FULLY DIGITIZED SYNCHRONIZING AND ORBIT FEED-BACK CONTROL SYSTEM IN THE KEK INDUCTION SYNCHROTRON

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Abstract

A full demonstration of the beam confinement and in the induction synchrotron acceleration was accomplished in March 2006. A discrete timing control unit to maneuver the generation of induction pulsevoltages was newly developed for controlling of the beam orbit in the induction synchrotron and employed in this demonstration.

INTRODUCTION

The Induction synchrotron has been eagerly developed at KEK since 2000. The concept is schematically shown in Figure 1.After accomplishing the key devices, such as the switching power supply, the switching power supply [1], the induction acceleration cell [2], and the trigger control system to realize induction acceleration in a circular ring, an induction acceleration experiment was carried out step-by-step using the existing KEK 12 GeV proton synchrotron (12GeV-PS). For the first time, induction acceleration in a high-energy circular ring was demonstrated in 2004 [3], in which a single proton bunch injected from the 500 MeV Booster ring and captured in the rf bucket, was accelerated from 500 MeV to 8 GeV. In a succeeding experiment [4] the proton bunch captured by the induction barrier voltages at an injection-energy of 500 MeV, and survived for more than 450 msec. The induction step-barrier voltages create a shallow notch potential, where the injected buch is trapped. The rf bunch shape injected from the 500 MeV Booster was not matched to the barrier bucket in the phase-space. After a large filamentation in the bucket, the bunch achieved its 600 nsec-long size.



Figure 1: Schematic view of the induction synchrotron. A long bunch is confined by step barrier voltages and accelerated by a long induction voltage, which are independently generated at induction cells.

The first proof-of-principle experiment of the induction synchrotron was successfully executed in March 2006 [5]. For this purpose, 10 induction units capable of generating ± 2.2 kV bipolar induction voltage have been employed.

An outline of the KEK induction synchrotron is shown together with the control system integrating the gate control system for the switching power supply and the beam monitoring systems in Figure 2.



Figure 2: Signal flow diagram of the induction synchrotron.

Differences between the induction synchrotron and a conventional rf synchrotron, where charged particles are confined in the longitudinal direction and accelerated by the rf, are summarized in Table 1. Synchronization between pulse voltages and a circulating bunch and beamorbit control are crucial in the induction synchrotron. They are quite different from that in the RF synchrotron, as well as the acceleration and confinement. In this paper, we will particularly focus our concern on these aspects.

Table 1: Comparison Between RF and Induction		
Properties	RF Synchrotron	Induction
-		Synchrotron
Acceleration	RF	induction step
		voltage
Confinement	phase focusing	barrier trapping
Synchronization	voltage control	active delay by
•	oscillator	digital timer
Beam-orbit	analog ΔR	digital ΔR
control	feedback	feedback

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TRIGGER CONTROL SYSTEM

Synchronization

One of difficulties to realize the induction synchrotron is to modulate an acceleration voltage so as to follow the ramping pattern of the bending magnet and to fix the beam orbit. The other is to modulate the delay during the trigger signal transfer for synchronizing the beam, which velocity changes from 0.75 to 0.99 through the

acceleration. In order to overcome these difficulties, A real-time discrete signal processor (DSP), shown in Figure 3, was employed. The DSP output synchronized trigger pulse with calculating the bending field strength from programmed function.

Orbit Control

Beam orbit signal is input to the DSP board from A/D converter. Amplitude of the charged voltage cannot be suddenly changed by the switching power supply itself, due to the large bank condenser for preventing fluctuation of the output voltage. In order to modulate acceleration voltage to fix the beam orbit, the DSP modulates the trigger pulse duty according to the beam orbit information. The DSP stops outputting trigger pulse when the beam orbit exceeds a definite value. The total signal flow is schematically shown in Figure 4.





Figure 4: Signal Process Loop in DSP Board.

EXPERIMENTAL RESULT

The beam orbit control test during the 460msec from beam injection (injection porch) was executed at the beam energy of 500MeV. Figure 5 shows a snapshot of the beam shape, barrier voltage and orbit control voltage, and Figure 6 shows the experimental result. The upper picture of Figure 6 shows the beam confinement without orbit control, and the lower shows the one with orbit control. The trigger signal for barrier, the beam orbit, and the trigger for beam control is depicted from top to bottom in each figure. The beam orbit control by the pulse voltage with feedback system was firstly achieved in this experiment.



Figure 5: Beam (Blue), Barrier Voltage (Yellow), and Beam Orbit Control Voltage (Pink) in the POP Experiment.



Figure 6: Measurement Result of the Beam Orbit Control.

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