SLOW BEAM EXTRACTION AT TARNII

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Abstract

Beam test of a slow extraction system by utilizing the 3rd-order resonance has been performed at the injection energy (10MeV/u) in order to investigate the characteristics of the extracted beam. Rather high extraction efficiency was obtained, although further accurate calibration of the beam intensity is needed. Profiles and its time dependence of the extracted beam from the ring were also measured. Higher frequency components were found in the peak modulated by 50Hz from a measurement of the beam spill.

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. After a baking process, a vacuum pressure of 1.1x10^{-10} and 4.9x10^{-10} torr has been achieved at the ESS and SM chamber, respectively. The test of beam extraction was performed using α beam at the injection energy (10MeV/u)[3]. The recent results of the beam extraction test are described in the present paper.

Experimental Procedure of Beam Extraction

Test of the beam extraction from the ring has been carried out by using α 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 as shown in Fig. 2.

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[4] and a DAC board followed by a personal computer. As shown in Fig. 3, the extracted beam from the SM passes through a stainless foil with a thickness of 100μm, 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 (see Fig. 4).

Table 1

Parameters of slow extraction system

Sextupole Magnet	$B''L/B\rho$ = 0.30 1/m^2 (DC mode)
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

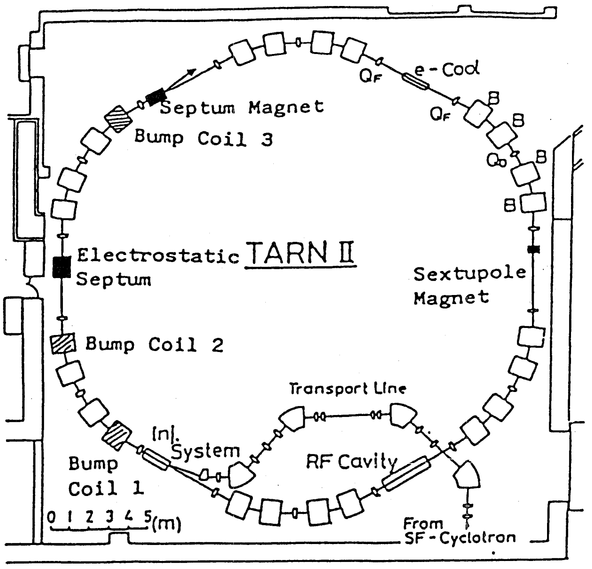


Fig. 1 Layout of the slow extraction system of TARNII.

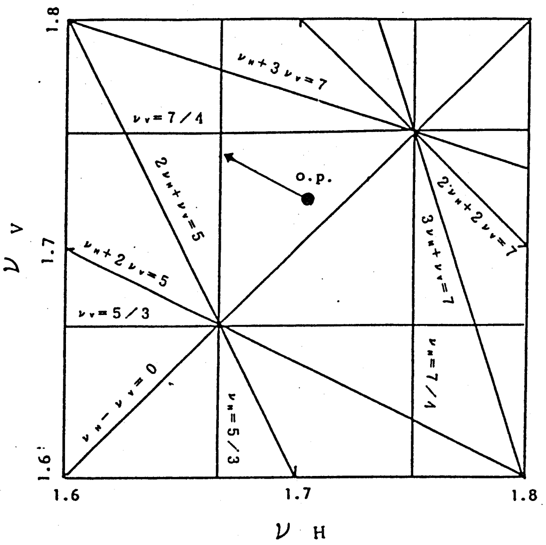


Fig. 2 Working line in the tune diagram during the beam extraction. The O.P. represents the operating point at the beam injection.

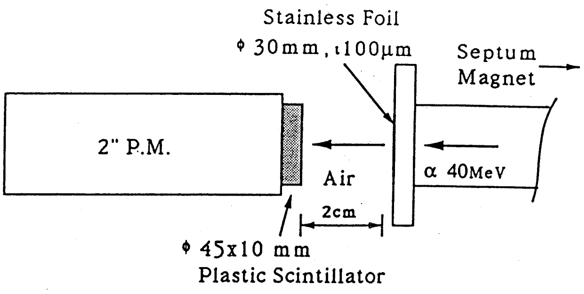


Fig. 3 Schematic view of the setup for the measurement of the extracted beam.

Results of the measurements

Figure 5 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

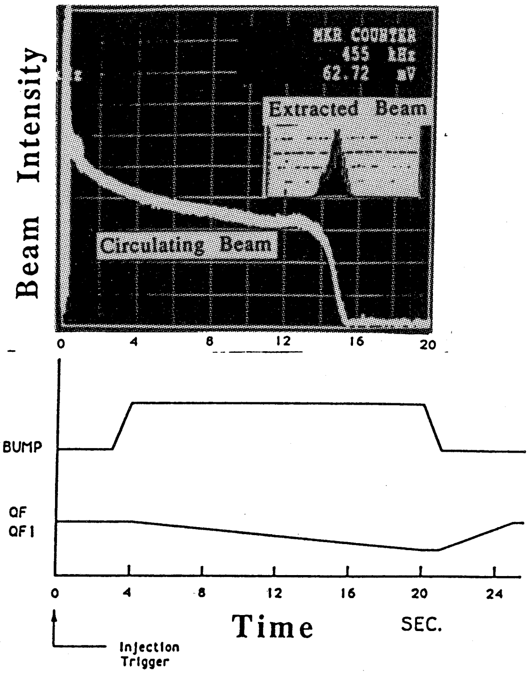


Fig. 5 Time variation of beam intensities of the circulating beam and extracted beam, and ramping patterns of the bump coils and quadrupole magnets also are shown.

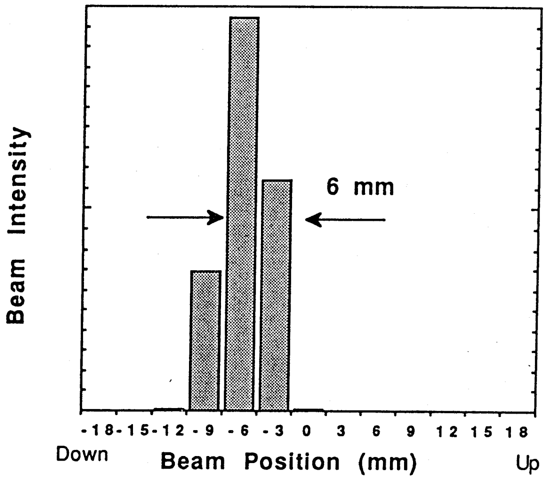
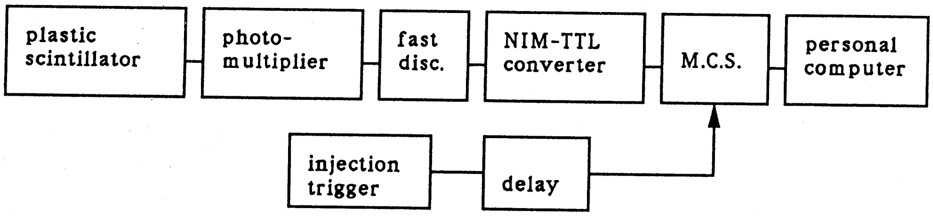


Fig. 6 Vertical Profile of the extracted beam.



(M.C.S.: multi-channel scaler)

Fig. 4 Block diagram of the electronics used to measure the spill of the extracted beam.

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 experimental extraction efficiency is considered to be rather high level, although further accurate calibration of the beam intensity in the ring is needed.

Profiles of the extracted beam were measured by using slits which was placed between the foil and the scintillation detector. The width of the slits to measure horizontal and vertical profiles is 2mm and 3mm, respectively. Figure 6 shows the measured a vertical beam profile. The beam has a width of 6mm (FWHM) and the center of the profile is shifted by 6mm downward. In order to correct this deviation, it is needed to install the equipment to steer the vertical beam orbit in the ring. Figure 7 shows a measured horizontal beam profile. The beam has a width of 10mm (FWHM) which is consistent with the design value[5].

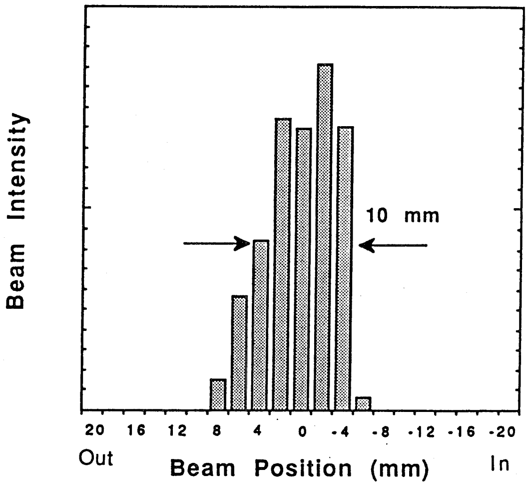


Fig. 7 Horizontal Profile of the extracted beam.

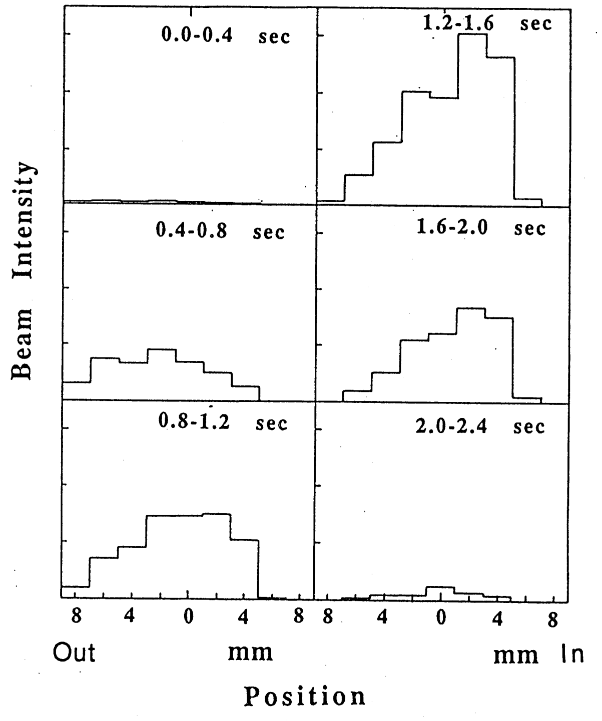


Fig. 8 Time dependence of the horizontal profile of the extracted beam.

Time dependence of the horizontal beam profile was measured by counting the particles passed through the slit by the multi channel scalar. In Fig. 8, 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 ($\Delta p/p$ is estimated to be 0.2%).

Figure 9 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) is 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.

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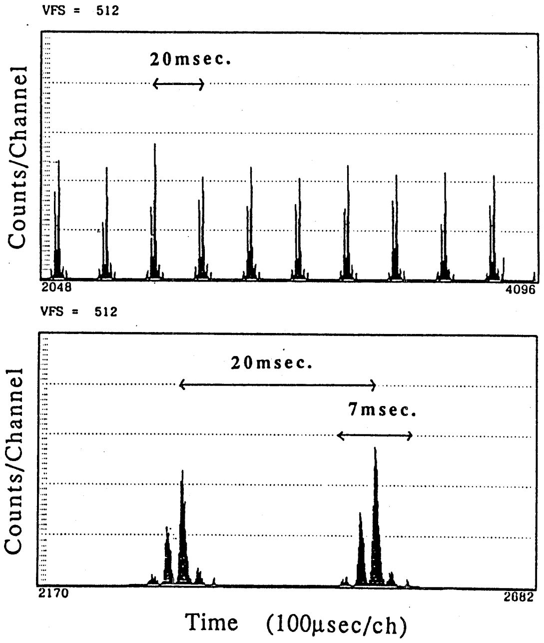

Fig. 9 Micro-structure of the spill of the extracted beam.