A Broad Band RF Cavity for JHF Synchrotrons

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Abstract

A broad band RF cavity in which *FINEMET* cores are loaded has been developed for JHF (Japanese Hadron Facility) synchrotrons. The *FINEMET* is a Fe-based soft magnetic alloy composed of amorphous and ultra-fine grain. It has a low Q value, high shunt impedance and permeability. Acceleration voltage of 8.5kV per gap has been achieved with 12 cores. Acceleration voltage of 10kV per gap has been achieved with an isolated RF pulse for a barrier bucket scheme.

1 INTRODUCTION

The main parameters of the two synchrotrons in JHF (Japanese Hadron Facility)[1] are listed in Table 1.

Table 1 : Main parameters

	3GeV booster	50GeV ring
average beam current	200μA	9.6μA
average circulating current	7A	7A
repetition rate	25 or 50Hz	0.3Hz
accelerating voltage	420kV	270kV
harmonic number	4	17
RF frequency	2~3.4MHz	3.4~3.5MHz

The requirements for the JHF RF cavity are as follows. Because of the space limitation for the RF apparatus, acceleration voltage of more than 10kV/m is required for the 50GeV ring. About 13kV/m is needed for the 3GeV booster. For the stable acceleration under the high beam current, the shunt impedance seen by the beam should be less than 1kΩ/m. In order to sweep RF frequency tuned to momentum of proton, the shunt impedance should be high enough over the wide frequency range. Because the growth rate of the coupled bunch instability is very fast for a high Q parasitic resonance[2], there should be no high Q resonances. A test cavity[3] has been fabricated so as to study the advantages of the broad band cavity. This paper presents the results of the measurements with the test cavity.

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2 TEST CAVITY

2.1 *Characteristics of* FINEMET

The test cavity was loaded with 24 pieces of *FINEMET*. They are Fe-based soft magnetic alloys composed of amorphous and ultra-fine grain. They are made of very thin tape which is coated with SiO_2 for insulation. The *FINEMET* has very high permeability and a low Q value[4]. The Curie temperature of the *FINEMET* is high enough, as 570 °C, for stable at high temperature. The shunt impedance of the *FINEMET* cores remains constant over a wide range of RF magnetic field strength. On the other hand that of ferrite decrease above about 80 gauss. Typical parameters of a *FINEMET* core are listed in Table 2.

Table 2 : Parameters of a *FINEMET* core

inner diameter	300mm
outer diameter	670mm
thickness	25mm
permeability@3.4MHz	1550
Q @3.4MHz	0.63
Rp @3.4MHz	83Ω

2.2 *Components of the Test Cavity*

The schematic view of the test cavity and the RF amplifier is shown in Fig. 1. The length of the test cavity is 1.5 meter. The test cavity have two acceleration gaps which are connected with each other by bus bars. It consists of four cells of *FINEMET* cores. Each cell is made of six cores. The RF power is inductively coupled with a one-turn-loop wound around 12 cores. The shunt impedance of the cavity is relatively high for the wide frequency range from 2MHz to 4MHz. Therefore it is not necessary to have a tuning loop. The RF amplifier has a tetrode, 4CW30,000A. Each piece of the *FINEMET* has a water pipe on the inner fringe for cooling. Also four fans and couple of water jacket attach on the cover of the cavity.

3 MEASUREMENTS

3.1 *Impedance*

We have tried to feed RF with a one-turn-loop and a two-turn-loop. The one-turn-loop was wound around

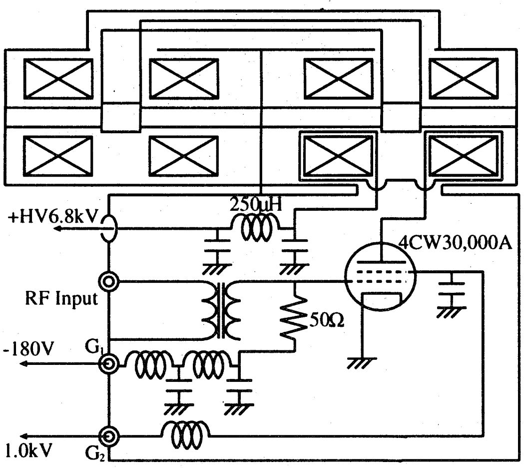


Figure 1: Schematic view of 30kW amplifier and test cavity.

12 cores and the two-turn-loop was surrounded 6 cores twice. The one-turn-loop was superior to the two-turn-loop because the frequency of a parasitic resonance was higher and its amplitude was less.

The impedance of the cavity was measured with a network analyzer. The measured impedance as a function of the frequency are shown in Fig. 2. The impedance seen at the gap point and the power feed point are presented in Fig. 2(a) and (b), respectively. The solid curve shows the impedance measured with the one-turn-loop and the dotted one shows the impedance measured with the two-turn-loop. There was a huge impedance peak seen from the power feed point. But no such peak was observed in the impedance curve seen from the gap point. This was a parasitic resonance originating in the coupling loop itself. It was hard to dump by putting parallel resistances to the coupling loops. The beam sees the gap impedance, therefore there is no harmful resonances up to 30MHz.

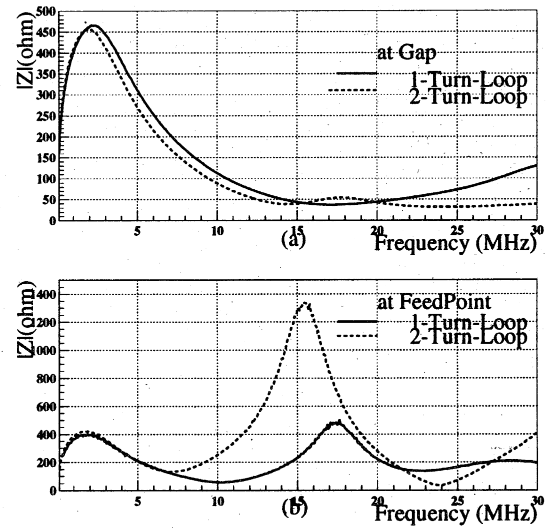


Figure 2: Impedance curves of the test cavity.

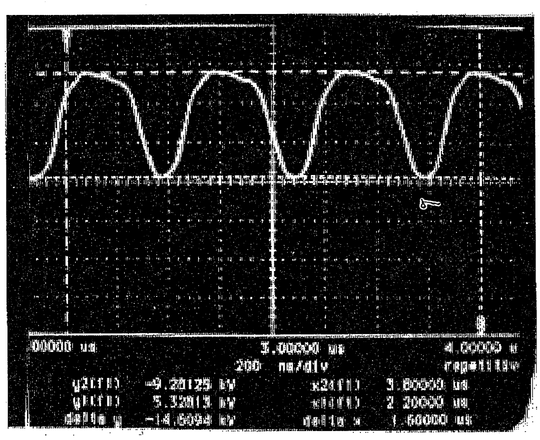


Figure 3: Voltage between the gap in class B operation.

3.2 RF Voltage

The RF voltage and the current of the cavity was measured with a high voltage probe and a current transformer, respectively. The maximum voltage was achieved, when the amplifier was operated in class B. We have obtained 8.5kV per gap, which corresponded to 17kV per cavity. Figure 3 shows the waveform of the voltage between the gap. This operation was done in a burst mode of 10 pulses with the repetition rate of 10Hz because the current in the anode power supply of the amplifier was limited. In case of continuous wave operation, we got the maximum voltage of 11kV per cavity. The waveform of the voltage in class AB operation is presented in Fig. 4. This waveform looks more like a sine wave compared with that in class B operation. When the amplifier is modified to a push-pull one, a sinusoidal waveform can be obtained. We have planed to modify the amplifier using two tetrodes to class B push-pull drive. It is hoped that the RF power is increased and the continuous wave operation at the maximum voltage becomes available.

The RF magnetic field strength becomes 143 gauss in the case of the gap voltage of 10kV. The RF power density in the core is 525 W/cc when the supplied RF power is 56kW.

The surface temperature of the cores at the several points was monitored with thermocouples. When the RF power of 10kW was fed, the maximum temperature of the surface reached 145°C after 4.5 hours and saturated. The RF voltage was very stable during the measurement even such high temperature.

4 BARRIER BUCKET

The barrier bucket[5][6] operation at the injection of the 50GeV ring has been considered to increase the beam

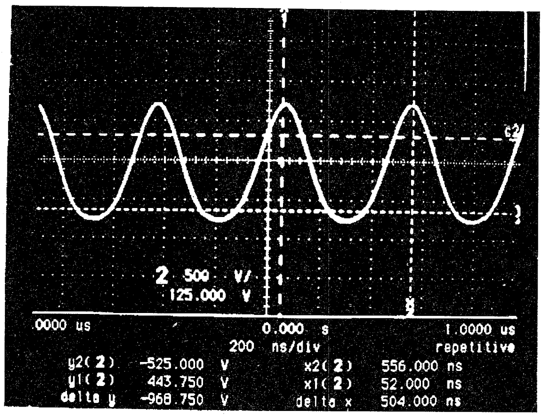


Figure 4: Waveform of the voltage in class AB operation.

intensity. It is necessary for the cavity to provide an isolated RF pulse so as to repulse the beam for the barrier bucket scheme. A broad band cavity has advantages to provide an isolated pulse:

- The required peak RF current for the broad band cavity to drive the waveform is much lower than that of the ferrite loaded cavity.

The cavity loaded with *FINEMET* cores is suited for the barrier bucket.

A barrier bucket experiment in the AGS is planed in next year. The test cavity will be modified to have four gaps. Fig. 5 shows the cavity design for this purpose. The length is about 2.6 meter. It has four gaps connected with bus bars and it is loaded with 48 *FINEMET* cores. It also has no loops for tuning. A couple of the one-turn-loops are used to feed RF from the push-pull amplifier.

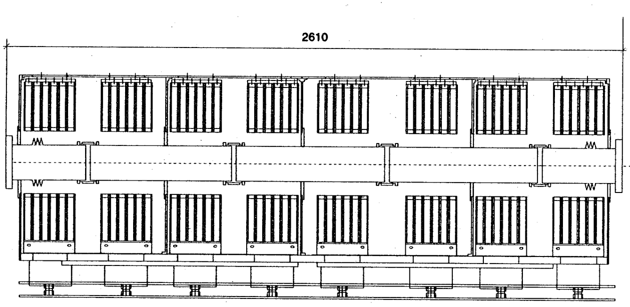
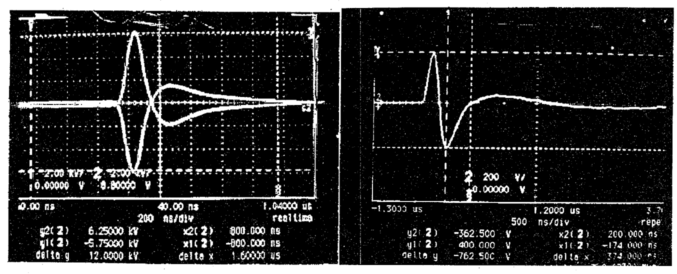


Figure 5: Schematic cross section of the modified cavity.

The maximum voltage of 40kV per cavity is necessary. The RF frequency is 2MHz and the isolated RF pulse is generated at the repetition rate of the revolution frequency of 357kHz. A peak voltage of 40kV allows a bucket height of $\Delta E = 7.7MeV$ and momentum deviation $\Delta p/p = 0.4\%$. The beam instabilities originating in the emittance growth will be studied. The beam acceleration after accumulation with the barrier bucket will be considered.



(a) (b)

Figure 6: (a) An isolated pulse of 10kV in class B operation. Each waveform shows the voltage between either sides of the gap and earth.(b) An isolated pulse in class AB operation.

The isolated pulse of 10kV per gap has been achieved already in class B operation. The waveforms of voltage between either sides of the gap and earth are given in Figure 6(a). Figure 6(b) shows an isolated pulse in class AB operation.

5 CONCLUSIONS

A test cavity loaded with the *FINEMET* cores has been developed. An acceleration voltage of 8.5kV per gap was obtained with class B operation of the tetrode and 10kV per gap for the barrier bucket. The impedance of the cavity was high enough over the range from 2MHz to 4MHz. There was no parasitic resonance up to 30MHz. The test cavity and amplifier are modified for the barrier bucket experiment in the AGS.

6 REFERENCES

[1] Y. Mori et al., "The Japanese Hadron Facility", Proc. 1997 Part. Accel. Conf., Vancouver B.C., 1997.

[2] T. Uesugi et al., "Longitudinal Coupled Bunch Instability in JHF 50GeV Main Ring", Proc. 1997 Part. Accel. Conf., Vancouver B.C., 1997.

[3] C. Ohmori et al., "A Broad Band Cavity for JHF Synchrotrons", Proc. 1997 Part. Accel. Conf., Vancouver B.C., 1997.

[4] M. Fujieda et al., "Studies of Magnetic Cores for JHF Synchrotrons", Proc. 1997 Part. Accel. Conf., Vancouver B.C., 1997.

[5] M. Blaskiewicz, J.M. Brennan, "A Barrier Bucket Experiment for Accumulating De-bunched Beam in the AGS", Proc. 1996 Euro. Part. Accel. Conf., Barcelona, 1996.

[6] J. F. Griffin et al., "Isolated Bucket RF System in the Fermilab Antiproton Facility", IEEE NS-30, No.4(1983) pp.3802-3804.