PREPARATION OF PAPERS FOR ACCELERATOR CONFERENCES

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Abstract

In Kyoto University Research Reactor Institute (KURRI), we have FFAG accelerator complex for Accelerator Driven Sub-critical reactor (ADS). The FFAG-ERIT has shown that the FFAG accelerator can be a high intensity neutron source with internal target, because of its large energy acceptance. The FFAG accelerator complex forADS has been already constructed and is under beam commissioning. In the main ring, proton beams will be accelerated up to 100 MeV in this summer.

１． Introduction

Kumatori Accelerator driven Reactor Test (KART)project has been started at Kyoto University ResearchReactor Institute (KURRI) from the fiscal year of 2002, aiming to demonstrate the basic feasibility of Accelerator. Driven Sub-critical system (ADS) and to develop and 150 MeV proton FFAG accelerator complex as a neutron production driver[1]. The accelerator complex is composed of three FFAG rings; injector, booster, and main ring[2]. The specifications of the each FFAG are summarized in Table1. As a first stage, the accelerator complex has been planned to output 100 MeV-0.1 nA proton beams in this summer.

Table 1: Specification of FFAG complex for ADS(design).

	Injector	Booster	Main Ring
Focusing	Spiral	Radial	Radial
	8 cells	8 cells	12 cells
Acceleration	Induction	RF	RF
Field index, *k*	2.5	4.5	7.5
Energy(MeV)	0.1-2.5	2.5-20	20-150
P_{ext}/P_{inj}	5.00(Max)	2.84	2.83
Orbit radius(m)	0.6-0.99	1.42-1.71	4.54-5.12

２． FFAG accelerator complex

The proton beams of 120 keV are accelerated in the injector. FFAG betatron, called IONBETA. The IONBETA is composed of eight spiral sector magnets, two acceleration gaps, and electric septa for injection and extraction, respectively. The field distribution in the radial direction can be controlled by trim-coils, and which makes variable energy acceleration possible. Maximum beam energy is 2.5 MeV in design. We have accomplished the acceleration of proton beams up to 1.5 MeV in the IONBETA. The average output current is about 10 nA. Betatron tunes are also variable by the trim-coils. We are experimentally investigating fast integer-resonance crossing with the IONBETA. The first experiment showed that the integer resonance was successfully crossed when the crossing speed was high enough [3].

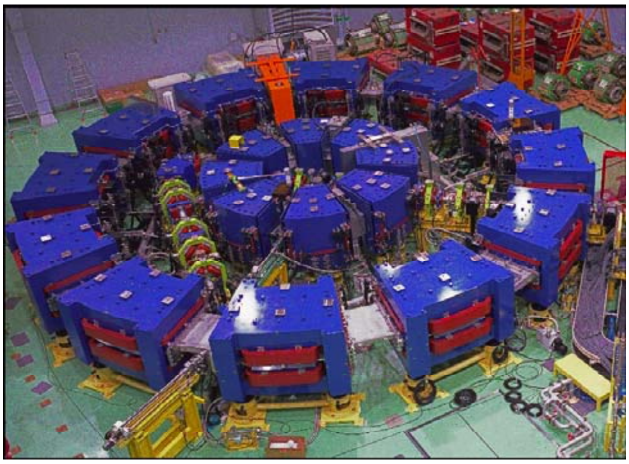

Figure 1: Photograph of FFAG-ADS accelerators

The booster FFAG adopts multi-turn beam injection using horizontal space, by a couple of bump magnets, an electrostatic septum (ES) and a pulse-magnetic septum (MS). Captured beam current is about 1 3 nA with 59 Hz repetition rate. Fast longitudinal matching with bunch rotation method [4] was tried. In a rapid-cycling accelerator, adiabatic capture cannot be used, because it essentially requires long capture time compared to the period of the synchrotron oscillation. In the booster FFAG, the accelerating time is about 7 ms, while the synchrotron period is 0.1 msec. In the bunch rotation method, the accelerating bucket was rapidly produced after 1/4 synchrotron oscillation in a waiting bucket. The bunch length and the momentum spread after the rotation was controlled by the capture rf voltage. Saw-tooth rf was employed in order to minimize the filamentation. One advantage of the method is that the longitudinal beam loss is suppressed. In addition, the longitudinal emittance is kept small and momentum spread of an extracted beam is improved. With the bunch rotation, the quadrupolar synchrotron oscillation could be minimized as shown Fig. 3 and the extracted beam intensity increased at least three times [5]. Final beam energy was estimated to be 11.6 MeV by the revolution frequency and the

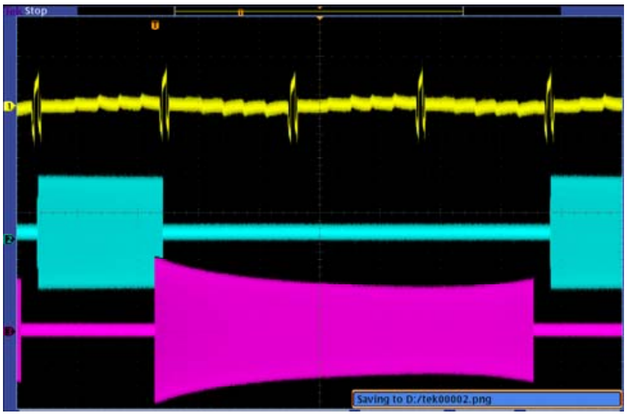

Figure 2: Input accelerating voltages of the accelerators;4 ms/div.

circumference.

Horizontal and vertical betatron tunes were measured in the booster FFAG. Horizontal coherent betatron oscillations were excited by rf-modulation, and vertical ones were excited by a perturbator electrode. The measured tunes agreed the designed ones. A rapidlotted as functio beam loss was observed when the current of defocusing magnets was increased, as shown in Fig. 4. It is assumed that the beam loss was caused by the coupling resonance

$$\nu_x + 3\nu_y = 6.$$

Proton beam of 11.6 MeV was injected in the main ring. The main ring is composed of 12 return-yoke free magnets. A magnetic material in the straight section gathers the fringing field near by, and thus distorts the closed orbit. The main source of the closed orbit distortion (COD) is the rf cavity, which is covered by a magnetic shield to protect the core from the fringing field. In order to correct the COD, a couple of correction magnet is put on both sides of the accelerating gap. The injected beam is kicked into the closed orbit by an electrostatic septum (ES) and a magnetic kicker (KCRI). Figure 5 shows the circulating beam picked up by an electrostatic bunch monitor (BMON) in the main ring.[6,7] The beam loss right after injection is assumed to be caused by horizontal aperture, which is limited by the ES. One method to increase the intensity is the beam injection without ES. In such case an additional kicker is necessary.

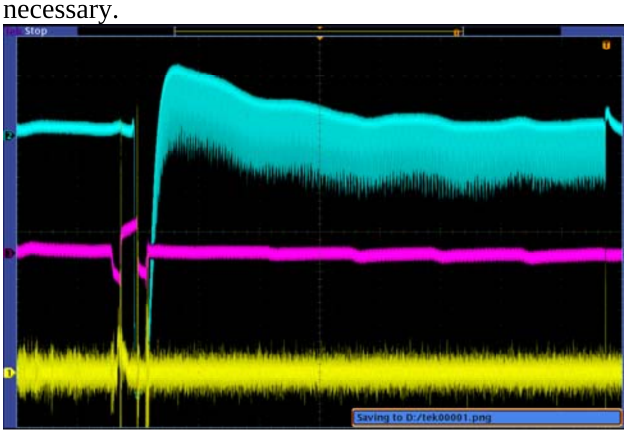

Figure 3: Output signal from current transformer (CT) right after the ion-source (yellow), and Booster bunch monitor (blue); 100 ms/div

The betatron-phase advance between the kickers is 550 deg, so that the kickers work on phase. This means that the strengths of them is complementary.

The beam was accelerated with the rf gap-voltage of 2.5 kV and the synchronous phase of 30 degree. A rapid beam-loss was observed at 4 ms at 20 25 MeV. The beamloss is related to $\nu_x - 2\nu_y = 1$. The beam-loss will be cured by putting locally additional yokes at the orbit. Accelerated beams after the beam-loss were observed by a radial probe with high-sensitivity fluorescent screen at its head. Beam energy can be estimated by the revolution frequency or the orbit radius, using scaling rule with

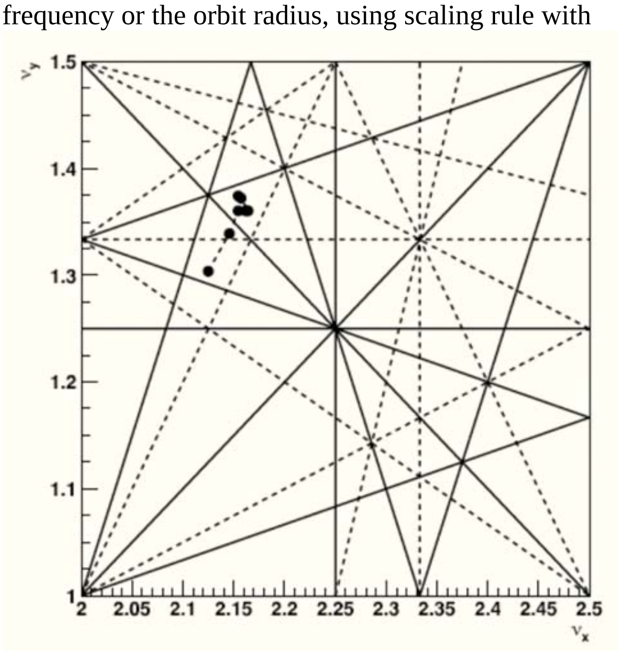

Figure 4: Measured betatron tunes in the booster

FFAG.

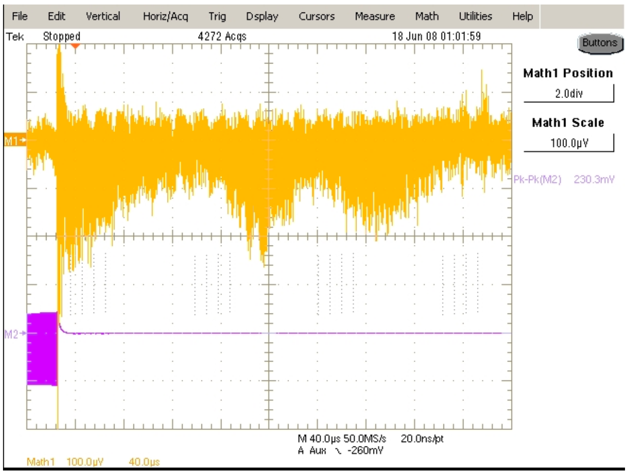

Figure 5: Output signals from bunch monitor of the main ring (yellow) and the booster (magenta); 40 us/div.

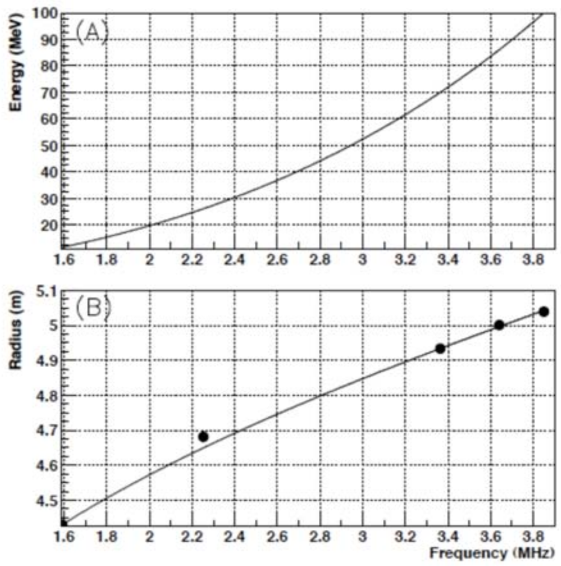

Figure 6: Calculated (A) beam energy and (B) radius at a center of a straight section as functions of revolution frequency; Symbols show the measured values.

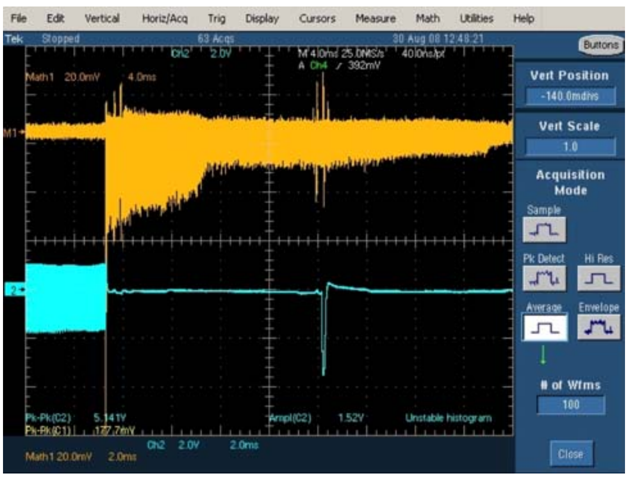

Figure 7: Beam in the main ring measured by a beam bunch monitor.

k=7.5. The injected beam energy was 11.6MeV, capture frequency 1591.84 kHz, and measured beam position was 4430 mm at injection energy. Figure 6 shows the relation between the revolution frequency, the beam energy and the orbit radius measured at the center of straight section. Figure 7 shows the beam intensity in the main ring.

３. Summary

The FFAG complex for ADS project was successfully accelerated proton beams up to 100 MeV, with the repetition rate of 59/2 Hz. After the optimization of the beam behaviors such as beam intensity is completed, the extraction of the beam from the main ring will be tried. The first trial for ADSR experiment with the reactor (KUCA) will be scheduled in this year.

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