extraction electrode and a Faraday cup for the measurement of the beam current. A 1000 ℓ/s turbo-molecular pump was used for evacuating the chamber. Fig. 2 shows the schematic diagram of the experimental set up. Electrons which were extracted with H^- ions were swept away by a ceramic magnet before entering the Faraday Cup. Fig. 3 shows the dimension of the LaB_6 filaments which have been tested in the experiment. We prepared two different types of the filaments; one ((a) in Fig. 3) was used for the operation at low arc current of 20 - 25 A and the other ((b)) for the operation at high arc current of 35 - 40 A. Those filaments are commercially available and can be easily machined. A thin rhenium metal plate was inserted between the filament and the molybdenum supporting electrode to avoid the poisoning effect of boron at high temperature. A couple of filaments were used at the same time and each one was directly heated by its own power supply. By adjusting the filament current separately, we could control the temperature of both filaments and eliminate the temperature difference between them.

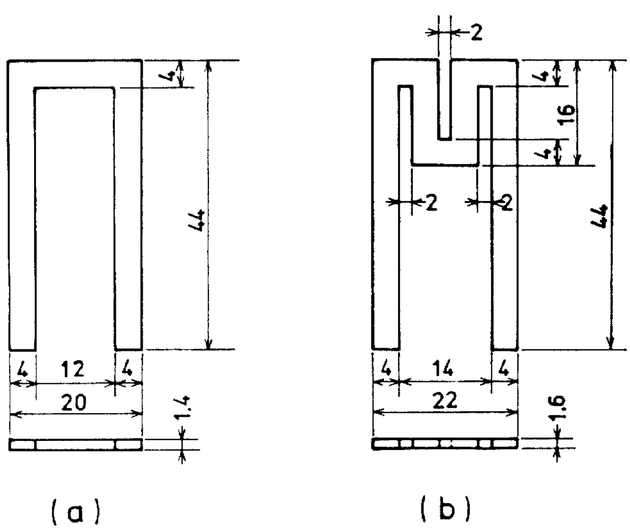
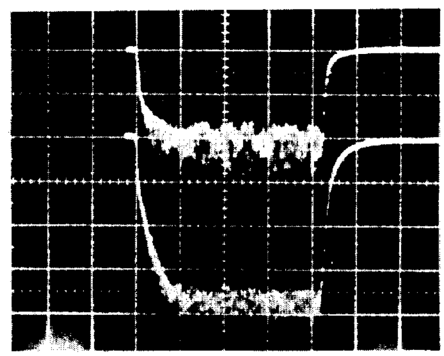


Fig. 3 Shaped LaB_6 filaments.
(a) Hair pin type
(b) Waved type

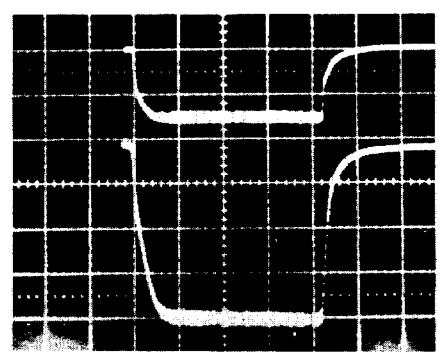
Proceeding to the normal operation, we carried out activation for the filament to remove impurities from the surface of the filament. Firstly, the temperature of the filament was raised to 900 - 1200°C until the vacuum inside the ion source became good and then kept 1650°C for two hours. After the ion source has been operated for four hours with a hydrogen arc mode at the arc current of about 20 A, the cesium reservoir was heated up to 150 - 160°C. Initially, the beam was very noisy as shown in Fig. 4(a), however, after 40 hours the beam became very quiet and stable as shown in Fig. 4(b). It was probably due to the fact that the impurities like O^- ions which might largely included in the extracted beam at the beginning have been decreased. The H^- ion beam current was increased to 20 mA by optimizing the temperature of the cesium reservoir and hydrogen gas pressure. In this condition, the experiment has been continued for more than 900 hours. Parameters of the ion source and beam configuration in the normal operation are shown in Table 1 and Fig. 5, respectively. The electron emission efficiency of the filament has been improved gradually and finally the arc current of 25 A was easily obtained even at the temperature of 1400°C, which was almost 150°C lower than that of the initial operation.

The extracted beam current was rather sensitive for the temperature of the cesium reservoir compared with the case of using tungsten filaments. It was very important to control the temperature of the reservoir within a few degrees for stable operation.

Fig. 6 shows the measured H^- ion beam currents and arc voltages as a function of the arc currents.



(a) before activation
U: 50 mA/div., L: 2 mA/div., H: 50 μs/div.



(b) after activation
U: 50 mA/div., L: 2 mA/div., H: 50 μs/div.

Fig. 4 Configurations of extraction electrode current (upper trace) and H^- ion beam current (lower trace) measured before and after activation.

When we used the different type of the filament ((b) in Fig. 3), we could obtain the H^- ion beam of 40 mA at the arc current of 45 - 50 A.

After passing 1022 hours, we opened the ion source to examine the filaments. The reduction of the thickness was only 6.5 % at the center part of each filament. However, the surface of the both filaments facing to the converter was covered by gray colored material. Examining the surface of the filaments with SEM (Scanning Electron Microscope), we found it was molybdenum which was sputtered from the converter as shown in Fig. 7. These coatings of molybdenum on the surface might cause the reduction in the electron emission efficiency of the filament after long period operation.

Conclusion

In a series of experiment, we found that LaB_6 was a very useful material for the filament of the surface plasma type multicusp H^- ion source. Especially, the evaporation rate seemed to be much smaller than that of the tungsten filament and the long period operation of more than 1000 hours has been achieved. The beam current of 20 mA was obtained at the relatively low arc current (20 - 24 A) compared with the tungsten filament. The beam intensity was very sensitive for the temperature of the cesium reservoir and it seems to be essential to control its temperature carefully for stable operation. The surface of the filament was eventually covered by molybdenum sputtered from the converter. This problem must be overcome in future.

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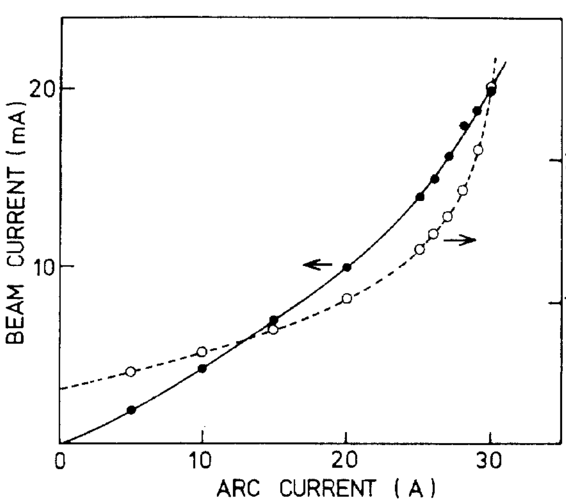

Fig. 6 Measured H^- ion beam currents and arc voltages as a function of arc current.

Table 1

Parameters of ion source in normal operation

Arc current	29 A
Arc voltage	173 V
Pulse duration	200 μsec.
Repetition rate	20 Hz
Converter voltage	- 498 V
Hydrogen gas flow rate	8.9 atm.cc/min.
Cesium reservoir temperature	149 °C
Filament current	R: 130 A, L: 130 A
Filament temperature	R: 1380 °C, L: 1420 °C
H^- beam current	21 mA
Electron beam current	∿ 90 mA

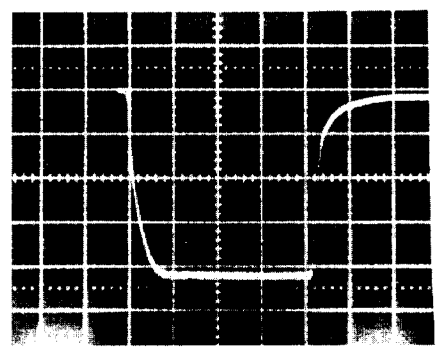

Fig. 5 H^- ion beam configuration in normal operation. V: 5 mA/div., H: 50 μsec/div.

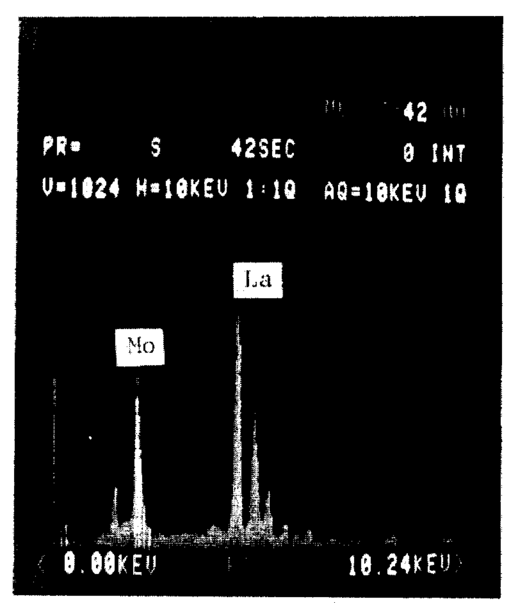

Fig. 7 Surface analysis by SEM for LaB_6 filament which has been used for 1,000 hours.