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RECENT PROGRESS ON THE CUSP H^- ION SOURCE AT KEK

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ABSTRACT

A cusp H^- ion source has been operated at the 12-GeV proton synchrotron at KEK. The ion source is pulsed (200 μsec × 20 Hz) and LaB_6 cathodes resulted in stable operation.

INTRODUCTION

In order to increase the beam intensity of the 500 MeV booster and the 12-GeV main ring at KEK, charge-exchange multi-turn injection with an H^- ion beam at the entrance of the booster synchrotron has been used since June 1985. A new intensity record of 1.5×10^{12} ppp at the booster has been recorded.[1]

A surface-plasma type of cusp-field H^- ion source has been developed for this purpose since 1983. Previously, we tried to use a magnetron type of H^- ion source. However, it had a serious stability problem at the relatively high duty factory of ∿ 0.5 %. The cusp H^- ion source was originally developed at LAMPF[2], based on the H^- ion source developed at LBL for their fusion project.[3]

The H^- ion source at KEK was mounted directly into the accelerating column of the 750 kV Cockcroft-Walton preinjector and provided stable 15 - 20 mA beams with a normalized 90 % emittance (ε = phase area × βγ) of 1.8 - 2.2 mm·mrad to the linac. The beam extracted from the source was very quiet without any significant plasma oscillation. This stable operation was mainly the result of the long lifetime of the hot cathodes. Multicrystalline lanthanum hexaboride (LaB_6) filaments, which have been developed for cathodes of the ion source since 1984, operate at a relatively low temperature, 1450°C. Even after continuous operation for 2600 hours, only a slight reduction in the thickness was observed. We found that LaB_6 filaments showed very good performance when used as the cathode of the cusp H^- ion source.

OPERATION OF THE ION SOURCE

The setup of the cusp H^- ion source is shown schematically in Fig. 1. The ion source consists of a cylindrical plasma chamber, a molybdenum converter and two LaB_6 filaments. The operating characteristics of the ion source are summarized in Table 1.

Table 1 Operating parameters of the H^- ion source

Arc Current	∿ 30 A
Arc Voltage	100 - 150 V
Filament Current	130 - 140 A
Required Electric Power for Two Filaments	600 - 700 W
Filament Temperature	1400°C
H_2 Gas Flowing Rate	5 - 7 atom·cc/min
Converter Voltage	- 500°C
C_s reservoir Temperature	∿ 155°C
C_s Consumption Rate	< 1 mg/hr
Pulse Width	200 μsec
Repetition Rate	20 Hz
Anode Hole Diameter	18 mmϕ

The beam shape extracted from the ion source is shown in Fig. 2. As can be seen from this figure, the H^- ion beam is stable and quiet. However, the beam intensity is rather sensitive to the temperature of the cesium reservoir. It was very important to control the temperature within a few degrees centigrade for stable operation. This differs from the case of using tungsten filaments and probably is due to the rather low working temperature of the LaB_6 filaments. The condition of the cesium coating on the converter is affected by the temperature at the surface of the converter, which is heated by radiation from the filaments. The low temperature also helps to reduce the cesium consumption rate, which is surprisingly low compared with the case of using tungsten filaments.

The emittance of the beam at the entrance of the linac is shown in Fig. 3. The normalized 90 % emittance is about 1.8 - 2.1 mm·mrad.

The hydrogen flowing rate is 5 - 7 atm·cc/min and the gas pressure in the ion source is about 8×10^{-4} Torr. The ion source is installed directly to the accelerating column and is evacuated together with the beam-transport line by four turbomolecular pumps (2 × 650 ℓ/s + 1500 ℓ/s + 1000 ℓ/s). The pressure in the column is about 1×10^{-5} Torr and 15 - 20 % of the H^- beam is lost by change stripping during passage through the beam line.

The ion source is installed directly to the acceleration column. This had led to worries that cesium contamination would cause frequent sparking in the column. In actual operation, the sparking rate was about 0.5 ∿ 1 times per one hour. This is not so serious at the moment, although high voltage pre-conditioning of the acceleration column is necessary for stable operation.

LaB_6 CATHODE

One of the problems with an ion source using hot cathodes is the lifetime of the filament. For this type of cusp-field ion source, tungsten filaments have been commonly used so far, although there are problems with long period operation. Leung et al. used directly heated LaB_6 filaments for a PIG H^- ion source and a multicusp H^+ ion source[3]. They found that LaB_6 filaments operated well at high arc currents. The work function of LaB_6 is about 2.66 eV, making possible operation of the filaments at 1450°C - 1500°C[4]. However, it was unclear whether LaB_6 filaments could be used because a large amount of cesium is present in the plasma. Since lanthanum hexaboride reacts with active species, for example oxygen and chlorine, it was predicted that the filament might be damaged by cesium in the ion source.

In order to clarify these points, we tested the LaB_6 filament. The shape and dimension of the commercially available filaments used in the experiments are shown in Fig. 4. A thin rhenium metal plate was placed between the filament and the molybdenum supporting electrode to avoid the poisoning effect of boron at high temperature. Two filaments were used at the same time. Each one was heated directly by its own power supply so as to control the temperature separately. The temperature of the filaments was first raised to 1650°C for activation, which was very important to get high arc current at lower temperature. Sometimes the beam was noisy at the beginning of the discharge, but after operating 40 - 50 hours the beam became very quiet. The noise was probably due to impurities in the extracted beam, for example, O^- ions.

After 1000 hours of operation, the efficiency of electron emission from the filaments was rather improved and an arc current of 25 - 30 A was easily obtained at a temperature of 1400°C. However, near 2000 hours the arc voltage began to increase gradually and it was necessary to increase the temperature of the filaments to 1450 - 1500°C. No serious problems have occurred on the LaB_6 up to 2500 operating hours, which is almost half of the total operating time of the machine in one year.

In the operation from 1985, we met several problems on the ion source: (1) The cooling water for the ion source chamber was interrpted by the rust from Alnico magnets. (2) The vacuum seal of molybdenum converter was damaged after about 10000 hours operation. It might be due to the oxidization effect of molybdenum with the purified water.

When we opened the ion source after long period operation, we found a grey coloured coating on the filament, especially on the surface facing the converter. By SEM examination the coating was found to be molybdenum, which was sputtered from the converter, as shown in Fig. 5. The reduction in the efficiency of the electron emission after 2000 hours operation was probably caused by this coating, not by cesium.

CONCLUSION

A surface-plasma type of cusp H^- ion source has been operated at the KEK 12-GeV synchrotron since June 1985 and has delivered stable beams of 15 - 20 mA to the linac. The stable operation is mainly due to the use of LaB_6 filaments. The lifetime of the filament exceeds 2500 hours and the relatively low temperature also helps to reduce the consumption rate of cesium.

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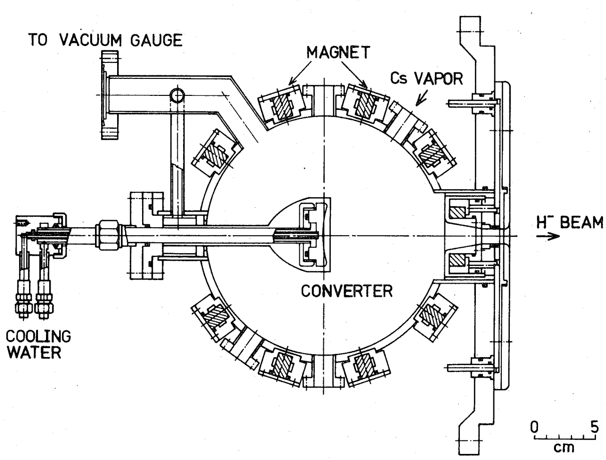

Fig. 1 Schematic setup of cusp H^- ion source.

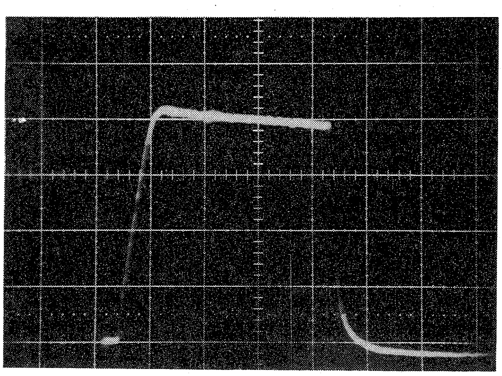

Fig. 2 Beam shape of H^- ion beam.

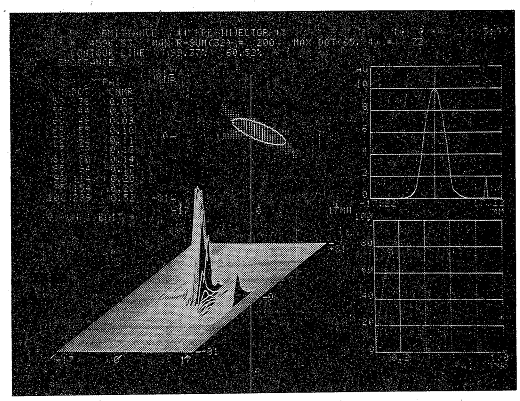

Fig. 3 Emittance of 750 keV H^- beam.

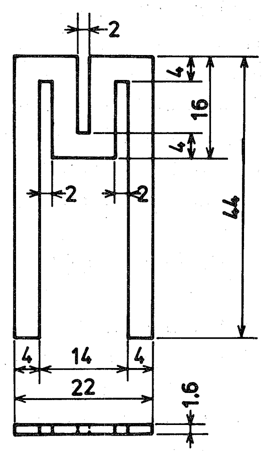

Fig. 4 Shape of LaB_6 filament.

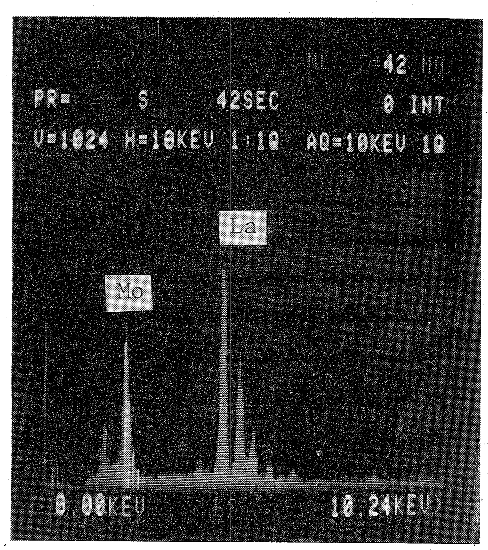

Fig. 5 Surface analysis by SEM.