RAPID CYCLING SYNCHROTRON OF J-PARC

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Abstract

JAERI and KEK are constructing the J-PARC facility. The accelerator complex consists of a 400-MeV linac, a 3-GeV rapid cycling synchrotron ring (RCS) and a 50-GeV synchrotron ring (MR). The RCS accelerates a 400-MeV proton beam from the linac up to 3 GeV and supplies the beam to the MR and the Material and Life science Facility (MLF). The MLF has a neutron production target in order to produce a high intensity neutron beam. For this purpose, the RCS aims to generate a high power proton beam of 1 MW. The construction of the RCS started in 2002 and will be finished in 2007.

INTRODUCTION

All the components were ordered in FY2002 and FY2003. The budged is started in FY2002 and will be finished in FY2006. The building will be accomplished by April 2005. The machine Installation will be started in May 2005. The overall test from the center control room will be carried out from October 2006. The beam commissioning of the RCS will be started in May 2007 and the beam will be extracted to the MR and the MLF in October 2007.

Fig. 1 shows a cut view of the RCS building. The main tunnel means the machine tunnel. The sub-tunnel is used for the utilities of the cables and the water-cooling pipes. The main building of the RCS is used for the power supply, the control and the utilities. Now this building is under construction up to the B1 floor.

The main parameters of the RCS are shown in Table 1. The injection energy is 181 MeV on the day one in 2007. The energy recovery of the 400-MeV injection will be started in 2008 and finished in 2010. The beam power of 1 MW will be achieved in the 400-MeV injection. The RCS is operated in 25 Hz. The painting method is used for the beam injection. The beam of the 600-pulse train is injected from the linac into two rf-buckets of the RCS during 500 μs.

Table 1: Main parameters

Circumference	348.333 m
Injection Energy	0.181/ 0.4 GeV
Extraction Energy	3.0 GeV
Beam Power	0.6 / 1 MW
Particle Per Pulse	5×10^{13} / 8.3×10^{13}
Repetition Rate	25 Hz
Harmonic Number	2
Average Current	200 / 333 μA
Circulating Current at extraction	6.7 / 11.1 A
Super Periodicity	3
Unit Module	3-Cell Straight + 3-Cell FODO x 2 module arc
Nominal tune (x/y)	6.72 / 6.35
Natural Chromaticity (x/y)	-8.5 / -8.8
Transition Gamma	9.14
Momentum Compaction	0.012
Transverse Emittance (from Linac)	4π mm-mrad
Painting Emittance	216π mm-mrad
Extraction Emittance to MLF	81π mm-mrad
Extraction Emittance to MR	54π mm-mrad
Collimation Emittance	324 π mm-mrad
Physical Aperture	>486π mm-mrad
Longitudinal Emittance (Inj./Ext.)	3.5 / 5 eV s
Tune Shift at injection	-0.20

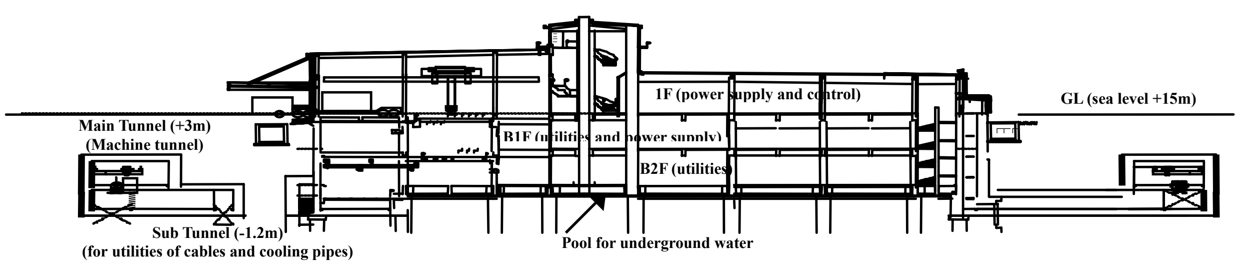

Figure 1: A cut view of the RCS building.

GENERAL DISCRIPTION

Lattice Design

The RCS has a threefold- and mirror- symmetric lattice [1]. Each super-period consists of two 3-DOFO arc modules with missing bends and a 3-DOFO insertion. Fig. 2 Shows the RCS layout. Each arc module has a missing-bend cell, where the horizontal dispersion function has the maximum value, raising the transition gamma to 9.14 compared to normal FODO lattices for an easier RF operation. The missing-bend cells are suitably utilized for chromaticity correction magnets and the longitudinal primary collimator. The horizontal beta function is suppressed there for effective longitudinal collimation. The insertions have no dispersion. The injection and collimation systems are in the first straight section. The H^- injection system uses the first one and a half cells and the collimator system occupies the rest. The extraction system is in the second straight section and the RF cavities in the third one.

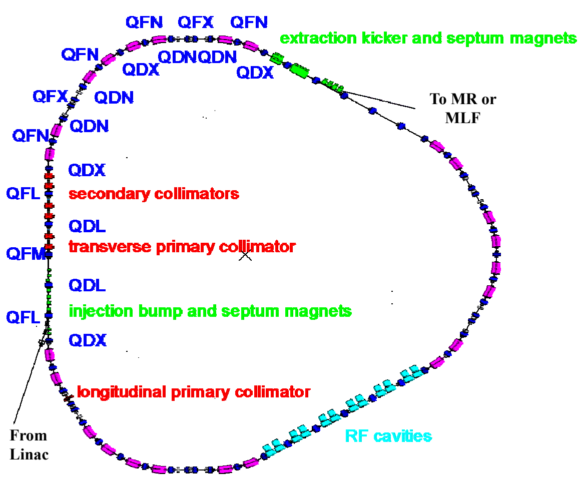

Figure 2: RCS Layout

Injection and Extraction Scheme

308-turns H^--beam will be repeatedly filled in the RCS with the charge-exchange injection through the carbon foil. The 618 pulse-trains with 8.3 x 10^{13} protons will be injected into two rf buckets during 500 µs. A schematic layout of the H^- injection system in the horizontal plane is shown in Fig. 3. The eight bump magnets are put into two categories according to their roles, that is, four closed orbit bump magnets (BMC) for the charge-exchange injection and four other closed orbit bump magnets (BMP) for the painting injection.

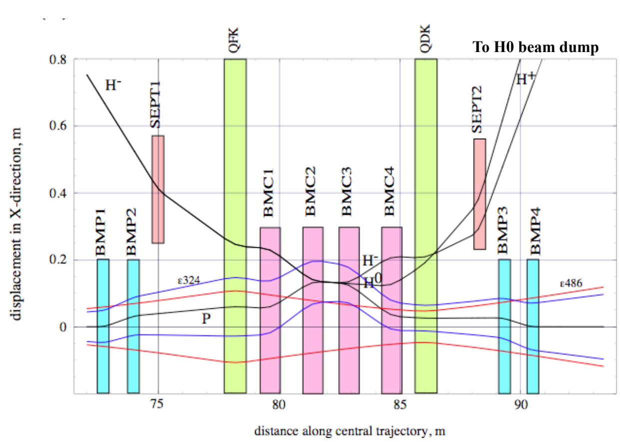

Figure 3: Outline of the injection bump orbit

The key issue of the RCS is to control and localize the beam loss and to decrease the uncontrolled loss. The average beam loss should be kept within 1 watt per meter in order to take hands-on maintenance. Accordingly, we have designed the beam-collimation system to localize the beam loss. The beam halo is scattered by the primary thin tungsten collimators, and the scattered particles is absorbed in the secondary copper block collimators. The secondary collimators are covered with the iron and concrete shelter. We designed the collimators so that the total beam loss was 4kW at most. By the estimation with the STRUCT code, we can localize 98% beam losses in the collimator region for the optimal parameters [2]. Only two percent of the total loss is lost in the other region.

The RCS is equipped with a fast extraction system consisting of eight kickers and three septum magnets. The first three half-cells of the straight section are allocated for the system, as shown in Fig. 4.

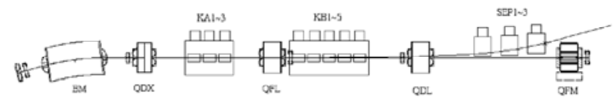

Figure 4: Schematic view of extraction system

MACHINE STATUS

Main magnet and Power supply

The issues of the main magnets are the reduction in the eddy-current effect and the rad-hard insulator [3], [4], [5]. We found two solutions for the issues. One is the stranded wire and the slits with the end plates and the pole ends. The other is the impregnation with the polyimide resin for the insulator, the rigidity and the high heat-conduction of the coil. The optimisation of the number, the position and the depth of the slits is simulated with the code and confirmed by the measurement. The 100% filling with the polyimide resin are achieved by the impregnation in the vacuum tank and by the precise temperature control. The choke coils and the capacitor array for the resonant power supply are mass-producing now.

RF System

The high-gradient magnetic alloy loaded cavity is used in the RCS and MR [6]. The characteristics are the maximum gap voltage of 43 kV, the direct cooling of the core and 5- kW loss per one core. The development of the cavity has been done successfully. The confirmation of the final design is ongoing. The anode power supplies are under construction. The high power test of the first three is ongoing. The final amplifier has been already constructed. We achieved the maximum output power of 1.2 MW. We have constructed and tested two types of grid-drive rf amplifier with the MOSFET. We will soon decide the final design.

Vacuum System

We have two requirements for the vacuum system. One is the minimization of maintenance and the other is the minimization of the eddy-current effects. The first means high reliability and long lifetime. They can be possible by realizing ultra-high-vacuum less than 10^{-7} Pa. To achieve lower outgas and rad-hard, we select the Ti chambers in general and the alumina-ceramics chambers in the magnet. The perturbation of the magnetic field must be less than $5x10^{-4}$. The almina-ceramics chambers minimize the eddy-current loss. The design and construction of the vacuum system and ceramics chamber was started in 2002 [7]. The production process was established and the ceramics-chamber sintering is ongoing. Fig. 5 is the ceramics chamber of the quadrupole. The diameter is about 260 mm and the length is 1200 mm. The maximum diameter for the largest bore quadrupole is over 400 mm. To make long chamber, we joint two or more chambers with brazing. The ceramics chambers for the quadrupole are jointed with two chambers. In the case of the dipole chambers, four ceramics chambers are jointed correctly and the length is over 3 meters. The titanium nitride is coated at the inside of the ceramics chambers before the joint process, to reduce the secondary-electron emission from the surface. The rf shield of copper is orderly electrotyped to decrease the impedance. The capacitors connect between the stripes and the flange to bypass the image current induced by the beam. We use the Ti flange to reduce the radio-activation.

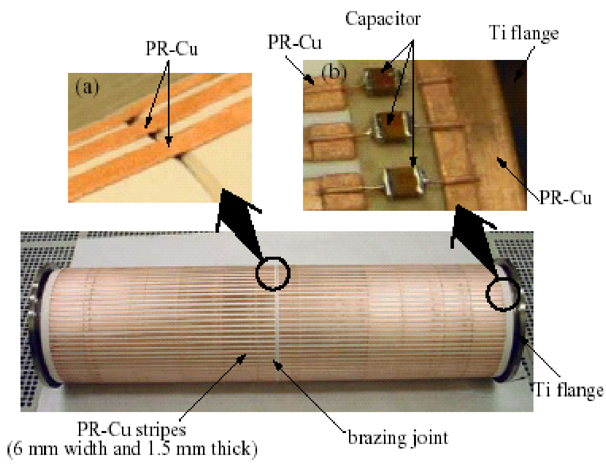

Figure 5: Ceramics chamber of quadrupole

Injection and Extraction System

The eight kicker magnets are used for beam extraction. Three of them are constructing now. The power supplies were completed and have been tested enough and improved a little. The gap height is about 160 mm and the gap width is about 280 mm.

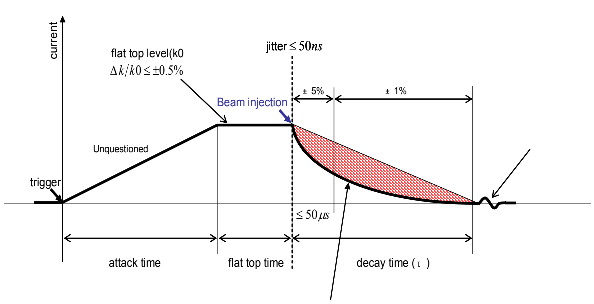

Figure 6: Current waveform of horizontal painting bump

The bump system for the beam injection has two vertical painting bump, four horizontal painting bump and four horizontal shift bump magnets. The Fig.6 is the current waveform of the horizontal painting bump. The slant-line area is used for painting. The area has many difficulties for the power supply and the essence for our painting process.

Two and three septum magnets are used for the beam injection and the extraction, respectively. The coils are made of the hollow conductor with the ceramics insulator. The maximum excitation current is 12,000 amperes DC. We confirmed the process and cooling efficiency by the R&D magnet in 2003.

Monitor and Control System

All the beam monitors have been ordered in FY2003. The design is in progress. The control system and the personnel protection system (PPS) were ordered in FY2003. The production will be started from 2004.

FUTURE PLAN

We have the recovery plan of the 400-MeV injection to achieve 1 MW. The plan will be scheduled from 2008 to 2010. One rf cavity and one power supply will be added for the compensation of 1-MW beam loading. We will upgrade the power supplies of the septum and bump magnets for the 400-MeV injection.

SUMMARY

The ordering of the accelerator components has been finished mostly (about 96%). The machine construction is started from 2002 and is mostly doing well. The beam commissioning of RCS will be start in May 2007. The construction of the 400-MeV injection is scheduled from 2008 to 2010.

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