BEAM COMMISSIONING OF J-PARC MR

T. Koseki# and J-PARC MR group, J-PARC Center, KEK and JAEA, Tokai, Ibaraki, Japan

Abstract

Beam commissioning of the J-PARC main ring synchrotron (MR) has started in May 2008. 3-GeV beam extracted from the rapid cycling synchrotron (RCS) is injected into the MR and circulated with rf capture, and then extracted to a beam dump. The results of the first stage commissioning run from May to June 2008 are presented.

INTRODUCTION

The J-PARC accelerator [1] comprises a 400 MeV H^- linac (181 MeV at the initial stage), a 3.0-GeV RCS, a 50-GeV MR and related experimental facilities. The RCS provides the proton beam to neutron and muon targets in the materials and life science experimental facility (MLF). A part of the beam extracted from the RCS (typically four pulses every 3 sec) is injected into the MR, which accelerates the beam up to 50 GeV (30 GeV at the Phase 1 of the construction project) and delivers the beam to the hadron beam facility (HD) using a slow extraction system and to a neutrino production target in the neutrino beamline using a fast extraction system.

The beam commissioning of the J-PARC facility is started from the upstream accelerators while the construction of the downstream accelerators and experimental facilities is in progress [2]. The beam commissioning of the linac and the RCS has started in November 2006 and October 2007, respectively. The linac provides quite stable beam for the commissioning of the downstream facilities [3]. The RCS completes the initial tuning of basic parameters and begins to study for the operation with higher beam intensity [4]. Beam commissioning of the MR and the MLF has started in May 2008 on schedule.

MR OVERVIEW AND COMMISSIONING SCHEDULE

Figure 1 shows a layout of the MR and the experimental facilities. The MR has a three-fold symmetry and a circumference of 1.6 km. Each arc section consists of eight 3-FODO arc modules. The arc module has a missing bend cell, which makes imaginary transition energy to avoid transition crossing during acceleration. The three dispersion-free 116-m long straight sections, each of which consists of 3-FODO section and matching sections, are dedicated to "injection and beam collimators", "slow extraction", and "rf cavities and fast extraction".

The MR has 96 dipoles, 216 quadrupoles with eleven families, 72 sextupoles with three families and 186 steerings (93 for horizontal and 93 for vertical). All the magnets are excited by IEGT/IGBT based power supplies. For the rf system, the high gradient and broadband cavity using magnetic alloy (MA) cut-cores is adopted [5]. The number of rf system is four at the initial stage of commissioning.

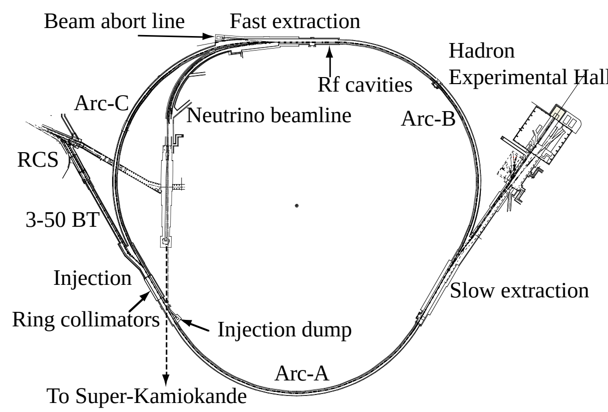

Figure 1: Layout of MR and experimental facilities.

Figure 2 shows a schematic view of the injection and collimator section. The beam is injected into the MR by the injection septa I, II and injection kickers. At the downstream of the collimators, we have a 3-GeV injection beam dump with a 3-kW capacity. The dump kickers and dump septa I and II extract the beam to the beam dump.

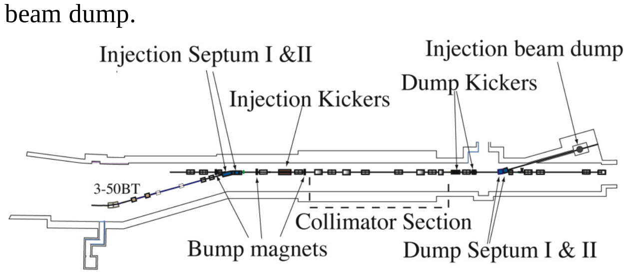

Figure 2: Injection and collimator section.

The beam diagnostics available during initial beam commissioning of the MR are 186 BPMs which can be used for both COD and turn-by-turn measurements by switching circuits, 11 current monitors, three transverse profile monitors, 238 beam loss monitors, horizontal and vertical tune meters and so on [6].

Beam commissioning of the MR is divided into three stages. The first stage took place from May to June 2008. Beam transportation through the transport line between the RCS and the MR (3-50 BT) and establishing closed orbit at the injection energy of 3 GeV were studied in this stage. From July to November 2008, the MR is shutdown and we install slow extraction devices and some of fast

#tadashi.koseki@kek.jp

extraction devices. Superconducting combined function magnets of the neutrino beamline are also installed during the shutdown. The second stage of the beam commissioning is scheduled from Dec. 2008 to Feb. 2009. Beam acceleration from 3 GeV to 30 GeV, beam extraction to the beam abort line using the fast extraction system, and beam transportation to the hadron beamline will take place in this stage. The third stage is scheduled from April 2009. Beam commissioning of the neutrino beamline will starts in this stage.

RESULTS OF THE 1ST STAGE COMMISSIONING

In order to minimize the activation of the accelerator components, the first stage commissioning was performed with a very low beam current and a low repetition. The beam parameters of the linac were as follows: a peak current of 5 mA, a macro pulse width 0.1 msec and a chopped beam width 280 nsec. In this case, the beam intensity in the RCS is 4×10^{11} ppb, which corresponds to 1 % beam intensity of the nominal beam power. The beam repetition was a single-shot (beam-on-demand) or 0.275 Hz, a typical cycle for the slow extraction operation. The RCS was operated in the single bunch mode. The transverse emittance and momentum spread of the extracted 3-GeV beam from the RCS were estimated to be 15 πmm.mrad and 0.2 %, respectively.

The first stage commissioning has started on May 19, 2008. It took the first four days to achieve the first order commissioning goals, i.e. beam transportation via the 3-50 BT, beam injection, beam circulation with rf capture and extraction to the injection beam dump with the injection energy of 3 GeV. After the achievement, we performed detailed beam studies, such as fine tuning of the beam diagnostics, COD measurement and correction, chromaticity measurement and correction, tune survey, measurements of orbit parameters, rf tuning and so on. Total operation time of the first stage was about 12 hours x 12 days.

For beam injection into the MR, we adjusted the injection kickers, the injection septum I and vertical steerings in the 3-50 BT to correct the injection error. All the BPMs were used in the turn-by-turn mode for monitoring the betatron motion of the first several turns just after the beam injection. The field of dipoles was also adjusted to match with the injection beam momentum. Figure 3 shows mountain plots of the vertical beam profile measured by the residual gas ionization profile monitor (IPM) [6] after the injection error correction. The stable beam positions and profiles show the injection error is sufficiently small. From the measured profile, size of the beam core is roughly estimated to be ± 20 mm and vertical emittance is calculated to be 14 πmm.mrad using a designed value of the beta function. Horizontal beam profile was measured by flying wire profile monitor [6]. A preliminary measurement shows that the horizontal beam emittance was 20-28 πmm.mrad at 0.6 sec after the beam injection.

Figure 4 shows a result of dispersion function measurement for 1/3 of the ring. The *dp/p* dependence of the closed orbit was measured by changing rf frequency after the beam injection. As shown in the figure, the measured results agree well with the design.

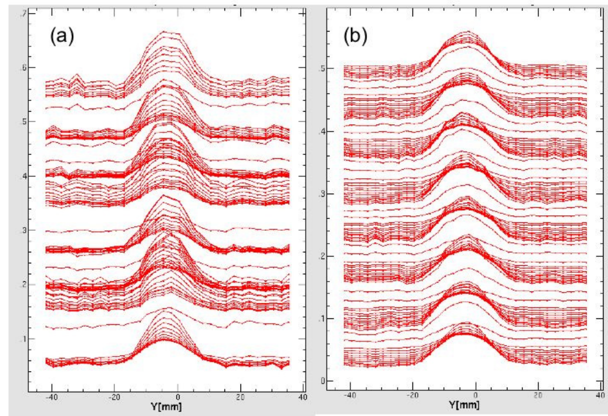

Figure 3: Mountain plots of vertical beam profile for (a) 16-23 turns and (b) 72-79 turns after the beam injection.

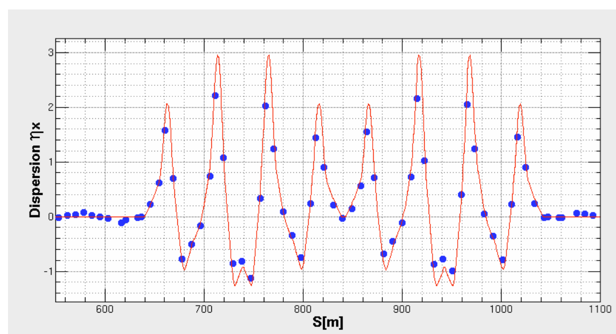

Figure 4: Horizontal dispersion function for one super-period. The solid line shows design and closed circles show measured results.

Figure 5 shows averaged beta function at the positions of each quadrupole family. The beta function was obtained by changing the quadrupole strength and measuring the tune shift. The measurement error is estimated to be about 10 %. The measured and designed values agree well within the error bars except for the QFP family. The reason of the discrepancy of the QFP family has not become clear yet.

The rf system adopts a full-digital low-level RF control scheme. It makes possible to generate the highly accurate and stable rf voltage in the cavities with a good reproducibility [7]. We adjusted the rf frequency to match with the main dipole field monitoring longitudinal oscillation of the beam bunch. Figure 6 shows mountain plots of longitudinal beam profiles measured by wall current monitor (WCM) after the frequency tuning. In this figure, the beam is extracted at 1000 turns after the injection. The beam is captured at the center of the rf bucket and almost no dipole oscillation is observed.

Although the quadrupole oscillation due to mismatching between the rf voltages of the RCS extraction and the MR injection is observed, we have also demonstrated already that the quadrupole oscillation can be suppressed by adjusting the rf voltage of the MR cavities just after the beam injection.

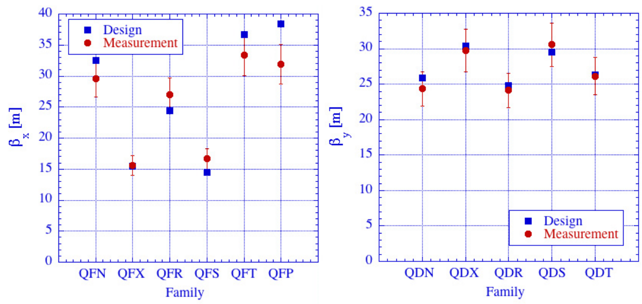

Figure 5: The beta function for each quadrupole family.

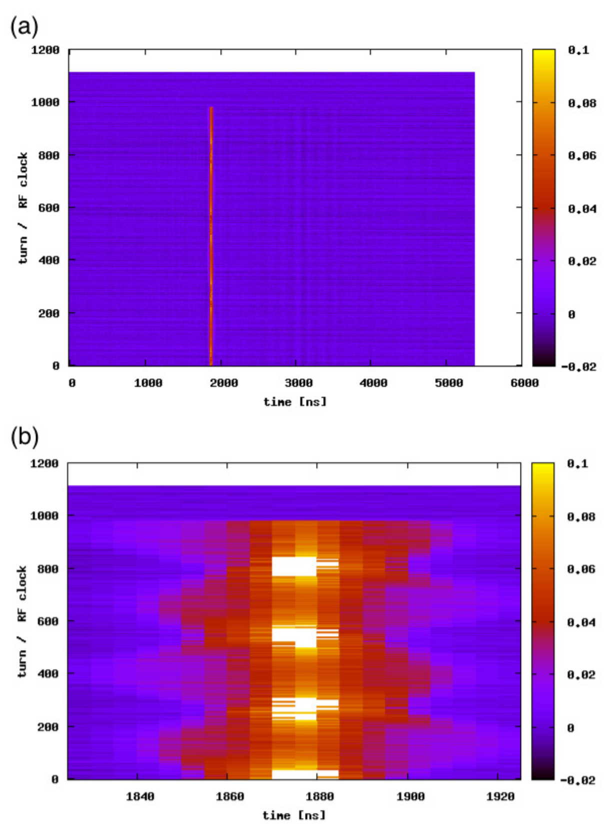

Figure 6: Mountain plots of longitudinal profile measured by the WCM. Time ranges are (a) 5.4 msec, (b) 100 nsec.

On the other hand, some hardware problems have been confirmed in the first stage commissioning. Current ripples of the dipole and quadrupole power supplies caused large horizontal orbit ripple ($\Delta x \sim 3$ mm peak-to-peak in max.) and tune fluctuation ($\Delta \nu \sim \pm 0.03$), respectively. After the commissioning run, we are carefully investigating the circuit design of the power supplies and making some improvements to reduce the ripples. Other problem is orbit shifts due to leakage fields of the injection and dump septa. We are planning to add magnetic shields to the circulating beam duct of the septa during the shutdown period from July to November of 2008.

Figure 7 shows residual activation surveyed 1.5 days after the shutdown of the first stage commissioning. The activation was measured by detectors at contact with the beam duct. The horizontal axis of the figure indicates the MR address, which corresponds to serial number of all the 216 quadrupoles. The peak around the address 10 is caused by the beam loss at the collimator section [8]. The most of beam losses concentrated on the collimators as we expected.

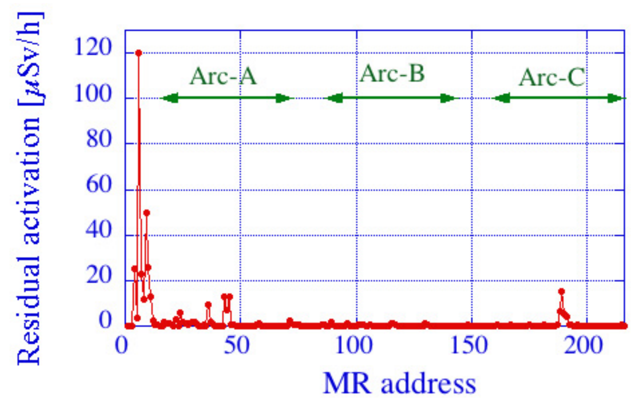

Figure 7: Residual activation after the first stage runs.

SUMMARY

Beam commissioning of the MR has started on May 2008 on schedule. It took four days to achieve the first order commissioning goal, injection, circulation with rf capture and extraction to the injection beam dump. We also successfully performed the COD correction, chromaticity correction, optics measurements and so on. The next milestone of the MR commissioning is acceleration to 30 GeV and beam extraction to the HD beamline in the second stage of beam commissioning. It will take place from December 2008 to February 2009.

REFERENCES

[1] "Accelerator Technical Design Report for J-PARC", KEK-Report 2002-13 and JAERI-Tech 2003-044.
[2] T. Koseki *et al.*, HB 2006, p. 329.
[3] M. Ikegami *et al.*, "Transition from Commissioning to Operation in the J-PARC Linac", these proceedings.
[4] H. Hotchi *et al.*, "Status of J-PARC Commissioning", these proceedings.
[5] M. Yoshii *et al.*, PAC07, p. 1511.
[6] K. Satou *et al.*,"Beam Diagnostic System of the Main Ring Synchrotron of the J-PARC", these proceedings.
[7] F. Tamura *et al.*, EPAC08, p. 364.
[8] T. Toyama *et al.*, "Beam Loss Monitoring Using Proportional Counters at J-PARC", these proceedings.