STATUS OF CENTER FOR ACCELERATOR AND BEAM APPLIED SCIENCE OF KYUSHU UNIVERSITY

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Abstract

A new accelerator facility of Center for Accelerator and Beam Applied Science is under construction on Ito Campus to promote research and education activities at Kyushu University. The facility consists mainly of a 10 MeV proton cyclotron as an injector and a 150 MeV Fixed Field Alternating Gradient (FFAG) accelerator, which was developed at KEK as a prototype of proton FFAG for various applications. In this paper, the status of the development of devices and the facility is described.

INTRODUCTION

Center for Accelerator and Beam Applied Science has been established in April 2007 to promote activities in all the related scientific, medical, engineering and educational fields at Kyushu University. To realize the purpose of the center, Kyushu University has decided to construct a new facility merging three institutes that are Cockcroft-Walton Accelerator Laboratory of Faculty of Engineering, Institute for Irradiation and Analysis of Quantum Radiations and Kyushu University Tandem Accelerator Laboratory of Faculty of Sciences, on its new campus (Ito Campus).

The facility mainly consists of a 10 MeV injector cyclotron and a 150 MeV Fixed Field Alternating Gradient (FFAG) accelerator [1-7] as a replacement of the Cockcroft-Walton accelerator. The 150 MeV FFAG, a prototype machine to prove its usefulness for various applications such as proton beam therapy, was developed at KEK. The construction of the 150 MeV FFAG was started in September 2002 at the east counter hall in KEK, and the beam extraction with 100 Hz operation was successfully demonstrated in November 2005. The 150 MeV FFAG, disassembled in June 2006, was transported by land from KEK to Ito Campus in March 2008.

The construction of the first stage building of the facility has already been completed. The development of the 150 MeV FFAG, the beam commissioning, the pilot researches on nuclear, medical and life science will be carried out from 2009 to 2013. In this stage, we are also planning to introduce a high intensity proton injector for the FFAG. In the second stage, from 2014 to 2016, experimental halls will be extended, and a new tandem accelerator for AMS and heavy-ion beam injection to the FFAG will be installed into the facility.

OVER VIEW OF 150 MEV FFAG

Details of devices of the 150 MeV FFAG are described in this section. The main parameters of the 150 MeV FFAG are summarized in Table 1. Figure 1 shows the schematic layout of the accelerator.

Table 1: Designed parameters of 150 MeV FFAG

Energy	10 - 125 MeV(proton)
Type of magnet	Triplet radial (DFD)
Number of Cell	12
Average radius	4.47 - 5.20 m
Betatron tune (injection)	3.62 (Horizontal) 1.45 (Vertical)
Magnetic field	Focus: 1.63 T Defocus: 0.78 T
Revolution Freq.	1.5 - 4.2 MHz
Repetition	100 Hz / 2 cavities
Beam Current	1.5 nA (In the first stage)

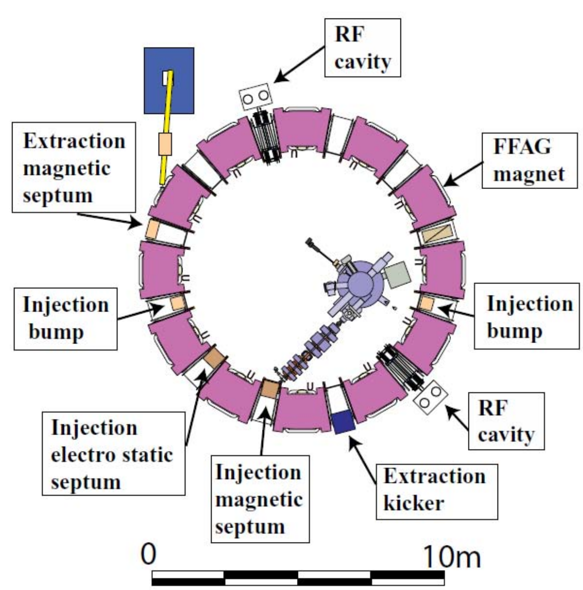

Figure 1: Schematic view of FFAG accelerator

Injector

As an injector of the 150 MeV FFAG, a Baby-Cyclotron is employed. The Baby-Cyclotron was developed by The Japan Steel Works for the positron emission tomography and material irradiation. The main parameters of the cyclotron are summarized in Table 2.

Table 2: Main Parameters of Baby-Cyclotron

Energy	10 MeV (proton)
Type	AVF Cyclotron
Ion Source	Internal PIG (LaB6 cathode)
RF Dee Voltage	40 kV
Extraction Radius	300 mm
Magnetic field	Max. 1.54 T
RF Frequency	47 MHz (2nd harmonic acceleration)
Beam Current	15 μA

Injection

The duty factor of the cyclotron has to be reduced due to a pulse operation of the 150 MeV FFAG. The modulation of cyclotron RF voltage makes a pulsed beam of about 100 μsec width to be injected into the 150 MeV FFAG. Thus, the mean current of the beam from the cyclotron is reduced to 150 nA, 100 times smaller than that in the DC operation mode.

The injection system consists of a septum magnet, an electrostatic septum, and a pair of bump magnets to make bump orbit in those septa. An injected beam is first deflected by the magnetic septum, and its position and angle are adjusted by the electrostatic septum.

Acceleration

To achieve the rapid cycle acceleration in the proton FFAG, an RF cavity with high field-gradient and broadband impedance is necessary. These requirements have been satisfied by using a high-permeability soft magnetic alloy (MA) core and a high power broadband amplifier. The parameters of the RF system are summarized in Table 3.

Table 3: Main Parameters of RF system

Number of Cavity	2
Gap Voltage	4 .0 kV/cavity
RF frequency	1.5 – 4.2 MHz
Power tube	4CW15000E × 2
Class	B class, Push-pull
Core material	FINEMET (FT-3M)[8]
RF output power	200 kW

Extraction

The extraction system consists of a fast kicker magnet and a septum magnet. The magnetic field and the length of the septum magnet are about 4 kG and 0.5 m, respectively. Details of the extraction kicker are described in the following section.

COLLABORATIVE DEVELOPMENT WITH KEK

RF cavity

The rapid cycling acceleration of the 150 MeV FFAG was successfully achieved with the large MA cavity developed at KEK. However, the cooling system for MA cores had a technical difficulty in terms of the thermo mechanical reliability. Since the efficiency of the heat cooling was low, the temperature on inner surface of the core reached over 150˚C[9].

To resolve this problem, a new type of the RF cavity with a high-efficiency cooling system has been developed. Figure 2 is a photograph of the cavity.

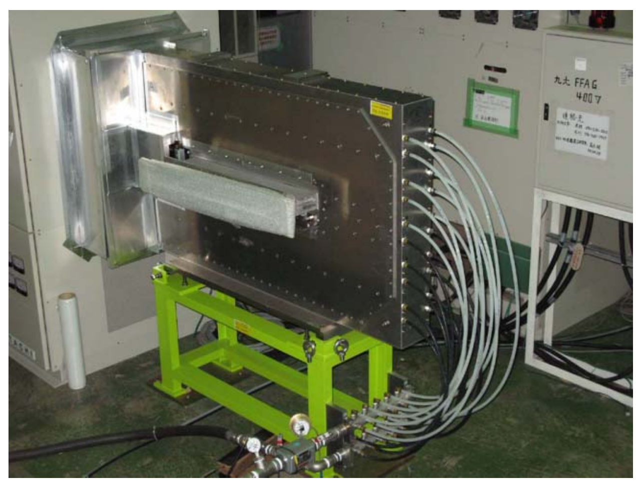

Figure 2: Developed RF cavity for 150 MeV FFAG

The cavity consists of two MA cores, and the water-cooled plates are attached to one side of the cores. A thin thermally conductive spacer (DENKA, FSL-B, 3 W/m K and 1 mm thickness) is inserted between the core and the cooling plate.

Figure 3 shows the water cooling plate for the RF cavity. The blue area and arrows indicate the coolant passage and the direction of water follow, respectively. Most part of the inside area of the cooling plate is covered by the coolant passage so as to significantly increase the contact area between the plate and cooling water.

The impedance of the RF cavity was measured with a network analyzer. Figure 4 shows the measured impedance of the cavity. The maximum shunt impedance was 200 Ω. The measured resonance frequency and the quality factor of the cavity were 2.7 MHz and 0.43, respectively.

The power test of the RF cavity using the high power amplifiers was carried out at Cryogenic and Vacuum Laboratory in KEK. The RF cavity and the cooling system worked well, and the power test was successfully demonstrated. The measured acceleration voltage is 4.0 kV, which was the voltage required to achieve the rapid acceleration of 100 Hz with two RF cavities.

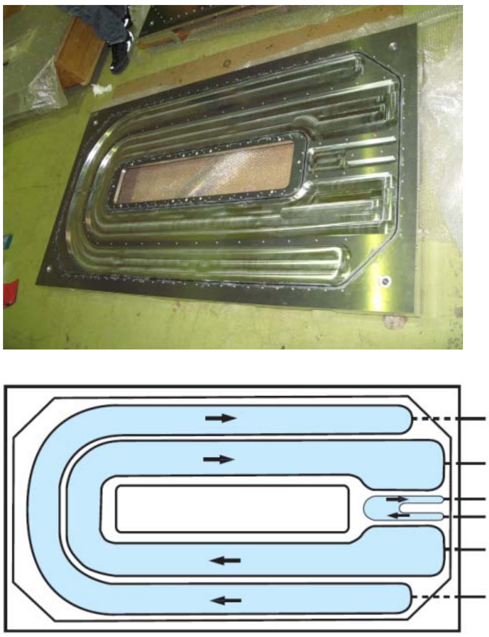

Figure 3: Water jacket type cooling plate.

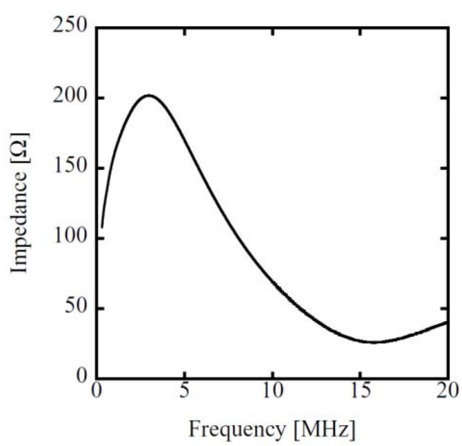

Figure 4: Impedance of the cavity

Extraction Kicker

Since the revolution frequency at extraction energy is 4.0 MHz, the rise time of the kicker field should be shorter than 250 ns. The BL product is required to be 0.3 Tm in order to ensure the orbit separation at the extraction septum.

In order to satisfy the requirements, the switching power supply and the kicker magnet have been developed. Figure 5 shows the developed kicker magnet with its dimensions. The kicker magnet is composed of three air core coils. These coils are electronically connected in parallel in order to reduce the total inductance of the kicker magnet. The measured inductance of the magnet is 1.1 μH.

The switching power supply consists of E2V CX1175 thyratron and PFN network. The voltage and current of the power supply are designed to be 40 kV and 5100 A, respectively in maximum. The rise time of the current is expected to be about 190 ns (0-96%).

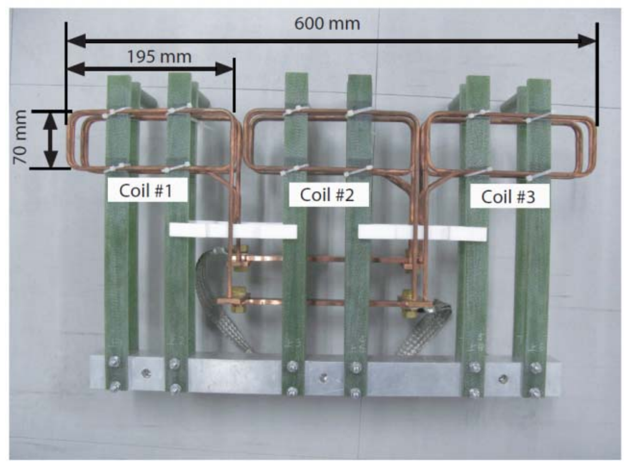

Figure 5: Overview of air core kicker magnet

SUMMARY

The first stage building of Center for Accelerator and Beam Applied Science has been constructed on Ito Campus of Kyushu University. The relocation of the FFAG accelerator from KEK has been completed and the beam commissioning will be started in 2009. The MA cavity with the high-efficiency cooling system and the fast kicker for the 150 MeV FFAG have successfully been developed.

REFERENCES

[1] T. Okawa, originally proposed at the symposium on Nuclear Physics of the Physical Society of Japan in 1953.
[2] M.Aiba et al., Proc. of PAC 01, pp 3254-3256
[3] J. Nakano et al., Proc. of EPAC02, pp1028-1030
[4] T. Yokoi et al., Proc. of EPAC02, pp3452-3454
[5] Y. Yonemura et al., Proc. of PAC03, pp3452-3454
[6] Y. Yonemura et al., Proc. of EPAC04, pp2640-2642
[7] M. Aiba et al., Proc. of EPAC06, pp1672-1674
[8] Products catalogs of Hitachi Metals, Ltd.
[9] Y. Yonemura et al., NIM A 576 (2007) 294-300