Experiments of Synchrotron Injection Using the Direct Fast Chopped H⁻ Beam Extracted from Surface-Plasma-Type Negative Hydrogen Ion Source

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Abstract

An experiment of synchrotron injection using the direct fast chopped H^- beam extracted from a surface-plasma-type H^- ion source has been successfully achieved. The injection phase of the fast chopped beam from linac into the booster synchrtron is adjustable against the center of rf bucket by using this beam. It was obtained that the longitudinal emittance was controlled at the extraction of the booster synchrotron, and that the beam loss during the injection into main ring of the KEK-PS was reduced by this fast chopped beam.

1 Introduction

Recently, high energy and high intensity beam acceleration programs are proposed and developed. For example, JHF project shows the beam intensity of 2×10^{14} particles per pulse at the 50 GeV proton synchrotron.[1] One of the difficulties to realize such a high intensity project is the beam loss due to the beam divergence by the space charge effect of the beam itself. To reduce the effect, some methods are examined.

The beam in the synchrotron is bunched and captured to the rf bucket. The space charge effect can be reduced by making the line density of the bunched beam small. Generally, the linac beam is continuous and this beam injects into the synchrotron. After the injection, the particles are captured by the rf bucket adiabatically and the beam acceleration is started. But in this method, the line density of the beam in the rf bucket cannot be controlled.

To control the line density of the beam, the injected beam from the linac has to be bunched beforehead to the same frequency of the rf bucket of the synchrotron. And the injection phase of the beam is shifted to the center of the rf bucket. Using this method, the beam can be spread into the rf bucket by the broadening of the synchrotron frequency. There are some methods to make the injection beam chopping.[2][3][4] One of the methods is the beam chopping directly at beam production in the ion source. At KEK, a surface-plasma-type H^- ion sourec is used to produce the H^- beam. The method to produce the chopped beam extracted from this ion source was reported previously.[5]

In this paper, the results of the experiment of the injection into KEK 12 GeV synchrotron using the direct fast chopped H^- beam extracted from the ion source is reported.

2 Experimental Apparatus and Control System

In KEK-PS, a surface-plasma-type negative hydrogen ion source is developped and used. The H^- ions are mainly produced by the sputtering process on the metal surface, called converter, which is negatively biased to the plasma. As the H^- ion beam current extracted from ion source depends on the converter bias voltage, the direct fast chopped H^- beam extracted from ion source is produced by modulating this bias voltage. The results of this chopped H^- beam experiment is reported at the previous symposium.[5]

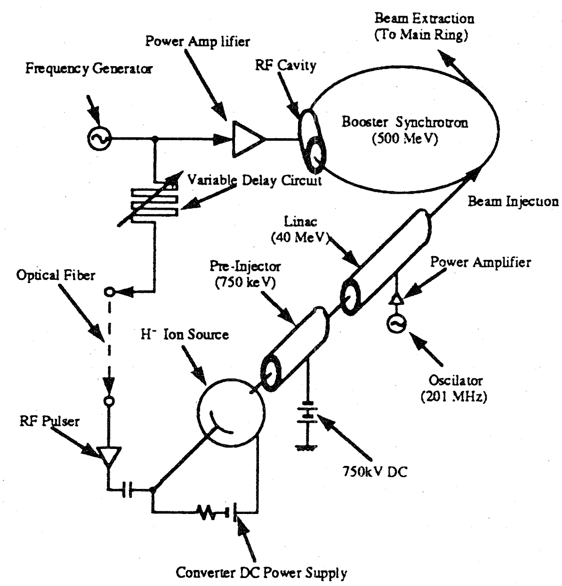


Fig. 1 Control system for the longitudunal emittance in the booster.

By mismatching the phase of the injected beam to the rf bucket of the booster synchrotron at injecting the chopped H^- beam from the ion source into the booster synchrotron, the particles spread into the bucket because of the broadening of the synchrotron frequency. And then, the longitudinal emittance of the beam extracted from the booster synchrotron can be controlled. The scheme of the longitudinal emittance controll system of the fast chopped H^- beam extracted from the ion source is shown in Fig. 1. The signal of the frequency generator of the rf cavity in the booster is triggered to the high voltage pulser biassing the converter in the ion source. The delay circuit is set between the frequency generator and the pulser to control the injection phase to the rf bucket. The acceleration frequency of the rf cavity at the beam injection is about 2.25 MHz, equal to about 444 ns period, and the injection phase control can be changed to 1 ns (about 0.81 radian). The rf pattern of the booster synchrotron is not that using for the adiabatic capture but that of high voltage beforehead at beam injection.

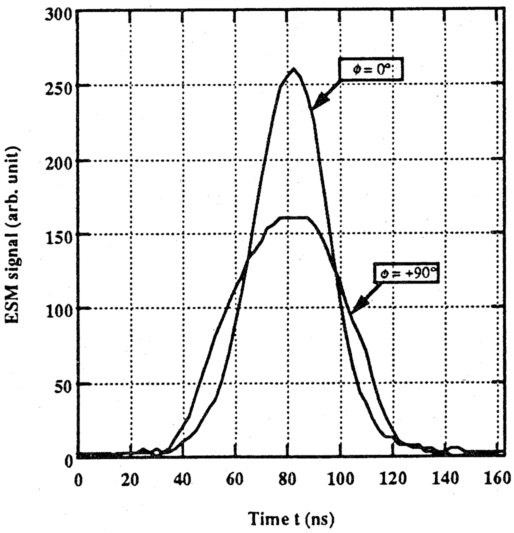


Fig. 2 The waveform of the bunched beam just before the extraction from 500 MeV booster synchrotron.

The experiments are examined using this rf pattern and the control unit.

3 Experimetal Results and Discussions

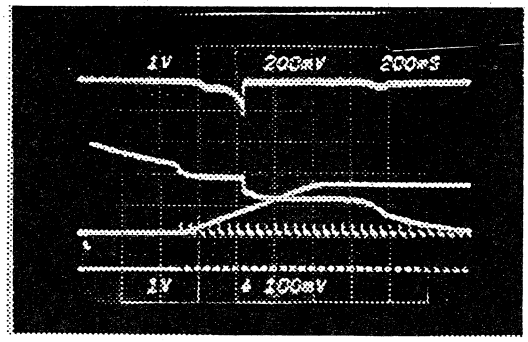
The injection phase of the linac beam is changed using the delay circuit between the frequency generator of the booster rf cavity and the high voltage pulser to modulate the converter bias voltage. At the injection phase of the linac beam matched to the center of the rf bucket, the longitudinal emittance is minimum. And it increases at the injection phase of the linac beam which is shifted until $\pm 90°$ to the center of the rf bucket.

The waveform of the bunched beam just before the extraction from 500 MeV booster synchrotron is shown in Fig. 2. The beam intensity of these bunched beam is same. This figure shows that the line density of the synchrotron beam can be controlled. The bunching factor of 90° shifted injection beam is about 0.34 although that of the center of rf bucket injection beam is about 0.22.

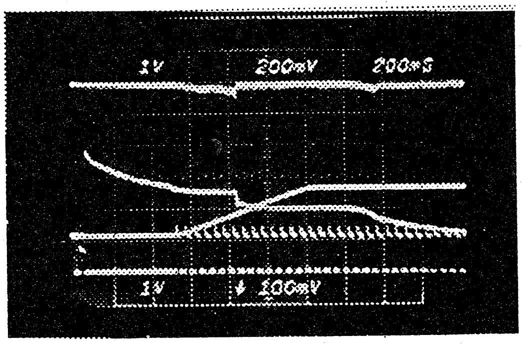
The waveforms of the beam intensity at the main ring is shown in Fig. 3. The decays of the beam intensity from the time of the injection into the main ring to that just before the acceleration is different. The decay of 90° shifted injection into booster synchrotron shows more gentle than that of the center of rf bucket injection. This is because the line density of the beam is controlled.

To confirm this, the beam size of the beam injected into the main ring is measured. To measure it, the fast wire scanner[6] is used. The beam size increment is shown in Fig. 4. The beam size increment of the 90° shifted to the center of the rf bucket injection is smaller than that of the center of the rf bucket injection, although the beam intensity of the 90° shifted to the center of the rf bucket injection is higher than that of the center of the rf bucket injection.

Using this method, the beam intensity of the 9 pulses injection into KEK-PS main ring is measured.



(a)



(b)

Fig. 3 The waveforms of the beam intensity. (a) 90° shifted. (b) center.

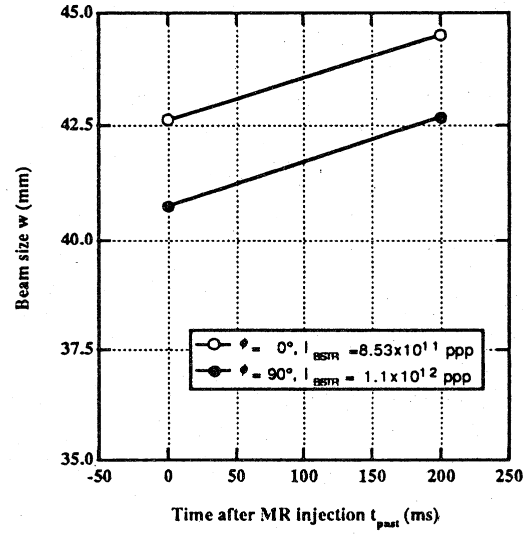


Fig. 4 The beam size measured by the fast wire scanner.

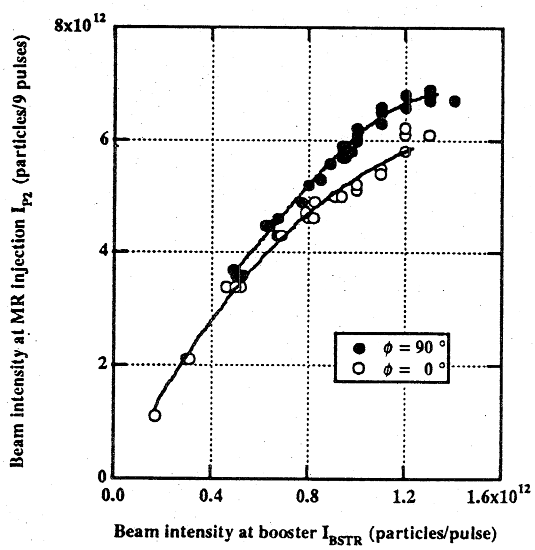


Fig. 5 The beam intensity of the 9 pulses injection into main ring using the fast chopped H^- beam and the injection phase control system.

The result is shown in Fig. 5. The beam intensity of 9 pulses injection using the 90° shifted to the center of the rf bucket injection could be obtained to 7.2×10^{12} particles, and this is the new record of the beam intensity at the KEK-PS main ring injection.

4 Summary

The experiment of synchrotron injection using the direct fast chopped H^- beam extracted from the surface-plasma-type H^- ion source has been achieved. The blow up of the transverse beam size due to the space charge effect by the beam itself could be reduced by the control of the longitudinal emittance from the booster synchrotron. Using this method, the beam intensity of the 9 pulses injection into the KEK-PS main ring is obtained the new record of the beam intensity at the KEK-PS main ring injection.

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