A WIDEBAND RF CAVITY FOR JHF SYNCHROTRONS

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Abstract

Thirty kilo watt "wide band" cavity has been developed for a test cavity of Japanese Hadron Facility(JHF). A new material, "FINEMET" which has very broad band impedance for the RF frequency, high permeability and large shunt impedance is used for the magnetic core of the cavity. Acceleration voltage of 10.4 kV which is larger than the designed value has been obtained. The characteristics of the core are also suitable to generate isolated RF pulses for the barrier bucket. The results for the barrier bucket are described.

1 INTRODUCTION

Accelerator complex of JHF[1, 2, 3] consists of 200 MeV linac, 3 GeV booster and 50 GeV main ring. The accelerators will be constructed at the north end of the KEK site. The booster is a rapid cycling proton synchrotron with a repetition rate of 25Hz. The required voltage for the acceleration is 420 kV and the frequency range is 2 to 3.4 MHz[4]. The voltage and frequency range for the main ring are 270 kV and 3.4 to 3.5 MHz, respectively. The expected beam intensity in the booster is $5x10^{13}$ppp (protons per pulse). The designed beam intensity in the main ring is $2x10^{14}$ppp. Circulating currents of both synchrotrons are about 7 A. Because of the very high beam currents, the cure of the space charge effects[5], the beam loading effects and some instabilities is essential. One of the most significant instabilities is the coupled bunch instability[6] because the harmonic numbers are 4 for the booster and 17 for the main ring. In order to cure these problems, a wide band radio frequency (RF) cavity is considered. It is expected that the wakefield which causes the coupled bunch instability is damped very quickly because of the low Q value.

1.1 *Requirements*

The requirements for the JHF cavity are following:

- Because of the limited space for the accelerating cavity, the RF voltage of more than 10 kV/m is necessary for the main ring. And about 13 kV/m is required for the booster.
- In order to satisfy the stability condition for the beam loading, the impedance seen by the beam should be about 1 kΩ/m.
- As the growth rate of the coupled bunch instability is very fast for the high-Q parasitic resonance, there should not be any high Q parasitic one.

1.2 *Characteristics of FINEMET*

The wide band cavity , in which the ring cores of a new material are loaded, has been developed in order to prove these advantages of the wide band cavity. The material, "FT3M(FINEMET)", is made with the thin tape of the Fe-based alloy which consists of amorphous and crystal with the size of nano-meter. The tape is coated with silica for insulation. It has a very high permeability and a low Q factor. Typical parameters of the core are tabulated in Table 1. Characteristics of the core have been measured by another ferrite test cavity[7,8] which has been developed for the measurements of magnetic cores in order to find the most suitable magnetic material for the RF cavities of the JHF synchrotrons. The amorphous cores have been measured. However, the FT3M core was the most suitable material for the wide band cavity at this moment. Other characteristics of the core are summarized as following:

- Shunt impedance is independent of the RF voltage.
- Characteristics of the core are stable for high temperature more than 150 °C because of very high Curie temperature (about 600 °C).
- It is technically possible to make a large core because it is not necessary to press the core with a heavy weight.

Table 1. Parameters of the core

Diameters	67 cm(O.D), 30cm(I.D)
Thickness	2.5 cm
Permeability@3.4MHz	1550
Q@3.4MHz	0.63
R@3.4MHz	83Ohm

1.2 *The aims of the test cavity*

The aim of the 30 kW test cavity is to prove the following:

- The required accelerating voltage of 10 kV/m can be obtained.
- The isolated pulse for the barrier bucket can be generated.

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- The frequency of the parasitic resonance is very high and/or the quality factor is low enough to avoid the dangerous growths of the instabilities.
- The beam loading and transient beam loading effects are controllable.

2 RF CAVITY

Figure 1 shows the test cavity and the 30 kW RF amplifier. Behind the cavity, there is a high voltage station and a power supply for an electron gun which will be used for the experiments on the beam loading effects. A tetrode, 4CM30,000A is employed to drive. The cavity has two acceleration gaps which are connected by bus bars. Figure 2 shows the schematic diagram of the cavity and amplifier. The RF excitation is provided inductively through a loop around 6 cores in the cavity without any direct DC connection to the cavity. The two turn loop between the plate of the tube and the plate power supply was employed to increase the impedance which the amplifier sees.

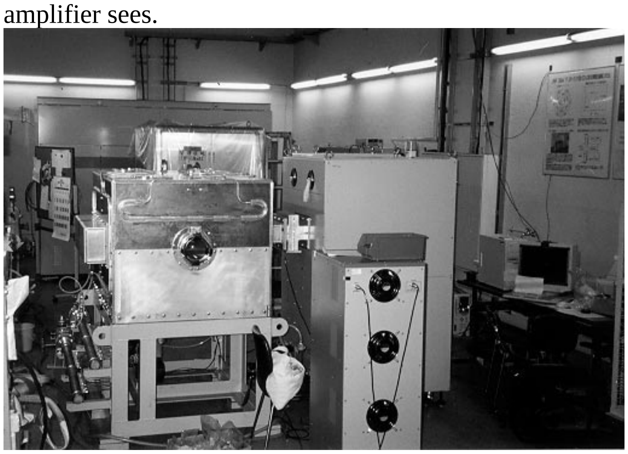

Figure: 1 The test cavity and amplifier.

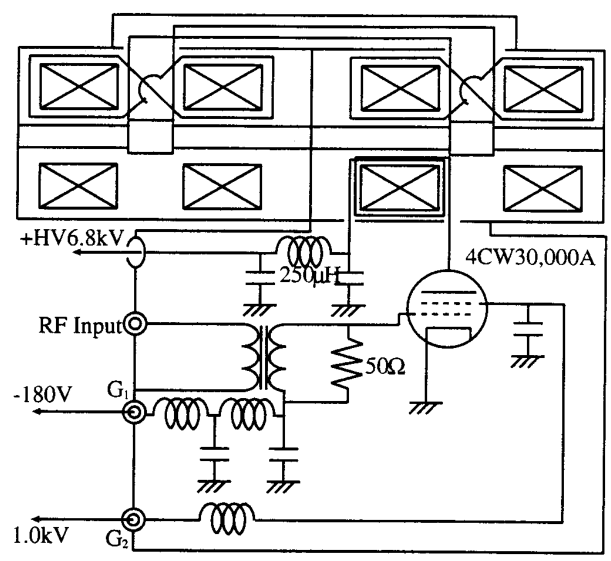

Figure: 2 The schematic diagram of the cavity and amplifier

3 IMPEDANCE MEASUREMENTS

The impedance of the cavity was measured by a network analyzer. No dangerous parasitic resonance which may excite the coupled bunch instability has not been observed up to 30 MHz by the measurement at the acceleration gap. Figure 3 shows the impedance curve obtained. The peak impedance is consistent with the measurement for each core by the ferrite test cavity. Each cell of the cavity has 12 cores and the total impedance of the cores is about 900 Ω at the resonant frequency. As the each cell is connected as a parallel circuit, the peak impedance becomes about 450 Ω.

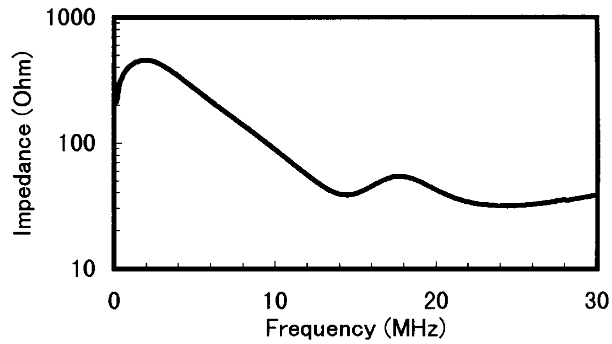

Figure: 3 The impedance of the cavity.

4 RF VOLTAGE

The RF voltage of the cavity was measured by the high voltage probe of 1000:1. The driving RF current wass also observed by a current transformer(CT). Figure 4 shows the typical RF voltage when the amplifier was operated in class AB operation. Because of the class AB, the distortion of the RF voltage by the higher harmonics was small. However, it became larger in the class B operation. The modification of the amplifier to the push-pull one by two tetrodes is being planed. Figure 5 shows the gap voltage respect to the observed RF current where Ip means the direct current from the plate power supply. The maximum voltage obtained in the safe operation condition was 10.4 kV per cavity and it is larger than required voltage for the main ring. The tetrode was driven by the class B operation. The impedance of the cavity calculated by this figure was 450 Ω and it was consistent with the impedance measured by the network analyzer. The maximum voltage obtained was limited by the available power of the amplifier and the plate voltage. It is expected that higher power amplifier can excite higher voltage because the impedance of the cavity is constant.

In order to obtain the higher voltage, the development of a new material has been started. The measurement for a small core of the material, FT3L, shows that it has higher Q-value and larger impedance than FT3M. The perpendicular magnetic field more than 3 kG is required during the heat treatment to make the core. We are designing the special high temperature oven and large aperture magnet.

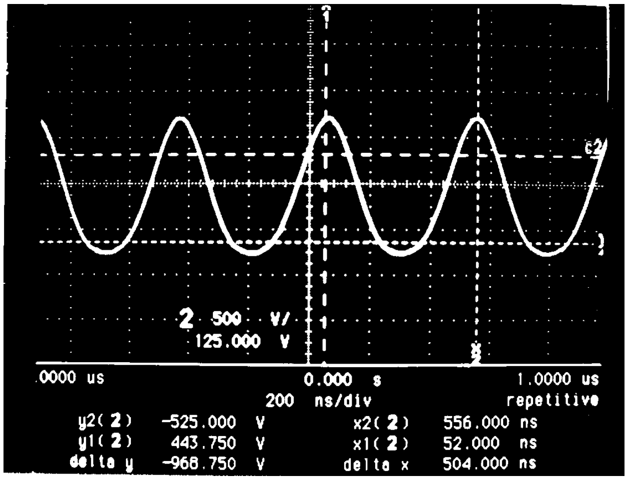

Figure 4: The typical RF voltage signal in the class AB operation.

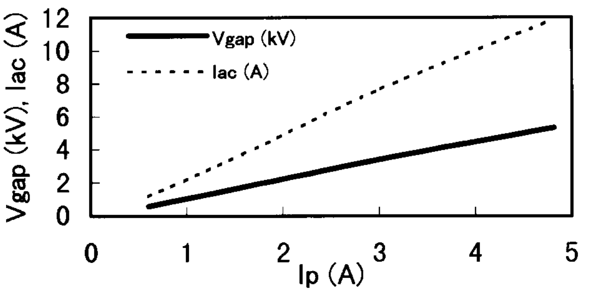

Figure: 5 The gap voltage (solid line) and RF current observed by the CT (dashed line) respect to the plate current.

The frequency sweep was performed with no bias condition. As shown in Fig. 3, the impedance was almost constant for the frequency range of 2 to 3.4 MHz. Although there is no tuning system, the RF voltage was very stable for the frequency sweep from 2 to 3.4 MHz as shown in Fig. 6.

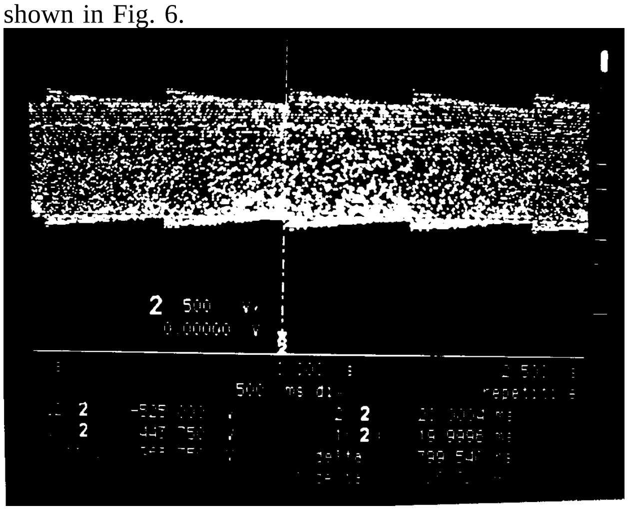

Figure 6: The RF voltage for the frequency sweep of the range of 2 to 3.4 MHz. The repetition rate is 1 Hz.

5 BARRIER BUCKET

Another advantage of the wide band cavity is that it is suitable for the barrier bucket. The brier bucket requires an isolated pulse. Figure 7 shows the typical RF voltage obtained in the class AB operation. The gap voltage was twice of the voltage measured. The maximum gap voltage of about 11.3 kV was obtained by the class B operation of the tube, increment of the plate voltage and modification of the cavity into one gap structure by removing the bus bars which is connecting with another cell. By this modification, the cavity impedance became twice and was suitable for the high voltage operation. However, the distortion of the voltage is not negligible as the operation of the tube was class B. This distortion will be cured by the modification of the amplifier into a push-pull amplifier by two tetrode tubes.

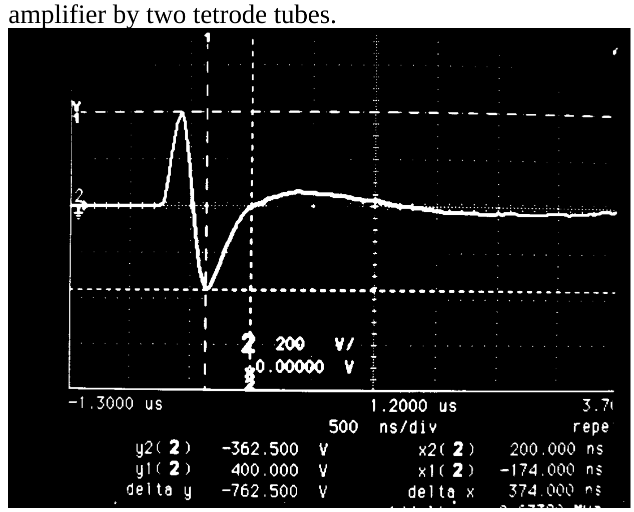

Figure 7: The typical barrier bucket voltage signal in the class AB operation.

CONCLUSIONS

The test cavity using a new material has been developed. The voltage more than the designed value has been obtained. In order to achieve the higher voltage, a new material is being developed. The impedance measurement shows that the cavity has no dangerous parasitic resonance. An isolated pulse for the barrier bucket was generated and the maximum voltage of 11.3 kV was obtained. However, the distortion of RF voltage was not small because of the class B operation of the single tube. It is expected that the distortion will be improved by the planned modification of the amplifier to a push-pull amplifier.

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