SLOW BEAM EXTRACTION AT TARNII

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Abstract

Beam test of a slow extraction by utilizing the 3rd order resonance has been performed to investigate the characteristics of the extraction system at TARNII and to develop a new technique with the slow extraction. High extraction efficiency was obtained by the extraction without accelerating beam.Time dependence of the profile of the extracted beam and micro-structure of the beam spill were measured. Furthermore we succeeded to extract the beam by a new method utilizing the emittance growth of the circulating beam in the ring.

1. INTRODUCTION

A slow beam extraction system utilizing the 3rd order resonance had been designed to extract the heavy ion beam accelerated up to the intermediate energies (several hundreds of MeV/u)[1,2]. The extraction system consists of an electrostatic septum (ESS), a magnetic septum (SM), a sextupole magnet (SX) and three bump coils wound around baglegs of the lattice dipole magnets as shown in Fig. 1. Design values of the hardware equipments for the slow extraction are shown in Table 1. The SM and ESS were installed in the TARNII ring on August in 1990. The test of beam extraction was performed . The recent results of the beam extraction using a beam at the injection energy (10MeV/u) are described in the present paper[3,4].

Table 1
Parameters of slow extraction system

Sextupole Magnet	B"L/Br = 0.30 1/m^2 (DCmode)
Electrostatic Septum	E_{max} = 85 KV/cm, L = 1 m, Deflection Angle = 6 mrad, Septum Thickness = 0.15 mm
Septum Magnet	B_{max} = 5 KG, L = 1 m, Deflection Angle = 85. mrad, Septum Thickness = 9 mm
Bump Coil 1	Deflection Angle = 2.4 mrad
Bump Coil 2	Deflection Angle = -0.83 mrad
Bump Coil 3	Deflection Angle = 2.4 mrad

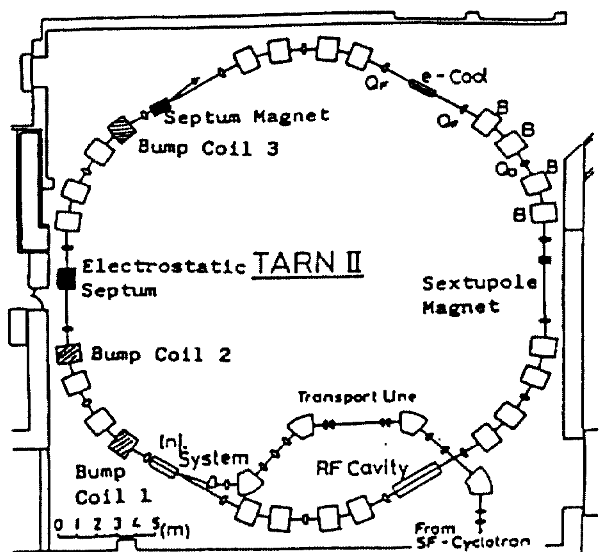

Fig.1 Layout of the slow extraction system of TARNII.

2. EXPERIMENTAL PROCEDURE

Test of the beam extraction from the ring has been carried out by using a beam at the injection energy without accelerating. The extraction process is performed as follows;
a) A sextupole magnet is used to excite the resonance with DC mode. The betatron tune is shifted from (Q_H,Q_V)=(1.71,1.73) to (1.66,1.74) by reducing the strength of field gradient of the radially focusing quadrupole magnets in the lattice.
b) At the beginning of the beam extraction process, the orbit bump coils are excited to make the beam aperture to be minimum at the entrance of the ESS.
c) Beam which deviated by a distance of more than 65 mm outside the central orbit at the entrance of the ESS are deflected outwards by as large as 6 mrad by the static high voltage of the ESS.
d) The SM, which is located almost one cell downstream from the ESS in order to accept all deflected beams in procedure c), gives a much larger deflection angle (85mrad) for guiding the beam outside the ring.

All of the extraction equipment are remotely controlled with a system using a CAMAC interface[5] and a DAC board followed by a personal computer. The extracted beam from the SM passes through a stainless foil with a thickness of 100mm, which separates the vacuum from air, and is detected by a plastic scintillator and a photomultiplier. The spill of the extracted beam is measured by using a multi-channel scaler.

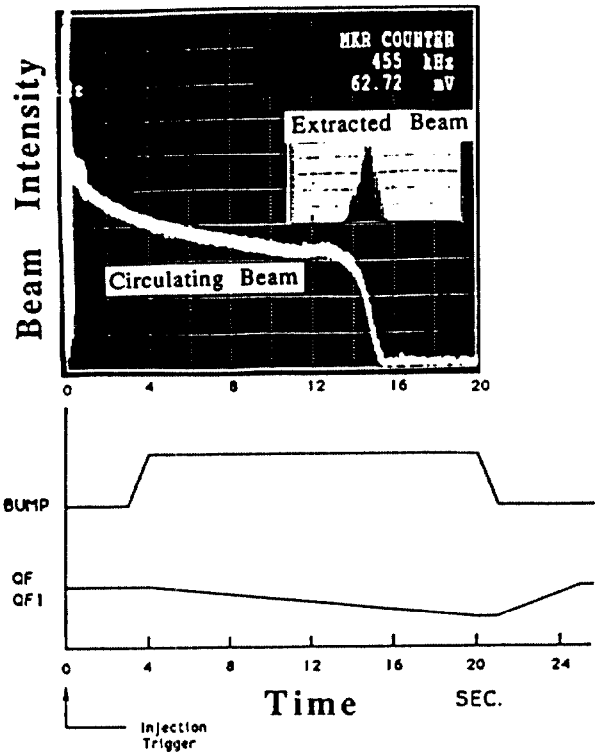

Fig. 2 Time variation of beam intensities of the circulating beam and extracted beam, and ramping patterns of the bump coils and quadrupole magnets also are shown.

3. Fundamental Measurements

Figure 2 shows the time variation of the intensity of the extracted beam as well as that of the circulating beam in the ring which is measured by a electrostatic monitor placed in the ring. In this case, the ramping of the focusing quadrupole magnets was slowly performed to reduce the pile-up of the output signals from the scintillation detector due to the high counting rate. It is clearly recognized that the beam is extracted by the resonance process, because the timing at which beam is extracted is coincident with that at which circulating beam is reduced. The time duration of extracted beam is about 2 seconds under such a ramping pattern.

The extraction efficiency was calculated by comparing the intensity of the circulating beam with that of the extracted beam. The intensity of the circulating beam was obtained by measuring the signal level from the electrostatic monitor which was calibrated by a permalloy core monitor. The intensity of extracted beam was measured by the method described above. The obtained experimental extraction efficiency is estimated to be 90%.

Profiles of the extracted beam were measured by using slits which was placed between the foil and the scintillation detector. The width of the slit to measure horizontal profile is 2mm. Time dependence of the horizontal beam profile was measured by counting the particles passed through the slit by the multi channel scalar. In Fig. 3, the profile is shown every 0.4 second from the beginning of the beam extraction. The peak of profile is shifted from outside to inside with the lapse of time ('outside' indicates the side far from the ring). Such a time dependence of the horizontal profile is mainly caused by a momentum spread of the circulating beam in the ring (dp/p is estimated to be ±0.1%).

Figure 4 shows the measured micro-structure of the beam spill. The duration of the extracted beam is about 2 seconds under the condition as mentioned previously, but the beam intensity is modulated from 100% to 0% by 50Hz. Further, higher frequency component (about 600Hz) was found in the peak modulated by 50Hz. It is estimated that this high frequency components in the spill is due to the power supply of the dipole magnets in the lattice which has large current ripple with the 600 Hz component.

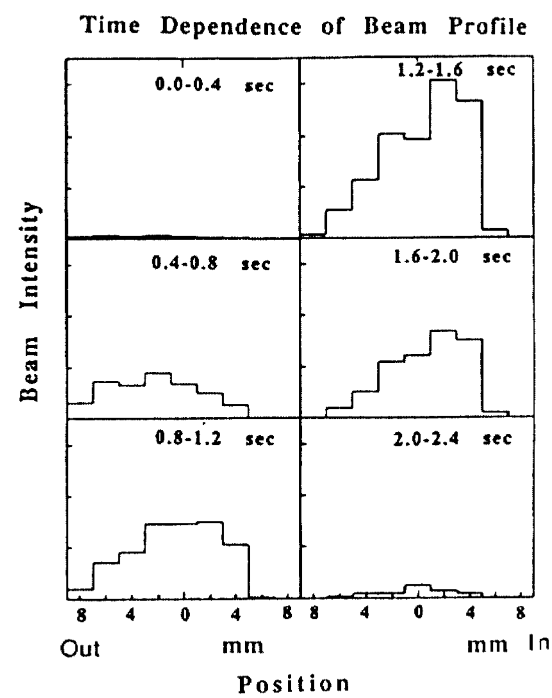

Fig. 3 Time dependence of the horizontal profile of the extracted beam.

4. Extraction Using A New Technuque

The beam can be extracted by increasing the emittance of the circulating beam in the ring without moving the betatron tune, because the stopband of the 3rd order resonance is dependent upon the emittance of the circulating beam. We tried to extract the beam by increasing the emittance of the circulating beam by two methods as followed.

4.1 Extraction Using Emittance Growth by Residual Gases

The emittance of the circulating beam is increased by the multiple scattering which is caused by Coulomb interaction between the beam and residual gas in the ring. Average vacuum pressure in the TARNII ring was 5×10^{-10} torr. For α beam at the energy of 10MeV/u, average emittance growth per a second is estimated to be about 0.01πmm·mrad (normalized). Tests of the beam extraction using this method was done by stopping ramping of the betatron tune just before resonance line. Figure 5 shows the measured spill of the beam. Beam was slowly extracted during about 800 seconds, which is quite longer than typical time duration of the usual extraction (see Fig.2).

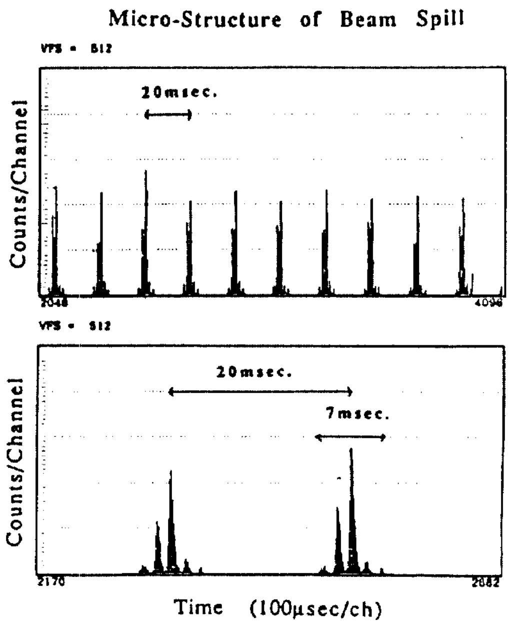

Fig. 4 Micro-structure in the spill of the extracted beam.

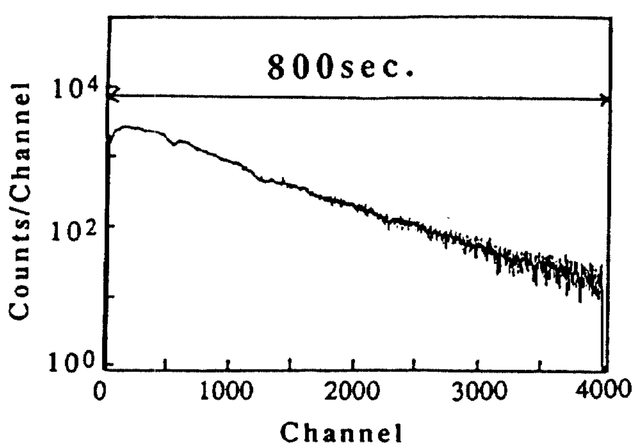

Fig. 5 Spill of the beam extracted by the utilizing the emittance growth due to the multiple scattering with residual gases in the ring.

4.2 Extraction Using Transverse RF Field

The emittance of the circulating beam also increases by supplying the transverse RF field to the beam. Especially the emittance is rapidly increased by the external RF field with a single frequency corresponding to the betatron oscillation of the beam, which is known as RF-knockout. We actually succeeded to extract the beam by this methods. Figure 6 shows the spill of the beam extracted by supplying the pulse-modulated RF field. The ON and OFF of the transverse RF field were alternately repeated every several seconds. The RF voltage at ON-operation is 150V, which corresponds to the transverse kick of 0.006mrad at maximum value. Thus the beam is easily extracted by supplying the transverse RF field without the ramping of tune.

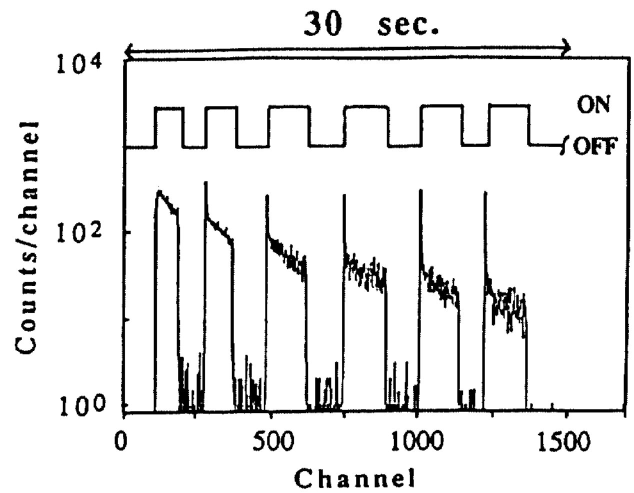

Fig. 6 Spill of the beam extracted by the pulse-modulated transverse RF field.

5. ACKOWLEDGEMENT

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