Development of RF for PRISM-FFAG

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Abstract

PRISM is a project to produce a high quality, high purity and high intensity muon beam by the bunch rotation technique in FFAG synchrotron using ultra-high field gradient RF systems. The system to achive the field gradient of ~200 kV/m at the low frequency (such as 4-5 MHz) is made and tested using a test cavity.

1 INTRODUCTION

PRISM[1] is an experimental proposal for construction of a highly intense muon source based on a novel idea of phase rotation in a FFAG synchrotron. PRISM stands for Phase Rotation Intense Slow Muon source. It would provide a muon beam having an intensity of about 10^{11}-10^{12} μ/sec, a narrow momentum width of a few % and no pion contamination. The energy of the PRISM beam is relatively low (20 MeV in kinetic energy), since it is aimed to be used for stopped muon beam experiment in general.

PRISM will use a pulsed proton beam from the J-PARC 50 GeV proton synchrotron[2] by fast extraction. PRISM will be placed at a pulsed proton beam facility, which is not included in the Phase I plan of J-PARC, but recently proposed.

PRISM consists of

- a pion capture system with large acceptance by a high selenoidal magnetic field,
- a pion decay and muon transport system in a long solenoid magnet of about 10 m long, and
- a phase rotation system which accelerates slow muons and decelerate fast muons by an RF filed.

Schematic layout of PRISM is shown in Fig. 1. One of features of PRISM is to do phase rotation with a Fixed-Field Alternating Gradient synchrotron ring(FFAG) where FFAG has a large momentum acceptance. Because of a short life time of muons, the bunch rotation should be completed in 5 turns (1 μs) and RF voltage of 2-3 MV in total is required.

To obtain the beam which has a small momentum spread after the rotation, the shape of RF voltage is important. Figure 2 shows the proposed saw tooth like RF voltage[3]. In case of the saw tooth RF voltage, the particle motion in the longitudinal phase space is linear and angular speed of rotation is constant. The other advantage of saw tooth RF is that it has larger momentum acceptance than an ordinary sinusoidal wave.

Figure 3 shows computer simulation result of the bunch rotation in the phase space. It shows that the particles which have ±20 % spread will be rotated and the final momentum after 4 turns is less than ±5 %. In case of the optimum energy and RF voltage shape, the final momentum spread of ±3 % will be obtained for initial spread of ±30 %.

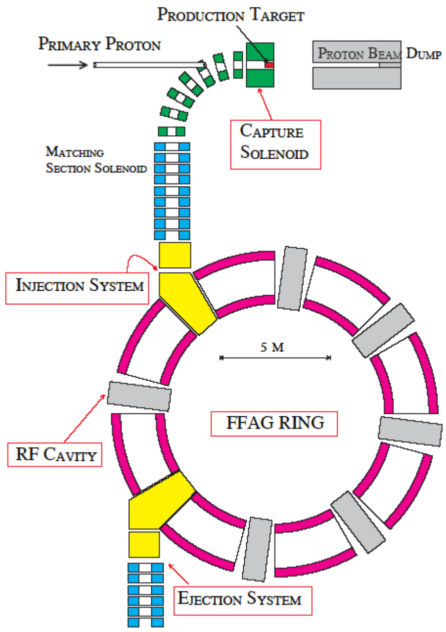

Figure 1: Schematic layout of PRISM.

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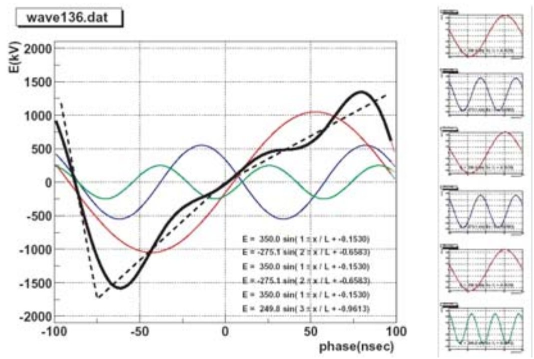

Figure 2: Saw-tooth-like RF voltage. The bold line is the sum of three harmonics (thin lines), H=1, H=2, H=3.

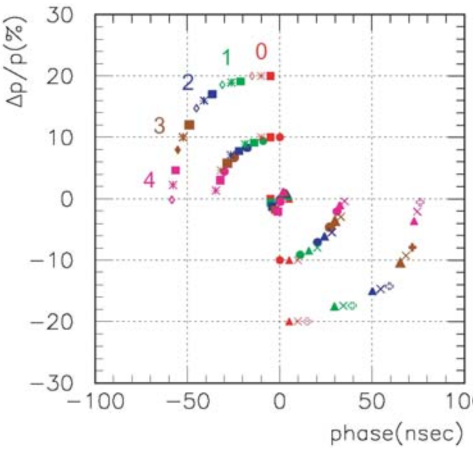

Figure 3: Bunch rotation in case of saw-tooth like RF voltage. Test particles which have different initial momentum and phase are tracked. The initial beam includes the bunch width of initial proton beam (±5 ns).

2 PRISM RF DESIGN

PRISM RF was designed to have the following features

- magnetic alloy cavity,
- wide band resonance,
- thin cavity design: 35cm/gap.
- tetrode tube amplifier with 30-40 kV DC voltage.

The magnetic field in the cores of PRISM RF system is estimated to be several hundreds gauss. The magnetic alloy (MA) is one of materials whose characteristics are stable at this level of magnetic filed, and thus we employ MA for the PRISM RF system[4]. To resonate at low frequency (such as 5 MHz), the cut core configuration[5] will be used to reduce the large core inductance to the optimum value. Another advantage of MA cavity is that it is possible to design it as a wide band system[5]. By choosing the optimum air gap of cut core and minimising the gap capacitance, it is possible to change the quality factor of the cavity at the fixed frequency. We are considering the dual harmonic operation of RF system by minimising the air gap.

Cores are all air-cooled since the RF power loss into the core is very small due to small duty factor (about 0.1 %) of the PRISM RF system operation. This enables us to realize thin cavity configuration. In the current design, six MA cores will be installed for each gaps, whose size along the beam direction is only 35 cm. Five gaps form a single cavity of 175 cm length. The thickness of MA core is 35 mm, and closely packed each other to secure more-than-9cm of gap size. The racetrack-shaped core is adopted. Parameters of the RF system are summarized in Table 1.

Number of gap per cavity	5
Length of cavity	1.75m
Number of core per gap	6
Core material	Magnetic Alloy
Core shape	Racetrack
Core size	1.4m X 1.0m X 3.5cm
Shunt impedance	~159Ω/core@5MHz
RF frequency	4~5MHz
Filed gradient	~200kV/m
Flux density in core	320 Gauss
Tetrode	4CW150,000E
Duty	<0.1%

Table 1: Parameters of PRISM-FFAG RF system

Each gap will be driven by push-pull amplifiers using tetrode tubes, 4CW150,000E. The tube can be used at the high DC voltage of 40 kV and RF current of 60 A is possible to generate. In case of 1 kΩ cavity impedance, 60 kV will be available as a gap voltage. Tetrode amplifiers are installed either on-the-top of or underneath the cavity to secure the total cavity length being less than 175 cm. A low duty factor enables the tubes to generate the maximum RF power of 1.8 MW. Parameters of AMP system are summarized in Table 2.

Operation mode of tube	Push-pull, class AB
Number of tubes per AMP	2
Size of AMP	1.35m X 0.8m X 0.7m
Tetrode	4CW150,000E
Max. RF current	60A
Max. cathode current (DC)	50A
Max. plate voltage	40kV
Max. RF power	1.8MW

Table 2: Parameters of RF system

3 A PROTOTYPE OF THE RF SYSTEM

A prototype of the RF system, which consists of an amplifier and an anode power supply and an auxiliary power supply, was built and installed in the RCNP, Osaka university. A test cavity and a drive amplifier were provided by JAERI for the initial test of the RF system. This cavity consists of ten finemet cut cores whose radius is 900mm and has 8 cm gap. The pictures of this prototype of the RF system are shown in Fig. 4.

Figure 4: A prototype of RF system in the RCNP, Osaka University.

4 RF TEST WITH THE TEST CAVITY

RF test with the test cavity had start at in the spring of 2004. Main purpose of this test is to test power AMP system. Through this test, we obtained 43 kV gap voltage at the 5 MHz frequency with 733 Ω cavity impedance.

5 ULTRA-THIN RF TEST CAVITY

Ultra-thin RF test cavity is being deigned. A single gap model of to match race-track MA core. This cavity consists of six MA cores with 9 cm gap, and whose size along the beam direction is 35 cm.

6 CONCLUSION

RF test with the test cavity had started and we obtained 43 kV gap voltage at the 5 MHz frequency with 733 Ω cavity impedance. The ultra-thin RF test cavity is being designed. The overall system test will be performed in the winter of 2004.

REFFERENCES

[1] Letter of Intent to the J-PARC 50 GeV Proton Synchrotron Experiments, (LoI-24,26)

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[3] M.Yamamoto et al., "Multi-Harmonic Acceleration with High Gradient MA Loaded Cavity", PAC99.

[4] C.Ohmori et al., "ULTRA-HIGH FIELD GRADIENT RF SYSTEM FOR PRISM-MUON BUNCH ROTAION", proceedings of SAST03.

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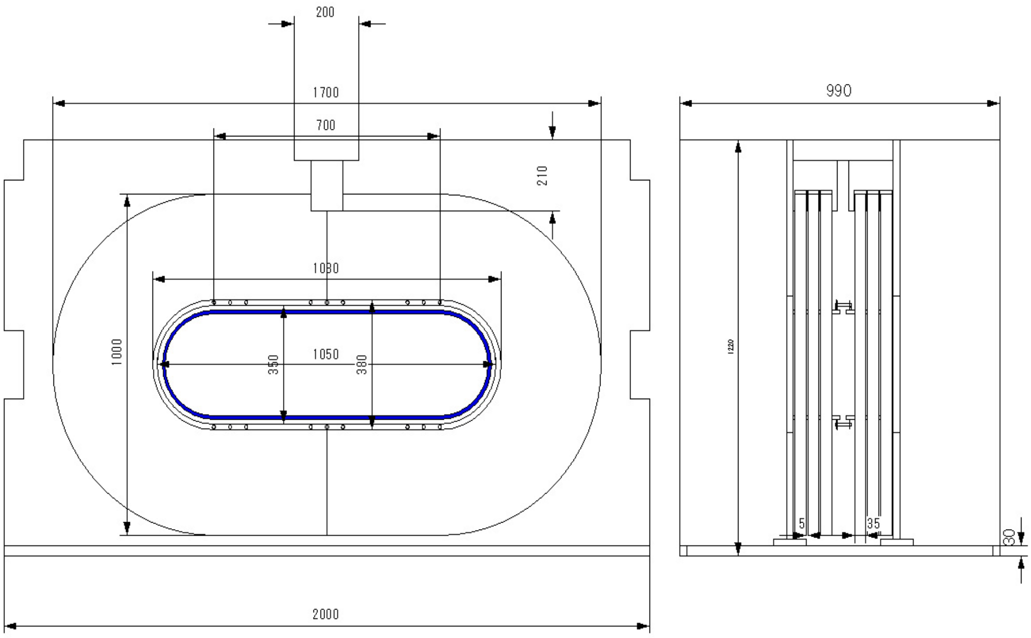

Figure 5: The ultra-thin RF cavity