STATUS OF J-PARC MAIN RING SYNCHROTRON

T. Koseki[#,A)] and J-PARC MR Group [A),B)]
[A)]Accelerator Laboratory, KEK, Tsukuba, Japan
[B)]JAEA, Tokai, Japan

Abstract

Presented in this paper is a construction status of 50-GeV slow cycling main ring synchrotron (MR) of Japan Proton Accelerator Research Complex (J-PARC).

INTRODUCTION

J-PARC is a joint project of High Energy Accelerator Research Organization (KEK) and Japan Atomic Energy Agency (JAEA) and aiming at realizing MW class beam power. The accelerator facility consists of a 400-MeV linac, a 3-GeV rapid cycling synchrotron (RCS), a 50-GeV slow cycling main ring synchrotron (MR) [1]. The RCS provides a 1-MW proton beam to neutron and muon targets in the Materials and Life Science Experimental Facility (MLF). The MR provides a 50-GeV, 0.75-MW proton beam to the hadron beam facility via slow extraction and to the neutrino beam facility via fast extraction.

The J-PARC project is being promoted in two phases. The facilities mentioned above are constructed in Phase I. However, the maximum beam energy of the MR is 40 GeV in Phase I. Because the 50-GeV operation becomes possible when a flywheel electric power system will be ready in Phase II.

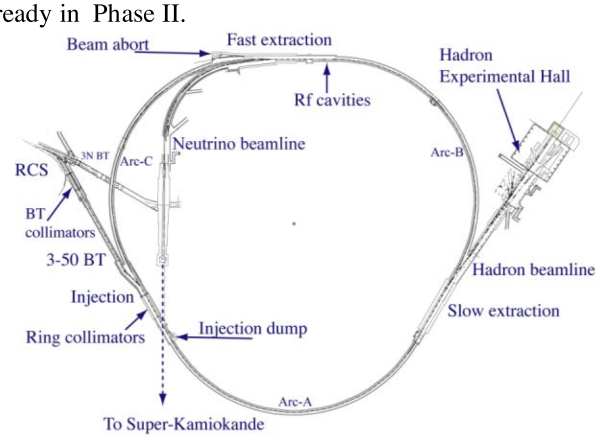

Figure 1: Plan view of MR and experimental facilities.

Figure 1 shows a plan view of the MR and the experimental facilities. The MR has an imaginary transition lattice structure to avoid transition crossing during acceleration. It has a three-fold symmetry and a circumference of 1567.5 m. Three dispersion-free 116-m long straight sections are dedicated to "injection and beam collimators", "fast extraction and rf system", and "slow extraction".

#tadashi.koseki@kek.jp

Beam commissioning of the linac has been started in November 2006. Beam acceleration up to 181 MeV, a nominal energy in the initial operation stage, has been achieved successfully in January 2007 [2]. For the RCS, all the accelerator components will be ready to start the beam operation within the next two months. Beam commissioning is scheduled to start in September 2007.

For the MR, civil construction of the accelerator tunnel has been completed in November 2006. Installation of the components is now in progress.

CONSTRUCTION STATUS

The MR has 96 dipoles, 216 quadrupoles with eleven families, 72 sextupoles with three families. The MR also has eight sextupoles with two families to excite the third order resonance for the slow extraction. The magnetic field measurement and installation of all these magnets have been completed already. Precise alignment of the magnets is now in progress and will be finished in the end of August 2007. The MR has 186 steerings in total. Most of the steerings have been manufactured, and their installation is underway. Installation of vacuum and beam diagnostic systems, and wiring of power cables are also in progress

The 3-50 BT, a 230-m long beam transport line from the RCS to the MR, comprises three horizontal and two vertical dipoles, 38 quadrupoles and 14 steerings. Installation of all the magnets and their wiring of power cables have been completed. Installation of the 3-50 BT beam collimator system has also been finished. Beam ducts and BPMs are now being installed.

DESIGN AND PERFORMANCE TEST OF ACCELERATOR COMPONENTS

Pulsed bending magnet

Extracted beam from the RCS is switched to the MR and to the MLF by a pulsed bending magnet [3]. The requirements to the magnetic field are rise/fall time of less than 40 msec and flatness of 5×10^{-4} during the injection period of the MR. Since the magnetic field pattern is deteriorated due to the effect of eddy current on magnet end-plates, we adopt a field correction scheme to achieve the requirements. The scheme is to make modification of the input current pattern to IGBT modules of the power supply. A field correction pattern to compensate the eddy current effect is made using a 16-bit pattern memory unit. The correction pattern is superimposed on the original current pattern, which is generated by DSP, and the modified pattern is fed into the IGBT modules via feedback control loop. By this method, a rise time less than 40 msec and a flatness of 1×10^{-4} were successfully achieved. The pulsed bending magnet has been installed in the 3-50 BT tunnel in March 2007 (Fig. 2).

Figure 2: The pulsed bending magnet installed in the 3-50 BT tunnel.

Injection and fast extraction devices

All the injection and fast extraction devices have been manufactured and delivered to KEK/JAEA except for one of the injection septum magnets, septum II. Performance test of the delivered devices is now underway. They will be installed in the ring after the good reliability of each device is confirmed. On “day-one”, an eddy current type septum is adopted as the septum II [4]. It is now being fabricated and will be delivered in December 2007.

The fast extraction system is composed of five kicker magnets and six septum magnet systems. It is a bipolar system and can bend the extraction beam both inside (to the neutrino facility) and outside (to abort beam line) of the ring [5].

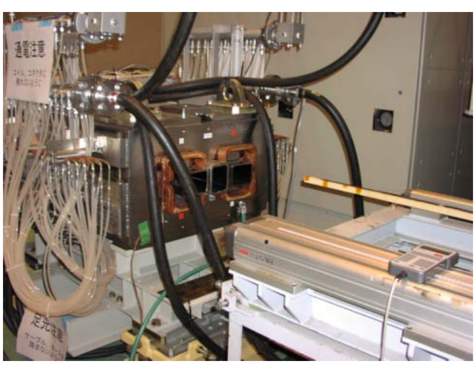

Figure 3: Field measurement of the fast-extraction septum magnets SM30.

Figure 3 shows one of the fast extraction septum magnets, SM30 under magnetic measurements. The SM30 has three beam ducts, which corresponds to the fast extraction beam, abort beam and circulating beam. Magnetic field in the fast extraction/abort beam ducts and leakage field in the circulating beam duct have been measured in detail. It is confirmed that the field quality of each beam duct meets the requirements of the beam optics. The vibration measurements of coil and beam duct have also been carried out. At the excitation level of 40-GeV operation, the measured vibration and thermal expansion are 20 μm and 100 μm, respectively.

Slow extraction devices

For the slow extraction system [6], detailed design of electrostatic septum (ESS), septum magnets [7], and bump magnets is in progress. They are ordered and manufactured within Japanese fiscal year 2007.

ESS is one of the crucial components for the slow extraction system. Especially, development of thin septum is a key subject to achieve high extraction efficiency. We have been carrying out an R&D of the thin septum wires using a half-length model of the ESS. Recently, we have examined 30 μm-thick ribbon type septum made of tungsten 26 % rhenium. The thin septum ribbon mounted on the yoke of the ESS model is shown in Fig. 4. High voltage of 170 kV in 25 mm gap, it corresponds to the field of the 50-GeV beam extraction, was successfully applied using the septum ribbon. Additionally, we measured alignment error of the septum ribbon and found it is 30 μm in maximum. These are quite satisfactory results, and we decided to adopt the 30 μm-thick ribbon type septum to the ESS.

Figure 4: The thin septum ribbon mounted on the yoke of the half-length ESS model.

MA loaded rf cavity

For both the MR and RCS, high gradient rf cavities using magnetic alloy (MA) cores are adopted [8]. On day-one, ten rf cavities are installed in the RCS and five cavities in the MR. Each cavity requires 18 MA cores. In the MR system, the cores are loaded to the cavity with the cut-core configuration. The manufacturing process of the MA cores and the cut surface treatment of the cut-core have been improved in 2006 in order to increase the reliability of high power operation. Before installation in the tunnel, all the cores are tested in long-term continuous operation of 300-2000 hrs with the nominal rf voltage.

Radiation maintenance

The radiation maintenance scenario is based on localizing beam loss on the beam collimators. The MR beam collimator system is now manufacturing and will be installed in September 2007. The highly activated areas in the MR other than the collimators are the injection and the fast/slow extraction sections. Therefore, appropriate

1-4244-0917-9/07/$25.00

radiation maintenance scenario for the injection/extraction devices is necessary for reliable operation of the MR. In order to detach the device from the beam line and install it to the beam line with precise position reproducibility, we adopt a method using linear motion guide rail, which is set on the tunnel floor perpendicular to the beam direction [9]. Figure 5 shows the fast extraction septum magnets SM31 and SM32 on a common support table, which is mounted on linear motion guide rail. They can move smoothly with a small amount of strength. The position reproducibility of the support table is measured to be less than 100 μm using a laser tracker alignment system.

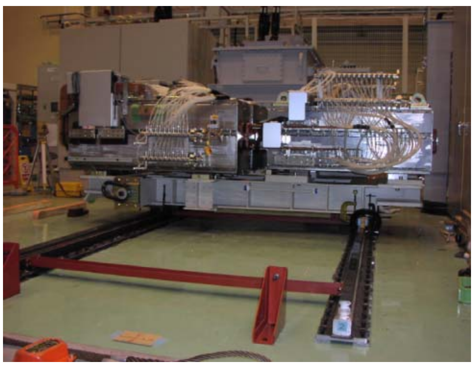

Figure 5: The fast extraction septum magnets SM31 and SM32 on the common support table. The table is mounted on the linear motion guide rail.

COMMISSIONING PLAN AND BEAM DYNAMICS STUDIES

Installation of the rf systems, most of the injection and fast extraction devices will be completed by the end of November 2007. The eddy current type injection septum and low-field septum magnets of the fast extraction will be installed in February 2008.

We will start the off-beam commissioning in December 2007. The components should be online and ready to start the beam operation in this stage. After that, we will start the beam commissioning in May 2008 [10].

In order to prevent the activation of the accelerator components, beam tuning will be started with a very low beam intensity. The MR is operated in the single or two-bunch mode. The typical number of particles per bunch is 4×10^{11}, 1 % of the nominal beam intensity.

Beam commissioning of the MR is divided into three stages. In the first stage, from May to June 2008, Beam transportation through the 3-50 BT, beam injection, establishing closed orbit are studied. After the first stage, the MR is shutdown from July to November 2008. The slow extraction devices and superconducting magnets of the neutrino beamline are installed in this period. The second stage of the beam commissioning is scheduled from December 2008 to February 2009. The fast extraction to the abort beamline and beam acceleration up to 30 GeV are studied. And then, the slow extraction and hadron beamline are commissioned. The third stage is scheduled from April 2009. The neutrino beamline is commissioned in this stage. After the initial beam commissioning days, our studies will be focus on a stable operation with higher intensity.

Now we are progressing various beam dynamics studies. Reduction of uncontrolled particle loss is one of the most crucial issues of the high intensity machine such as the MR. The space charge effects in the injection and acceleration periods are studied in detail [11, 12]. Dynamic collimator system for cutting the tail particles during acceleration is also being discussed [13]. Correction schemes, which can suppress linear and nonlinear resonances due to machine imperfection, are investigated well [14].

SUMMARY

Installation and performance tests of accelerator components of the MR are now in progress. Most of the components will be installed by the end of November 2007 except for the slow extraction devices. Off-beam commissioning of the MR will be started in December 2007. Beam commissioning is scheduled to start in May 2008. The slow extraction devices will be installed in the summer of 2008.

REFERENCES

[1] "Accelerator Technical Design Report for J-PARC", KEK-Report 2002-13 and JAERI-Tech 2003-044.

[2] K. Hasegawa, "Commissioning of the J-PARC Linac", in these proceedings.

[3] K. Koseki *et al.*, "Pulsed Bending Magnet of the J-PARC MR", EPAC 2006, p. 1747.

[4] K. Fan *et al.*, "Design Study of a Very Large Aperture Eddy Current Septum for J-PARC", in these proceedings.

[5] M. Tomizawa *et al.*, "New Beam Optics Design of Injection /Fast Extraction /Abort Lines of J-PARC Main Ring", in these proceedings.

[6] M. Tomizawa *et al.*, "Design of Slow Extraction From 50-GeV Proton Synchrotron", EPAC 2002, p. 1058.

[7] K. Fan *et al.*, "High Field Septum Magnets for Slow Extraction System of J-PARC", in these proceedings.

[8] M. Yoshii *et al.*, "J-PARC Ring RF Accelerating Systems", in these proceedings.

[9] M. Yoshioka *et al.*, "Installation and Assembling of Accelerator Components for J-PARC 50 GeV Synchrotron", to be published in Proc. APAC07.

[10] T. Koseki *et al.*, "Commissioning Scenarios for the J-PARC Accelerator Complex", HB 2006, p.329.

[11] A. Molodozhentsev *et al.*, " Space Charge Effects for J-PARC Main Ring", in these proceedings.

[12] K. Ohmi *et al.*, " Study of Halo Formation for J-PARC MR", in these proceedings.

[13] M. Tomizawa *et al.*, " Design of Dynamic Collimator for J-PARC Main Ring", in these proceedings.

[14] A. Molodozhentsev *et al.*, " Correction Systems for J-PARC Main Ring", in these proceedings.

