PRESENT STATUS OF J-PARC MR SYNCHROTRON

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Abstract

The J-PARC (Japan Proton Accelerator Research Complex) is a joint project of High Energy Accelerator Research Organization (KEK) and Japan Atomic Energy Agency (JAEA). Presented in this paper is a recent status of a 50-GeV slow cycling main ring synchrotron (MR) of J-PARC. Installation and performance test of accelerator components are now in progress. Beam commissioning of the MR is scheduled to start in May 2008.

INTRODUCTION

The J-PARC facility consists of a 400-MeV linac, a 3.0-GeV rapid cycling synchrotron (RCS), a 50-GeV slow cycling main ring synchrotron (MR) [1, 2] and related experimental facilities for use in various fields of science and technology. The RCS will provide a 3.0-GeV, 1-MW proton beam to neutron and muon targets in the Materials and Life Science Experimental Facility (MLF). The MR will provide a 50-GeV, 0.75-MW proton beam to the Hadron Beam Facility (HD) and a neutrino production target in the Neutrino Facility.

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 of flywheel electric power system will be ready for only Phase II. Furthermore the Linac starts with a beam energy of 181 MeV, then the beam power of the RCS will be limited to 0.6 MW in maximum.

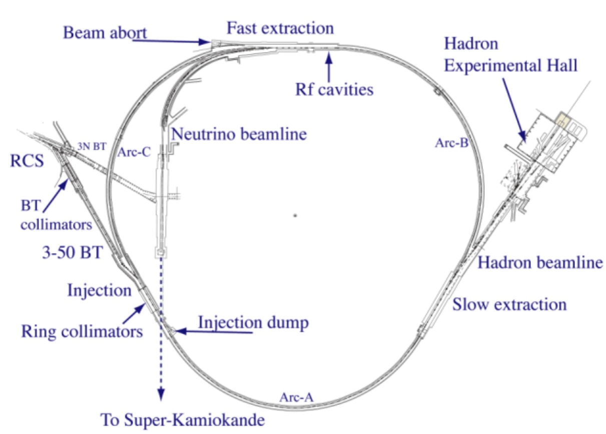

Figure 1: Plan view of MR and experimental facilities.

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". The slow extraction beam is delivered to the HD experimental Hall for particle and nuclear physics experiments. The fast extraction beam is delivered to the neutrino production target. The produced neutrino beam is sent to Super-Kamiokande, a large water Cherenkov detector, located 300 km west for long baseline neutrino oscillation experiment. The main parameters of the MR are summarized in Table 1.

Table 1: Main Parameters of MR.

Circumference [m]	1567.5
Superperiodicity	3
Repetition rate [Hz]	~ 0.3
Injection Energy [GeV]	3.0
Extraction Energy [GeV]	30/40(Phase I), 50 (Phase II)
Harmonic number	9
Number of bunches	8
Transition γ	j31.7
Typical tune	22.4, 20.8
Transverse emittance at inj. [πmm-mrad]	54
Transverse emittance at ext.[πmm-mrad]	10(at 30 GeV) 6.1(at 50GeV)
Rf frequency [MHz]	1.67 – 1.72

Beam commissioning is started from the upstream accelerators while the construction of the downstream accelerators and experimental facilities is in progress. The construction of the linac has been completed and beam commissioning started in November 2006. Recently, we have achieved beam acceleration up to the nominal beam energy of 181 MeV [3]. The construction of the RCS will be completed in April 2007. The beam commissioning of the RCS is scheduled to start in this September.

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

CONSTRUCTION STATUS

The MR lattice requires 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 mass production and magnetic field measurement of

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all these magnets have been completed [4]. More than 80 % of the magnets have been installed in the MR ring tunnel and aligned by the end of 2006 [5,6]. In addition, the MR has 186 steerings. Most of the steerings have been manufactured and delivered to the J-PARC cite.

For vacuum system, about 30 % of beam ducts in both the Arc-B, and Arc-s sections have been connected. A vacuum evacuation test is now well underway. Figure 2 shows the installed magnets and vacuum components in the Arc-B section.

The MR has 186 BPMs. Each BPM has a diagonal cut electrostatic pickup [7]. The position calibration of all the BPMs has been completed already. The position accuracy less than ±0.1 mm was achieved using the wire method. So far, about half of the BPMs have been installed.

Figure 2: Magnets and beam duct in the MR ring tunnel. The vacuum evacuation test is in progress.

For 3-50 BT, the beam transport line from the RCS to the MR, installation of 80 % of the magnets, and beam collimators has been completed. Beam ducts and BPMs are now being installed well.

PERFORMANCE TEST OF ACCELERATOR COMPONENTS

Injection and extraction devices

All the injection and extraction devices except for the slow extraction system have been fabricated and delivered to KEK/JAEA. Performance test of them is being carried out. Each device will be installed in the ring tunnel after the good reliability is confirmed.

The fast extraction section has six septum magnets (S1, S2, S30-S33). Each septum magnet is bipolar system and can extract the beam both inward and outward of the ring. They correspond to the neutrino beamline and the abort beamline, respectively. Figure 3 shows the septum magnets installed in an experimental hall for the performance test. Magnetic field in the extraction beam side and leakage field in the circulating beam side are being measured for all the septum magnets. In addition, vibration measurements of coil and beam duct are being carried out. We are also planning long-term continuous operation for about 1000 hrs. For the power supply of the septum magnets, EPICS based control system, the same scheme of the MR control system, has been built and being operated successfully. The fast extraction section is one of five areas in which the beam loss should be localized in the MR. Radiation maintenance scenario of the septum magnets is also investigated vigorously [5]. Installation of the septum magnets will be started in September 2007.

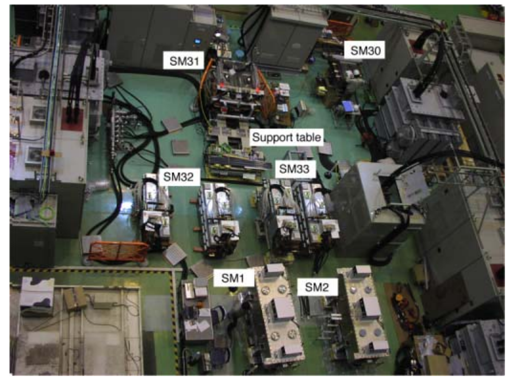

Figure 3: Fast-extraction septum magnets. SM31 is under testing.

Extracted beam from the RCS is switched to the MR and to the MLF by a pulse bending magnet. The requirements to magnetic field of the magnet 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, some correction schemes are necessary to achieve the requirements. We have already reported a method to compensate the eddy current effect by attaching phase advance-circuits to the magnet in parallel [8]. Recently, a new method has also been developed and tested. A field correction pattern to compensate the eddy current effect is made using pattern memory unit. The correction pattern is superimposed on the pattern input of feedback control loop of the power supply. By the new method, the measured rise time and flatness are improved sufficiently and satisfy the requirements. The pulse bending magnet will be installed in April 2007.

For the other devices, such as injection kicker/septum magnets, injection-dump kicker/septum magnets and fast extraction kicker magnets, their performances are being tested now in detail.

For the slow extraction system, detailed design of the components, electrostatic septum, septum magnets, bump magnets is in progress. They will be ordered and fabricated in Japanese fiscal year 2007.

MA Loaded RF Cavity

A high gradient rf cavity using magnetic alloy (MA) cores has been developed for the RCS and MR [9]. The maximum accelerating voltages required for the RCS and MR are 450 kV and 280 kV, respectively. In order to obtained the voltages, field gradient larger than 20 kV/m is necessary.

In 2006, we have improved the manufacturing process of the MA cores to increase reliability of operation [10,11]. As already reported [2], we observed some damages on the MA cores in test operation with 25 kV/m. Detailed study shows it is reasonable to assume that the core was damaged by electric field and that the damages occurred due to poor insulation between the MA layers. We have investigated the manufacturing process of the core and improved the winding process so as not to decrease a DC resistance of the core. By this improvement, impedance of the cores is increased about 10 %. Another improvement is a treatment of cut core surface. In the MR, the MA cores are loaded to the cavity with cut-core configuration. The core is cut by water jet and then the cut surfaces are polished. In order to improve surface quality, we adopt diamond polishing. The core surfaces are polished with fine diamond powder without any oils and acids.

Figure 4 shows the cavities under long-term operation for test of the cut-cores. The cut-cores, which manufactured by the improved processes, are installed on the accelerating gap side. So far six cores have been tested for 2000 hrs and 12 cores for 1000 hrs without any serious troubles. These cores are now ready to install. Installation of the cavity is planned to start in September 2007.

Figure 4: The cut-core loaded cavities under long-term continuous operation with nominal voltage of 15 kV/gap and 60 % duty.

Magnet power supplies

Performance test of steering power supplies has been carried out. Required tracking error of less than 0.1 % was obtained with 4 msec-step pattern control. Electric and magnetic noises due to the steering system were also investigated. Recently, performance test of quadrupole power supplies has been started.

BEAM COMMISSIONING PLAN

All the components will be installed in the MR tunnel by December 2007 except for the slow extraction components. At first, we will start the off-beam commissioning. All 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. In order to allow hands-on maintenance of the hardware components, beam loss should be controlled as low as reasonably achievable. The maximum beam loss at the regular zones (not hot zones) is assumed to be less than 0.5 W/m [5]. Then we adopt the following approaches for the beam commissioning; 1) the beam tuning is started with very low intensity to minimize the activation of the components. 2) beam transport to a proper beam dump should be established at first, and then fine tuning is performed.

Beam commissioning of the MR is divided into three stages [12]. The first stage is from May to June 2008. Beam transportation through the 3-50 BT, beam Injection, establishing closed orbit, and beam acceleration will be studied. From July 2008, the MR will be shutdown, and we will install the slow extraction devices. In addition, installation of superconducting magnets of the Neutrino beamline will be started. The second stage of the beam commissioning is scheduled from Nov. 2008 to Jan. 2009 although the schedule is not completely fixed yet. In this stage, slow extraction system and beam transport to the hadron beamline will be commissioned. The third stage is scheduled to start from April 2009. Commissioning of the neutrino beamline will start in this stage.

SUMMARY

The construction of the MR is now under way. The off beam commissioning is scheduled to start from December 2007 and beam commissioning from May 2008.

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