PRESENT STATUS OF THE FFAG ACCELERATORS IN KURRI FOR ADS STUDY

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Abstract

KART (Kumatori Accelerator driven Reactor Test) project has started at Kyoto University Research Reactor Institute (KURRI) from the fiscal year of 2002. The purpose of this project is to demonstrate the basic feasibility of ADS, studying the effect of incident neutron energy on the effective multiplication factor of the subcritical nuclear fuel system. A proton FFAG accelerator complex as the neutron production driver for this project is now in the final stage of the test operation.

INTRODUCTION

As a substitute for the 5 MW reactor at Kyoto University (KUR), a neutron source based on the Accelerator Driven Sub-critical Reactor system (ADSR) concept has been proposed in 1996[1]. The conceptual design study on ADSR using the MCNPX code clarified the lack of reliable effective multiplication factor k_{eff} in the proton energy region between 20 MeV and 150 MeV. Since our current experimental studies are limited to those with a 300 keV Cockcroft-Walton accelerator[2, 3], a proton beam source which covers between 20 MeV and 150 MeV is required to extend our study on ADSR system.

A Fixed Field Altenating Gradient (FFAG) accelerator orignally proposed by Ohkawa 40 years ago[4] has a lot of advantages compared to synchrotrons such as a large acceptance, a possible fast repetition rate because of no active feed back in the acceleration. In ADS system, the stability of beam acceleration is directly connected to the stability of reactor itself. In such meaning, FFAG accelerators can be a good candidate for the neutron source driver in ADS system.

While an FFAG has a potential to a neutron source driver, there are still technical difficulties in FFAG accelerators, such as the lack of wide band high voltage RF cavity or the short straight section insufficient for beam injection and extraction. Mori has demonstrated that these difficulties can be overcome by recent developments [5], [6] with the successes of a 500 keV PoP FFAG and an 150 MeV FFAG with RF.

On such basis of our study and the technical developments on FFAG, KART project has been approved and started from the fiscal year of 2002. In this project, a practical proton FFAG accelerator complex of $E_p = 20 \sim 150$ MeV as a proton driver for ADSR is constructed in KURRI and the basic feasibility of ADSR system and the multiplication factor k_{eff} in the energy region of $E_p = 20 \sim 150$ MeV will be studied.

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FFAG ACCELERATOR COMPLEX

The FFAG accelerator complex for KART project consists of one FFAG with an induction acceleration as the injector and two FFAG with RF as the booster and main accelerators, respectively. Basic specifications for this FFAG complex are summarized in Table 1. The layout of these FFAG accelerators in the accelerator room is shown in Fig. 1. All of these accelerators will be in pulse operation up to the repetition rate of 120 Hz. The beam energy of the current FFAG complex can be varied between $20 \sim 150$ MeV by the change of beam energy from the injector.

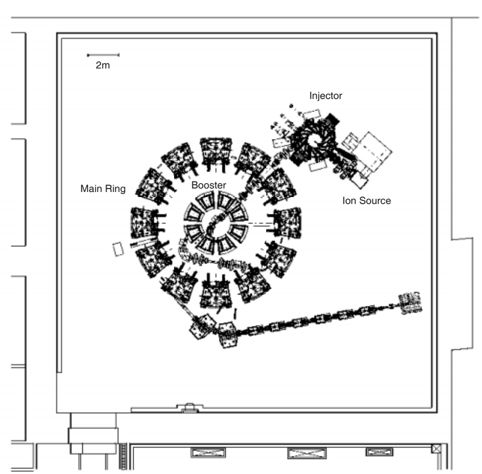

Figure 1: FFAG complex at KURRI.

Ion source and injector FFAG with induction acceleration

H^+ ions are extracted from the typical multi-cusp type ion source and accelerated to 100 keV, then transported to the injector. Since all of the FFAG complex are operated in the pulse mode, the ion source itself is also operated in the pulse mode for less power consumption. The arc voltage is pulsed at the duty of $\sim 10\%$, then the pulsed beam is

Table 1: Specification of the FFAG complex at KUR

	Injector	Booster	Main
Focusing	Spiral	Radial	Radial
Acceleration	Induction	RF	RF
k	2	2.45	7.5
E_{inj}	100 keV	2.5 MeV	20 MeV
E_{ext}	2.5 MeV	20 MeV	150 MeV
p_{ext} / p_{inj}	5.00	2.84	2.83
r_{inj}	0.60 m	1.27 m	4.54 m
r_{ext}	0.99 m	1.86 m	5.12 m

shaped to $\sim 50\mu$s at the beam chopper placed in the transport line between the ion source and the following injector.

The injector FFAG is a 2.5 MeV FFAG with induction acceleration scheme. 8 sprial sector magnets with the spiral angle of 42 degrees (Fig. 2) produces the FFAG magnetic field. The spiral sector type is chosen to this injector because of its rather long straight section and its higher packing factor. The index k for the FFAG field is determined by adjusting the currents of 32 trim coils placed on the pole face along the r direction (Fig. 3, 4). The beam energy of the current FFAG complex can be varied through the change of this k by supplying the proper current set for trim coils.

Booster FFAG with RF

The beam from the injector is then accelerated up to 20 MeV in this booster ring. This FFAG with RF is the radial sector type, consisting of 8 cells of DFD magnets. The FFAG magnetic field is produced by its pole shape with the half gap proportional to $(r/r_0)^k$. In this booster ring, $k = 2.45$ is chosen to minimize the beam excursion and the resonance variation. The window-frame type magnetic shield is attached to the both sides of the magnet to reduce the fringing field at the straight sections. The fringing field at the center of the straight section is confirmed to be less than 100 Gauss from the magnetic field measurement. The beam injection is performed by a septum magnet, an inflector electrode and a pair of bump magnets. Acceleration voltage is supplied by an RF cavity with very low Q (~ 1) for the flat output voltage over the acceleration frequency range. The beam extraction is performed by kicker and septum magnets. All the components for beam injection/extraction except the inflector for beam injection are in pulse operation. The booster ring under construction is shown in Fig. 5.

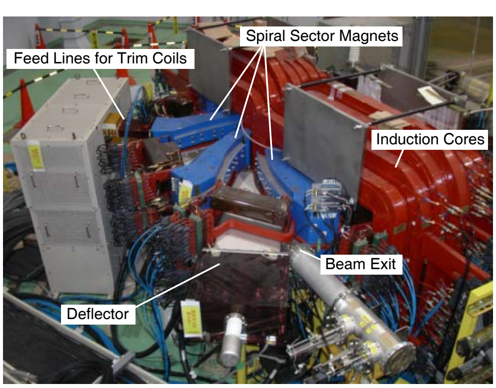

Figure 2: FFAG injector and ion source.

Figure 3: 32 trim coils attached to the pole piece of the injector.

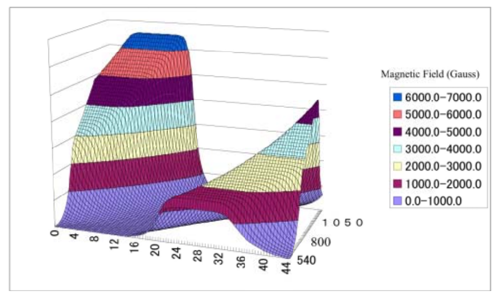

Figure 4: A typical FFAG magnetic field of the injector ring magnet with trim coils obtained by the field measurement.

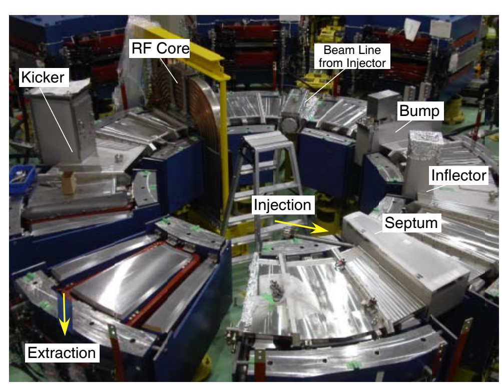

Figure 5: The booster FFAG under construction. DFD structure of the radial sector magnets can be seen in the front-left lattice. The remaining bump magnet and the septum for beam extraction are to be placed in the straight section before the lattice with beam extraction channel.

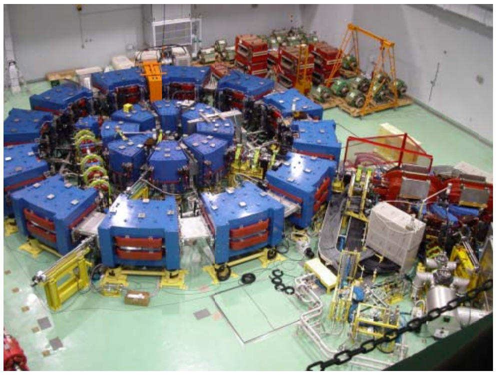

Figure 6: Current status of the accelerator room in "Innovation Research Laboratory".

Main FFAG with RF

The main accelerator is basically identical to the 150 MeV FFAG in KEK. Detailed discussions are available in ref. [6]. This time, the purity of iron in the magnets are increased to accept a high magnetic flux required for acceleration at 200 MeV, aiming the beam energy upgrade by the reinforcement of power supplies in near future. In our 150 MeV FFAG, a conventional amorphous core, not the finemet core, is used in the RF cavity. Then rather a larger size of the magnetic shield for the core is expected to be resulting in a COD source in our FFAG ring. A pair of dipole magnets are placed in both sides of RF cavity to minimize this effect.

CURRENT STATUS AND FUTURE PROSPECTS

The construction of FFAG accelerator complex is in progress since the construction of "Innovation Research Laboratory" was completed in March, 2004. This buliding is not only for FFAG accelerator complex, but also for the multipurpose usage of the beam from the FFAG complex in future, such as nuclear physics, chemistry, material science and cancer therapy. Currently, the construction of our accelerator complex are almost completed (Fig. 6). The basic studies for injector and booster are almost finished. Studies for beam injection and acceleration in the main ring are now in progress. The first beam from this FFAG complex is expected in the first quarter of 2007. The preparation of the subcritical core and the target for the neutron production are almost completed and the inspection for the actual operation will be held as soon as the accelerator complex is approved by the government.

This paper contains some results obtained within the task gFeasibility Study on ADSR Using Fixed Field Alternating Gradient (FFAG) Synchrotron as an Energy Amplifierh entrusted from the Ministry of Education, Culture, Sports, Science and Technology of Japan.

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