RF ACCELERATION SYSTEMS FOR THE JOINT PROJECT

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Abstract

A RF acceleration system has been designed for the Joint Project for High-Intensity Proton Accelerators in Japan. A new type of RF cavity using MA(Magnetic Alloy) cores will be used for synchrotrons in order to achieve the high field gradient for the acceleration. The status of R&D on the cavity is also reported.

1 INTRODUCTION

The accelerator complex of the Joint Project[1,2] consists of a 400 MeV linac, 3 GeV PS and 50 GeV PS. The accelerators provide high intensity proton beams for high-energy physics, solid state physics, biology and other fields. The accelerators will be constructed at the JAERI(Japan Atomic Energy Research Institute)-Tokai site. The 3 GeV PS is a rapid-cycling synchrotron and will provide 1MW proton beams for the pulsed neutron source and 15.6μA for the 50GeV PS, respectively. The main parameters of the synchrotrons are listed in Table 1.

Table 1: Main parameters

	3GeV PS	**50GeV PS**
Rep. Rate	25 Hz	0.3 Hz(3.42 s)
Rise time	20 ms	1.9 s
Harmonics	2	10
Circumference	1567.5 m	313.5 m
Energy	0.4-3 GeV	3-50 GeV
RF frequency	1.36-1.86 MHz	1.86-1.91MHz
Max. Voltage	420 kV	280 kV

2 RF SYSTEM

2.1 RF Voltage

The RF voltage patterns for both rings has been calculated using the computer code, RAMA[3]. To reduce the space charge tune shift at injection in the 3 GeV PS, the beam is injected with the momentum offset of 0.1-0.3 % respect to the synchronous value and the longitudinal emittance will be increased up to 3.2 eVs. The 3 GeV PS requires the maximum voltage of 420 kV for the acceleration of the beam having a large emittance. The large emittance also causes the maximum momentum spread of 1 % during few ms after injection. Figure 1 shows the RF voltage, bunching factor, filling factor, momentum spread and incoherent tune shift of the 3 GeV PS. The emittance of a beam bunch which goes to the 50 GeV PS will be increased up to 10 eVs during the acceleration for the relaxation of the space charge force and to avoid the instability in the 50 GeV PS. Figure 1 shows that the momentum spread is increasing after 12 ms because of the controlled emittance growth.

The two bunches of the 3 GeV PS are injected four times to the 50 GeV PS. Two buckets are remained empty to allow the fast-extraction kickers to turn on. The maximum RF voltage of 280 kV is constant during accumulation and acceleration. Figure 2 shows the RF voltage, bunching factor, filling factor, momentum spread and incoherent tune shift of the 50 GeV PS.

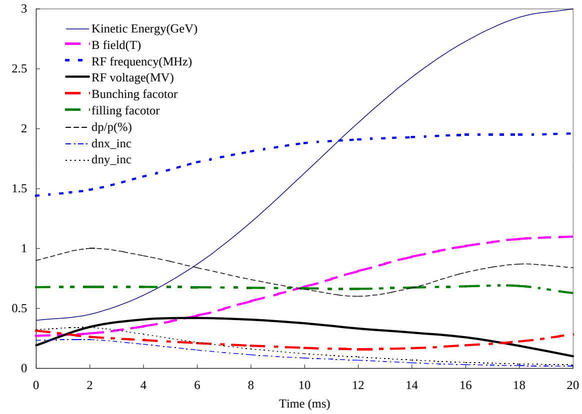

Figure 1: The RF voltage, bunching factor, filling factor, momentum spread and incoherent tune shift of the 3 GeV PS

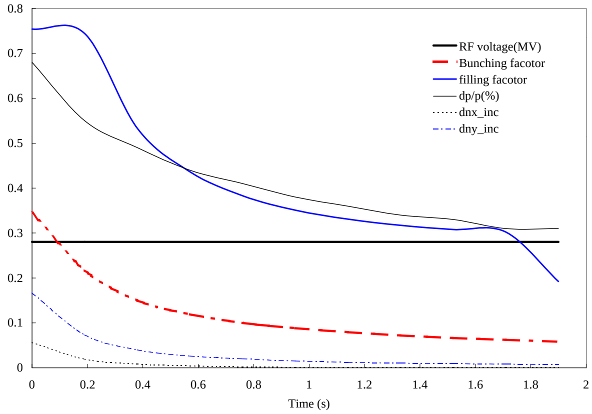

Figure 2: The RF voltage, bunching factor, filling factor, momentum spread and incoherent tune shift of the 50 GeV PS

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2.2 MA Cavity

The Magnetic Alloys(MA), for example, FINEMET, will be used for the magnetic cores of the RF cavities of both synchrotrons[4]. The advantages are followings;

- Stable characteristics under the high magnetic field and high voltage. In other words, high field gradient for the acceleration is available.
- Because of low Q value, the tuning circuit is not necessary and the feedback system becomes simple and stable. Using a cut-core technique, the quality factor of the cavity is variable by changing the gap height between two halves of core and an optimum Q-value can be chosen.

The parameters of the MA cavity for both synchrotrons are listed in Table 2. The resonant frequency of the cavity is about 2 MHz to minimise the total power of the RF system that includes the beam loading. By choosing the optimum Q-value and frequency, the phase angle of the generator current respected to the RF voltage will be minimum. Because the cavity for the 3 GeV PS has low Q value of 3, it will generate both fundamental and second harmonic frequencies at the gap simultaneously. The amplitude of the second harmonic frequency will be gradually reduced according to the increase of the beam energy. When the RF voltage becomes maximum, the amplitude of the second harmonics will be zero.

Table 2: Parameters of MA cavity

	3GeV PS	**50GeV PS**
Number of cavity	10	6+1
Max. Voltage	42 kV	46.7 kV
Number of gaps	3	3
Impedance	2.1 kΩ	3 kΩ
Quality factor	3	10
Duty	50 %	59 %
Number of cores	24	24
Length	1.65 m	1.65 m
Max. Power loss	420 kW	363 kW
Averaged loss	105* kW	214 kW
Loss per core	4.9 kW	8.9 kW
Outer diameter of core	90 cm	90 cm
Inner diameter of core	36 cm	25 cm
Thickness of core	2.6 cm	2.6 cm
Diameter of beam pipe	24.6 cm	14 cm
Power Density in core	0.35 W/cc	0.58 W/cc

*Considering the RF voltage pattern (see Fig. 1), the power loss becomes a half of the maximum power loss multiplied by the duty factor.

2.3 Amplifier

Each cavity of both synchrotrons will be driven by a push-pull amplifier using two 600 kW class tetrode tubes. A 5 kW solid-state amplifier will be used to drive the main amplifier. Both main and solid-state amplifiers have a wide bandwidth of 4 MHz to drive dual frequencies.

2.4 DDS and Low Level

A DDS system will be used to generate the RF frequency, accurately. A feed forward compensation system[5] will be used to manage the heavy beam loading. For the 3 GeV PS, the beam loading by the higher harmonics components[6,7] is not negligible. The feed forward system includes some higher harmonic frequencies to cancel them. For the 50 GeV PS, the beam loading by the higher components is not significant because of high Q-value. However, the periodic transient is the significant problem as there will be two empty buckets in the ring. To compensate the transient beam loading, the feed forward scheme will also used.

3 R&D STATUS

A test cavity using the cut-core has been developed and operated using a 1 MW class push-pull amplifier. Figure 4 shows the photo of the cavity and amplifier. In the cavity, 6 cores, which have the outer diameter of 95 cm, can be installed. The cores are set in the water tank, directly for the efficient cooling. The diameter of the cavity is as large as that of the Joint Project. The unloaded Q-value of the cavity is 5 and the resonant frequency is 1.95MHz. In the amplifier, two set of 600 kW tetrode, TH558, are installed. To drive the main amplifier, a 5 kW solid state amplifier is used.

For the low duty operation, the maximum voltage of 28 kV has been obtained. The waveform of the gap voltage was measured for the frequency range of 1.4 to 2 MHz. The significant waveform distortion was not observed although the resonant frequency was fixed and the tuning system was not used. The CW operation has been performed up to 10 kW per core that is larger than the required power dissipation for the Joint Project.

The cavity will be modified and installed in KEK 12 GeV PS as a second harmonic RF to relax the space charge effect during the injection period. The resonant frequency of the cavity will be 12 MHz by enlarging the gap between the halves of core. And, a fully fluorinated perfluorocarbon liquid will be used as a coolant instead of water to increase the resonant frequency. A new low-level system using DDS will be installed for the dual harmonic experiment[8].

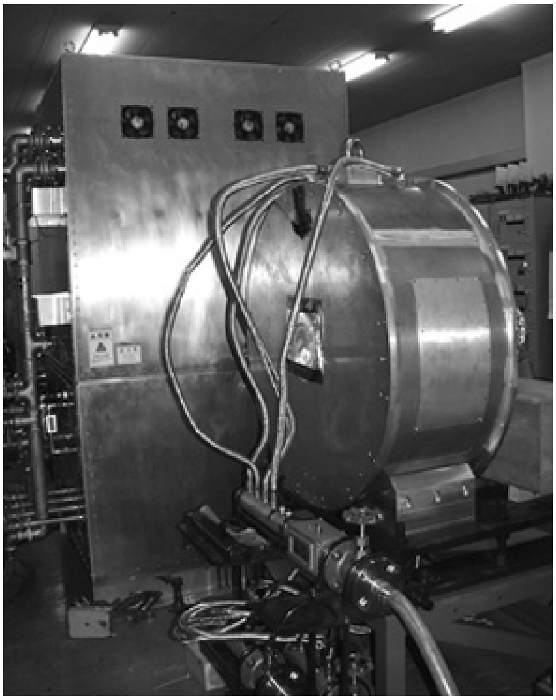

Figure 3: The test cavity and 1 MW power amplifier

4 CONCLUSIONS

RF system for the 3 GeV and 50 GeV Proton synchrotrons of Joint Project has been designed. The high field-gradient cavity will be used for both rings. The test cavity has been developed. The high power test has been performed.

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