2p1-5

RF Beam Chopping in a Surface-Plasma Type Negative Ion Source

K. Shinto*A. Takagi, M. Kinsho, K. Ikegami,
Z. Igarashi, S. Machida, M Yoshii, Y. Mori†
National Laboratory for High Energy Physics (KEK)
1-1 Oho, Tsukuba, Ibaraki 305, JAPAN

Abstract

A direct fast chopped beam extracted from a surface-plasma H^- ion source is proposed and a preliminary test has been examined. The converter bias voltage is modulated by rf pulses and the extracted H^- beam is observed. The direct fast chopped H^- beam extracted from the ion source has a good response to the modulation of the converter bias voltage as expected. The chopped H^- beam extracted by this method has been injected into the 500 MeV booster synchrotron at KEK-PS.

1 Introduction

Recently, the increase of the beam intensity is more desired at 12 GeV proton synchrotron in KEK(KEK-PS). One of the difficulties to increase the beam intensity is the beam loss at the beam injection from the linac to the booster synchrotron. In order to eliminate the beam loss at the beam injection, the fast chopped beam synchronized with the rf frequency of the booster synchrotron is required.

The fast beam choppers such as electrostatic deflection devices have been developed and successfully achieved. However the space charge neutralization is distracted, and then the beam loss and the emittance growth become severe in this device. Therefore, it would be ideal that the fast beam chopping can be achieved the H^- formation in the ion source. Some new methods are attempted to make the fast chopped beam in the ion source. For example, there are two methods to make the fast chopped beam by applying the pulsed high voltage at the collar electrode in the PIG type H^- ion source[1] and at the plasma electrode in the volume-production-type H^- ion source[2].

At KEK-PS, a surface-plasma type H^- ion source(BLAKE)[3][4][5] is used for the H^- beam formation. In this ion source, the negative ions are produced by the interaction between the positive ions in the plasma and the metal surface called converter that is shielded from plasma. The converter bias voltage is modulated by the synchronized pulses with the rf frequency of the booster synchrotron. The direct fast chopped H^- beam is produced by changing the H^- production efficiency.

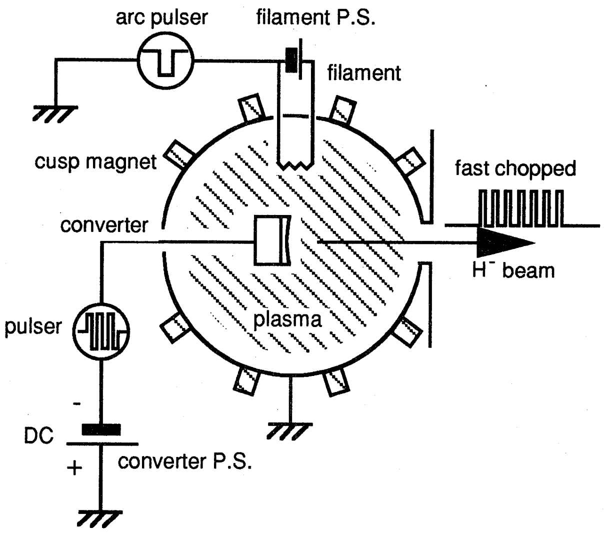

Fig.1: The schematic drawing of the surface-plasma H^- ion source.

In this paper, a new method of the fast beam chopping in the surface-plasma H^- ion source at KEK and preliminary results from the direct fast H^- beam chopping are presented.

2 Experimental setup

Schematic drawing of a surface-plasma type H^- ion source used in this experiment is shown in Fig. 1. Permanent magnets surrounding a plasma chamber are used to confine the plasma by cusp magnetic field. The hydrogen plasma is produced by the electron emission from a couple of LaB_6 filaments. To enhance the H^- beam, the work function of the converter must be lowered. Cs vapor is introduced into the plasma chamber and

*The Graduate University for Advanced Studies, 1-1 Oho, Tsukuba, Ibaraki 305, JAPAN
†Institute for Nuclear Study, University of Tokyo, 3-2-1 Midori-cho, Tanashi, Tokyo 188, JAPAN

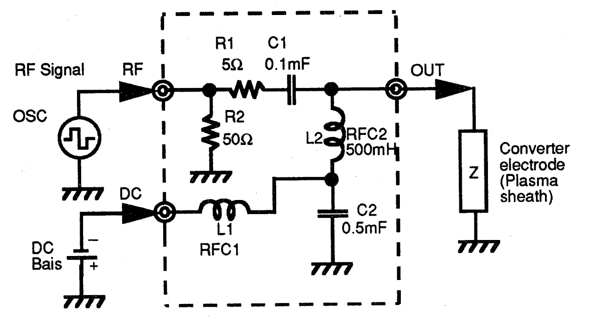

Fig.2: The circuit diagram of the rf modulated power supply for the converter.

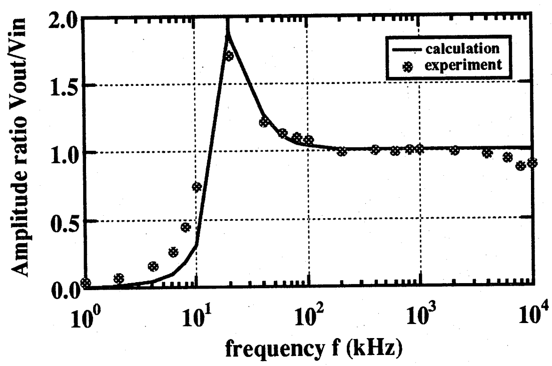

Fig.3: The characteristic of the ratio of the output voltage for input voltage as a function of the rf frequency.

the thin layer of Cs atom is formed onto the converter surface. H^- ion is produced by the interaction between the plasma and the converter surface. The direct fast chopped H^- beam is produced by changing the efficiency of H^- formation following the frequently changed voltage of the converter bias. The extracted H^- beam is accelerated up to 750 keV by Cockcroft-Walton type pre-accelerator and up to 40 MeV by the linac. The frequency of the direct chopped H^- beam is synchronized with that of the rf cavity in the 500 MeV booster synchrotron. Therefore by injecting a chopped H^- beam into each rf bucket, the beam loss caused by the leak of the rf bucket is decreased in principle.

3 Result and discussion

3.1 Production of direct fast chopped H^- beam

The circuit diagram of the rf modulated power supply for the converter is shown in Fig. 2. The converter bias is modulated with the high voltage pulse triggered by the clock pulse of rf frequency of the booster synchrotron. The characteristic of the output voltage for the input voltage of the matching circuit as a function of the rf frequency is shown in Fig. 3. In the region of this experiment (about 2.2 MHz), the matching circuit is designed to make the unique ratio of input voltage to output voltage and not to cause any resonance. The converter is shielded from the plasma by the ion sheath. However the ion sheath is broken by applying the rf voltage beyond the ion-plasma frequency. The ion-plasma frequency, ω_i, is given by,

$$\omega_i = \sqrt{\frac{Z^2 e^2 n_i}{\epsilon_0 m_i}}, \qquad (1)$$

where n_i is the ion density in the plasma. In this ion source, the ion density seems to be about 1×10^{12} (cm^{-3}). The ion-plasma frequency is estimated about 200 MHz. The frequency of modulated voltage for the direct fast beam chopping is about 2.2 MHz which is a negligible value from the ion-plasma frequency. The H^- ion source is operated in pulse mode (200 μsec $\times$ 20 Hz) and the fast chopped H^- beam produced from the ion source is accelerated up to 30 keV at the test stand. The H^- production efficiency was changed by the modulated voltage of converter bias with this circuit, and the direct fast chopped H^- beam was produced successfully.

3.2 Acceleration of the direct fast chopped H^- beam

The power supply for the rf modulation of converter bias is installed in the high voltage station of the Cockcroft-Walton type pre-accelerator. A direct fast chopped H^- beam extracted from the ion source is accelerated up to 750 keV, injected into the 40 MeV linac and then injected into the 500 MeV booster synchrotron of the KEK-PS. The wave form of the direct fast chopped H^- beam measured by the Faraday cup after the 40 MeV linac is shown in Fig. 4. About 94% of the maximum H^- beam current is suppressed by the modulation of converter bias voltage[6].

3.3 Longitudinal emittance of the direct fast chopped H^- beam in the booster synchrotron

The direct fast chopped H^- beam is accelerated at the linac and injected into the booster synchrotron. The wave form of each bunched H^-

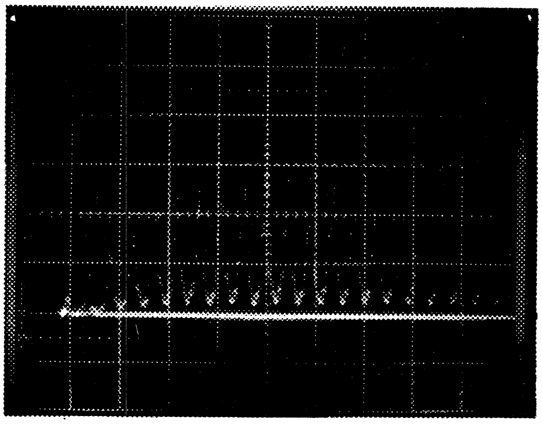

Fig.4: An example of the waveform of the fast chopped H^- beam measured by the Faraday cup at 40 MeV beam line. (vertical axis:2 mA/div., horizontal axis:1 μsec/div.) About 94% of the maximum H^- beam current is suppressed by the converter bias modulation.

beam is observed during the accelerating period in the booster synchrotron, and the bunch length including 90% of the bunch height is measured. The longitudinal emittance is derived from the bunch length of each bunch in the direct fast chopped H^- beam injected into the booster synchrotron. From the phase equation[7], the longitudinal emittance, ϵ_l, is given by,

$$\epsilon_l = \Delta E \cdot \frac{\tau}{2}, \qquad (2)$$

where ΔE, τ are the energy spread for the energy of the synchronous particle and the bunch length of 90% of the bunch height, respectively. The longitudinal emittance as a function of the time delay from the particle injection is shown in Fig. 5. The particle number injected into the booster make to be almost equal in each experiment; about 4×10^{11}ppp. In non-chopped H^- beam directly from the ion source, the beam intensity is decreased by the carbon mesh. The longitudinal emittance with the direct fast chopped H^- beam is almost equal to that without chopped H^- beam directly from the ion source. Using the direct chopped H^- beam, the beam loss of the leak from the rf bucket could be suppressed by a good matching between rf bucket and linac beam. From this figure, the longitudinal emittance depends upon the amplitude of the rf voltage, nevertheless the particle number is equal in each experiment.

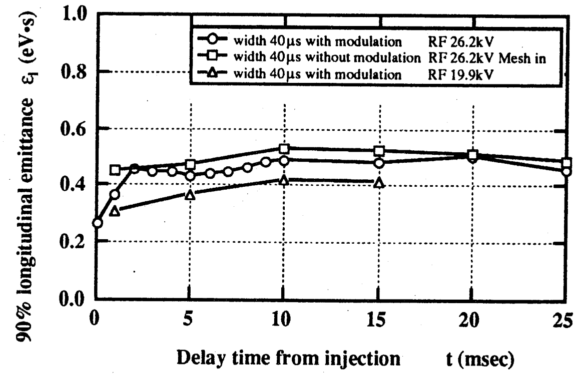

Fig.5: The longitudinal emittace as a function of the injection time.

4 Summary

The direct fast chopped H^- beam is produced from the ion source and injected into the 500 MeV booster synchrotron of the KEK-PS. And it is confimed that the longitudinal emittance depends upon the amplitude of the rf bucket.

The authors would like to thank Prof. Yamane and PS group for valuable comments.

References

[1] J. M. Brennan, L. Ahrens, J. Alessi, J. Brodwski, J. Kats and W. van Asselt, Proc. of the 1989 IEEE Particle Accelerator Conference, Chicago, pp.1154-1156.

[2] R. L. York, D. Tupa, D. R. Swenson and R. Damjanovich, Proc. of 1993 IEEE Particle Accelerator Conference, Washington, pp.3175-3177.

[3] K. W. Ehlers and K. N. Leung, Rev. Sci. Instrum., **51**, pp721-727(1980).

[4] R. L. York and R. R. Stevens, Jr., AIP Conf. Proc. No. 111, pp.410-417(1984).

[5] Y. Mori,A. Takagi, K. Ikegami and S. Fukumoto, AIP Conf. Proc. No. 158, pp378-383(1986).

[6] K. Shinto, A. Takagi, M. Kinsho, K. Ikegami, Z. Igarashi, S. Machida, M. Yoshii and Y. Mori, Submitted to Proc. of 1995 IEEE Particle Accelerator Conference, Dallas.

[7] J. L. Duff, Cern Accelerator School General Accelerator Physics (CERN 85-19), pp.125-143.