Development of Ultra-High Field Gradient RF System for PRISM

M. Aoki[a], Y. Arimoto[a], M. Yoshida[a], A. Sato[a], Y. Kuno[a], S. Ninomiya[b], Y. Iwashita[c], C. Ohmori[d] and Y. Mori[d]

[a]*School of Science, Osaka University, Toyonaka, Osaka 560-0043, Japan*
[b]*Research Center for Nuclear Physics (RCNP), Ibaraki, Osaka 567-0047, Japan*
[c]*NSRF, ICR, Kyoto University, Uji, Kyoto 611-0011, Japan*
[d]*KEK, Oho 1-1, Tsukuba 305-0801, Japan*

Muon is a key particle in the future of elementary particle physics. Improving the experimental sensitivity to the muon lepton flavor violation process by a few orders of magnitude will reveal the physics beyond the standard mode[1]. Measuring muon electric dipole moment at a level of 10^{-24}[2] is critically important as suggested from the recent result of muon $g-2$ measurement[3]. Muon can be also used as the source of neutrinos; a neutrino factory will provide high-intensity high-energy neutrinos by using accelerated muon beam[4].

PRISM, which stands for Phase Rotated Intense Slow Muon source, aims to provide slow muon beam with high intensity, high brightness and high purity by using a phase-rotation technique in order to boost the experimental research activity for the muon lepton flavor violation process[5]. Figure 1 shows a schematic diagram of the PRISM system. The PRISM consists of 1) high power pulsed proton driver, 2) pion capture system, 3) pion-decay and muon-transport section, and 4) phase rotation system. It will use a pulsed proton beam at J-PARC 50 GeV proton synchrotron. The central momentum of muon is 70 MeV/c, and the designed intensity is 10^{11}-10^{12} muons per second, which is almost four orders of magnitude higher than the currently-available muon source at PSI. It is also worth to mention that the above intensity will be available for both μ^+ and μ^-, while the intensity of μ^- is much less than that of μ^+ at present facilities in the world.

The key technology toward the realization of PRISM is a Fixed-Field Alternating Gradient (FFAG) phase-rotation ring, in which an injected muon beam with $\pm30\%$ momentum spread will be phase-rotated, and the momentum spread will be decreased down to $\pm3\%$ after several turns in the ring. The "phase rotation" is actually one fourth turns of the synchrotron oscillation in the ring. Thus, the narrow momentum spread after the phase rotation is secured by the narrow time spread of the initial muon beam, which is designed to be about 10 nsec.

Since the muon is unstable particle and its life time is only 2.2 μsec, it is important to phase-rotate as quick as possible in order to save the loss of muon from its decay. The current design requires 200 kV/m of RF voltage. It is also important to drive a RF cavity with dual harmonic signal for the good phase rotation. The development of ultra-high field gradient RF system is thus vital to the success of PRISM project.

PRISM RF system was designed to have the following features: 1) magnetic alloy cavity, 2) wide band resonance, 3) thin cavity design: 25 cm/gap. 4) tetrode tube amplifier with 30-40kV 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 field, and thus we employs MA for the PRISM RF system.

Cores are all air-cooled since the RF power loss into the core is very small due to small duty factor (about 1/1000) of the PRISM RF system operation. This enables us to realize thin cavity configuration. In the current design, four MA cores will be installed for each gap, whose size along the beam direction is only 25 cm. Four gaps form a single cavity of 1 m length. The thickness of MA cores are 35 mm, and closely packed each others to secure more-than-8-cm of gap size.

Each gap will be driven by push-pull amplifiers using tetrode tubes, 4CW150,000E. The plate voltage of 30-40 kV will be applied and RF current of 60 A per gap maximum is possible to generate. Tetrode amplifiers are installed either on-the-top-of or underneath the cavity to secure the total cavity length being less than 1 m.

The size of the anode power supply for this system is relatively small since the low duty factor of the operation. A single power supply provide 40 kV, 400 A maximum to four sets of the amplifiers (8 tubes). The maximum current is 400 A only for the duration of 15 μs at 100 Hz of pulse frequency. Thus the average power is only below 10 kW. The filament, control grid and screen grid power supplies for 4 amplifiers are packed into a single auxiliary power supply unit. The PLC controller installed in the auxiliary power supply unit controls the whole RF system of a single cavity.

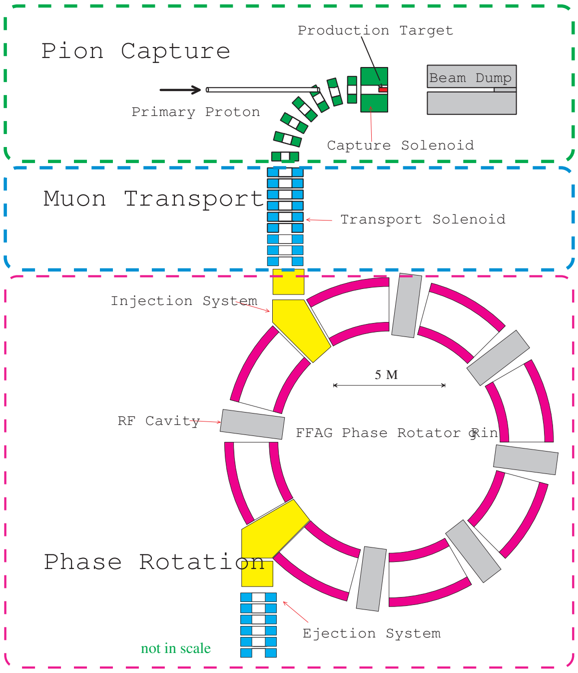

Figure 1: PRISM layout.

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 M experimental hall of the AVF cyclotron. A test cavity and a drive amplifier were provided by JAERI for the initial test of the RF system. RF test with the test cavity had started in the spring of 2004 and the promising result was emerging, but the result will be reported in the annual report next year. The prototype cavity will be fabricated in 2004 and the overall system test will be performed in the winter.

References

[1] Letter of Intent for J-PARC, *An Experimental Search for the μ^--e^- Conversion Process at an Ultimate Sensitivity of the Order of 10^{-18} with PRISM*, contact person Y. Mori, K. Yoshimura, N. Sasao.

[2] Letter of Intent for J-PARC, *Search for a Permanent Muon Electric Dipole Moment at the 10^{-24} $e{\cdot}cm$ Level*, contact person J.P. Miller, Y.K. Semertzidis, Y. Kuno.

[3] Letter of Intent for J-PARC, *An Improved Muon $(g-2)$ Experiment at J-PARC*, contact person B.L. Roberts.

[4] Letter of Intent for J-PARC, *A Study of a Neutrino Factory in Japan (Nufact-J)*, contact person Y. Mori, Y. Kuno.

[5] Letter of Intent for J-PARC, *The PRISM Project – A Muon Source of the World-Highest Brightness by Phase Rotation –*, contact person Y. Mori, K. Yoshimura, N. Sasao, Y. Kuno.