DIRECT FAST BEAM CHOPPING OF H^- ION BEAM IN THE SURFACE-PLASMA H^- ION SOURCE

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Abstract

A fast beam chopping directly in a surface-plasma H^- ion source was proposed and a preliminary test has been examined. The converter bias voltage is modulated and the extracted H^- beam is observed. The direct fast chopped H^- beam extracted from the ion source responds to the modulated converter bias voltage as expected. The extracted beam using this method has been accelerated by the 40 MeV linac.

I. Introduction

Recently, the increase of the beam intensity is more desired at 12 GeV proton synchrotron in KEK(KEK-PS)[1]. 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.

Although the fast beam choppers such as electrostatic deflection devices have been developed and successfully achieved, the serious problems have arisen in actual operation. Because of the destruction of the space charge neutralization, the beam loss and the emittance growth become severe. In the case of the negative ion beam, the neutralizing particles are the positive ions and those mobility is too small to take more than several hundred nsec to sweep out the beam line. The frequency of the fast chopper is several MHz adjusted to the injection rf frequency of the booster synchrotron. Hence, the tune of the transport line would be affected by the chopped pulse length of the beam.

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[2] and at the plasma electrode in the volume-production-type H^- ion source[3].

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

II. Experimental Apparatus

At KEK-PS, a surface-plasma H^- ion source has been used for the formation of H^- ion beam. In this ion source, an electrode called *converter* is put into the ion source chamber to produce the H^- ions. The converter is shielded from the plasma by the ion sheath. By applying the negative bias voltage to the converter in the ion source, the H^- ions are produced by the interaction between the positive ions in the plasma and the converter surface. 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,

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

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 MHz which is a negligible value from the ion-plasma frequency. Therefore, in principle it is possible to produce the direct fast beam chopping in the surface-plasma H^- ion source.

Schematic drawing of a surface-plasma H^- ion source used in this experiment is shown in figure 1. There are permanent magnets surrounding to a plasma chamber to confine the plasma by the cusp magnetic field. The hydrogen plasma is produced by the electron emission from a couple of LaB_6 filaments. To produce much more H^- ions, the work function of the converter must be lowered. By introducing the Cs vapor into the ion source, the thin layer (half-monolayer) of Cs atoms is formed on the converter surface and then the work function of the converter can be lowered. The fast chopped H^- beam is produced by changing the H^- formation efficiency following the frequently changed bias voltage of the converter.

A circuit diagram of the rf modulated power supply for the converter is shown in figure 2. In this circuit, the modulation frequency can be changed from 100 kHz to 10 MHz. The rf power amplifier can be operated up to 300 W maximum output.

The rf pulse is supplied through a coupling circuit to overlap the dc bias voltage of the converter. The flatness of the rf pulse height depends on a coupling capacitance in the coupling circuit. The dc component of the rf pulse is decreased transiently,

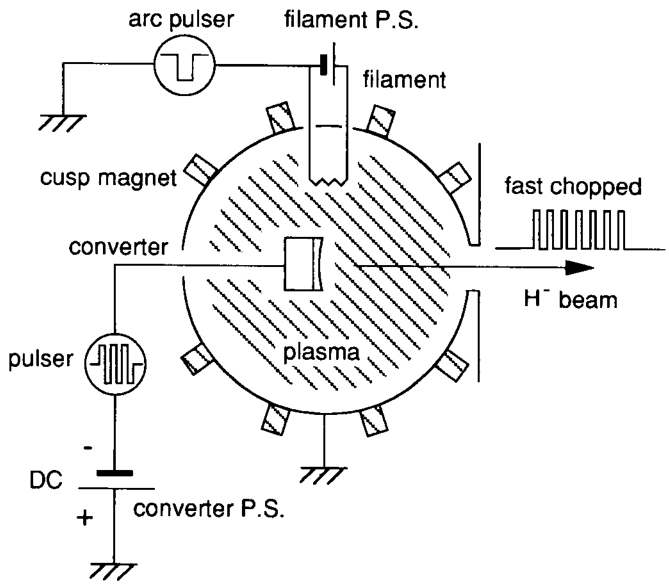


Figure. 1. The schematic drawing of the surface-plasma H$^-$ ion source.

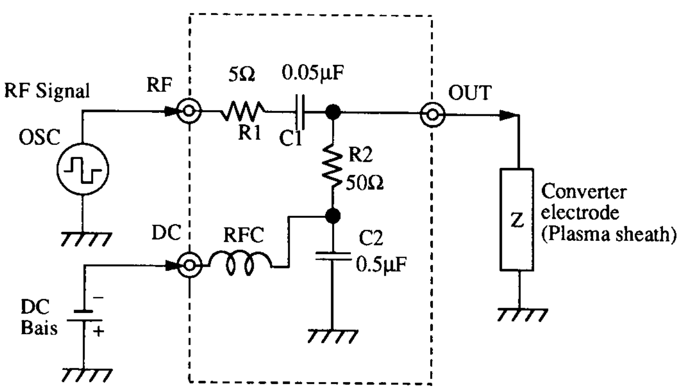
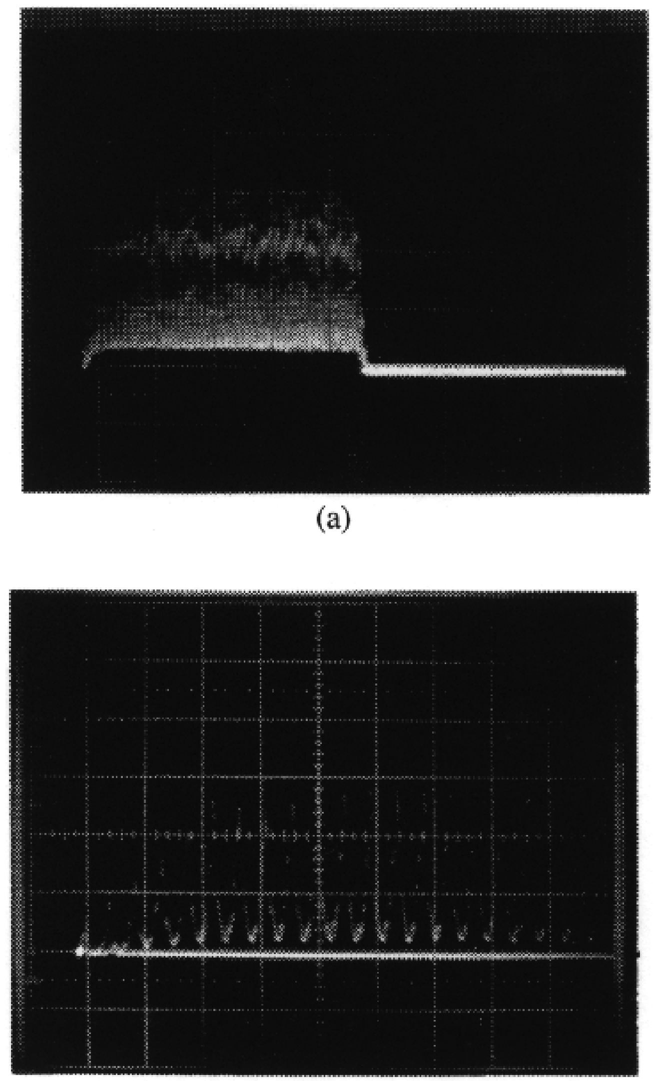


Figure. 2. The circuit diagram of the rf frequency modulated power supply for the converter.

because the value of a coupling capacitance for the rf modulation of the converter bias voltage is in sufficient, and then a new coupling circuit whose coupling capacitance is larger than the present one is under prepared. The large amplitude of the rf modulating voltage is required to overcome the negative potential of the floating electrode in the rf plasma.[4] To solve this problem, a new pulsed power supply which can operate with high voltage (500 V_{p-p}) and fast rise time (10 nsec) for the direct fast H$^-$ beam chopping is under construction.

III. Extraction of rf Modulated H$^-$ Beam

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 chopped H$^-$ beam current is measured by the Faraday cup after passing the magnetic mass separator. It is found that the fast chopped H$^-$ beam current is in good response to the modulated converter voltage for the wide range (from 100 kHz to 10 MHz).



(a)

(b)

Figure. 3. An example of the waveform of the fast chopped H$^-$ beam measured by the Faraday cup at 40 MeV beam line. (a):vertical axis:2 mA/div., horizontal axis:10 μsec/div. (b):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.

IV. 40 MeV Beam Acceleration of Direct Fast Chopped H$^-$ Beam

The fast chopped H$^-$ beam current is measured by a bunch monitor at the 40 MeV beam transport line between the linac and the booster synchrotron. An example of the waveform of the fast chopped H$^-$ beam measured by the Faraday cup at 40 MeV beam line is shown in figure 3. In this figure, about 94% of the maximum H$^-$ beam current is suppressed by the converter bias modulation.

An example of the waveform of the fast chopped H$^-$ beam synchronizing the rf frequency of the booster synchrotron is shown in figure 4. The rectangle fast pulse (2.2 MHz, 220 nsec width, 300 V_{p-p}) is applied to produce the chopped H$^-$ beam.

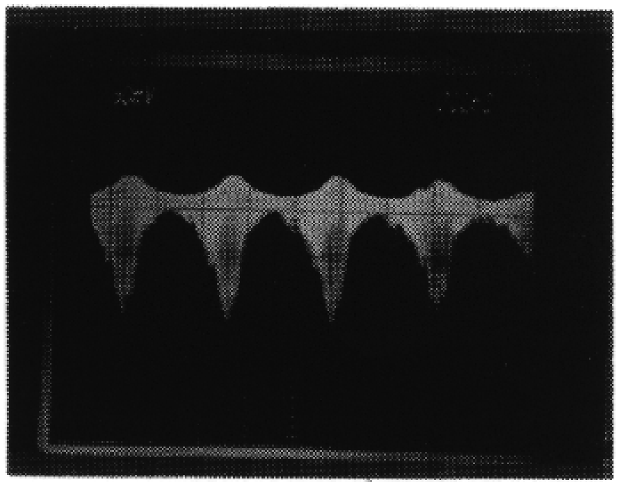


Figure. 4. An example waveform of the fast chopped H^- beam synchronized with the rf frequency of the booster synchrotron. This beam is measured by a bunch monitor at the 40 MeV beam transport line between the linac and the booster synchrotron.

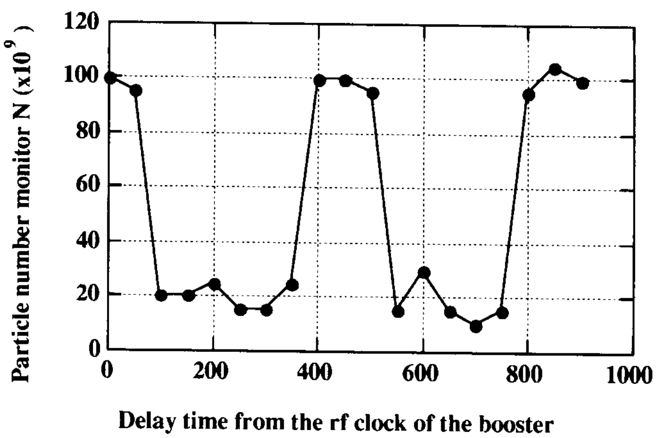


Figure. 5. The capture efficiency of the booster synchrotron as a function of the delay time of the direct fast H^- beam chopping

However the waveform of the H^- beam has not the ideal shape of the waveform which is applied to the converter. There might be a reason why the nonlinearity of the H^- formation efficiency as a function of the converter bias voltage.

The capture efficiency of the booster synchrotron as a function of the delayed time of the direct fast chopped H^- beam is shown in figure 5. From this figure, the correlation between the capturing efficiency and the delayed time from the rf clock is observed obviousely. To eliminate the beam loss at the injection, the fine adjustment of the delayed timing to the rf bucket in the booster synchrotron is very important.

V. Summary and future plan

The production of the direct fast chopped H^- beam in a surface-plasma H^- ion source is realized by the high frequency voltage modulation of the converter voltage. The extracted chopped H^- beam is in good response to that of the modulation of the converter bias voltage, and the 40 MeV beam acceleration of the direct fast chopped H^- beam for a surface-plasma H^- ion source has been examined successfully.

In near future, the comparision of the capture efficiency at the booster injection with the bunch to bucket method using the direct fast chopped H^- beam and the adiabatic capture method using the continuous beam will be investigated.

References

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