A PROTOTYPE MODULE OF A SUPERCONDUCTING DAMPED CAVITY FOR KEKB

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Abstract

For the feasibility study of a superconducting cavity for KEK B-factory, a prototype module of a 508MHz single cell niobium structure, which has a coaxial-type input coupler and a pair of HOM ferrite dampers, has been constructed. The field gradient of 11.4MV/m was achieved in the first cold test at a test stand This module was installed in TRISTAN Accumulation Ring and stored the single bunch current of 110mA with 2.3MV/cavity.

1 INTRODUCTION

KEKB is an asymmetric electron-positron collider with two rings of 8GeV x 1.1A(HER) and 3.5GeV x 2.6A (LER). These high currents require the RF system which has sufficiently damped higher order modes(HOMs) to suppress beam instabilities. Another problem in KEKB-RF is a multibunch instability due to the accelerating mode. To avoid this instability, the amount of frequency detuning of the accelerating mode should be below the revolution frequency of 100kHz for minimizing the generator power. For these requirements, two types of accelerating cavities are under investigation: a new normal conducting cavity(ARES) and a superconducting(SC) damped cavity[1][2].

Since 1991, the development of an SC damped cavity has been continued. A single cell with a large aperture size has been optimized, so as to propagate HOMs toward the beam axis and damp them by ferrite absorbers bonded on the inner surface of beam pipes. A large cylindrical beam pipe(LBP) of 300mm diameter is connected on one side to obtain a sufficient coupling of the lowest dipole modes. This scheme has been verified using a model cavity[3].

The optimization study of HOM dampers has been made on IB-004 ferrite because of its superior RF properties around 1GHz. HIPping(Hot Isostatic Pressing) has been tested as the fabrication method of ferrite cylinders of 4t x 220ϕ x 120mm and 4t x 300ϕ x 150mm, where the powder of IB-004 is packed in an iron vessel together with a copper cylinder and heated to 900°C in a furnace under 1500bar after vacuum pumping inside the vessel. In this process a cylindrical ferrite is sintered and bonded on the copper wall simultaneously under the vacuum circumstance[4].

A coaxial antenna coupler has been tested as an input coupler, which has the same design as what has been developed for the TRISTAN SC cavities. In the power test at a test stand, test couplers could be exposed to traveling RF of 850kW and standing of 150kW stably[5].

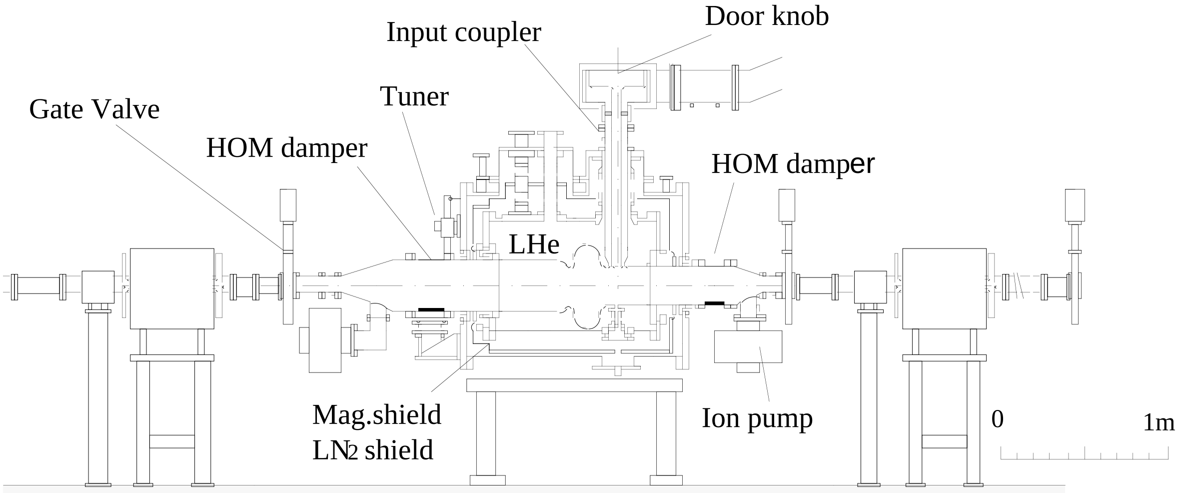

Figure: 1 A sketch of the prototype module in TRISTAN Accumulation Ring.

On the basis of these developments, a prototype module has been constructed for the beam test in TRISTAN Accumulation Ring(AR). After the cold test at a test stand, the module was installed in AR.

2 PROTOTYPE MODULE

The prototype module is illustrated in Fig.1. The fabrication process of the Nb cavity is the same as that for TRISTAN cavities, except for the final rinsing using ozonized pure water. Before assembling, the cavity was tested in a vertical cryostat and showed the gradient of 13.1MV/m[6].

The loss parameter of this scheme is 2.9V/pC for the designed bunch length of 4mm. The main part of the loss comes from the tapers between the cell and beam ducts. Therefore, the loss parameter can be reduced to 1.6V/pC in KEKB by the beam ducts of larger diameter and longer tapers, which causes the HOM load of 6kW per module in HER. The power test of the dampers was made using a coaxial line with 508MHz Klystron. The RF power of 11.7kW and 14.8kW was given to the 220ϕ damper and the 300ϕ damper. The average power density was 14.6W/cm^2 and 10.8W/cm^2, respectively[7]. Further, the 300ϕ damper was installed in TRISTAN Main Ring and exposed to the TRISTAN beam. Because of a small total current of 12mA and the bunch shape, the maximum power absorbed by the ferrite was 273W. A large bunch charge of 4 x 10^{-8}C did not cause any cracking or discharging on the ferrite surface. Out gas rate of the HIPped ferrite was 1 x 10^{-10} Torrl/seccm^2 after the baking of 120˚C x 5 days.

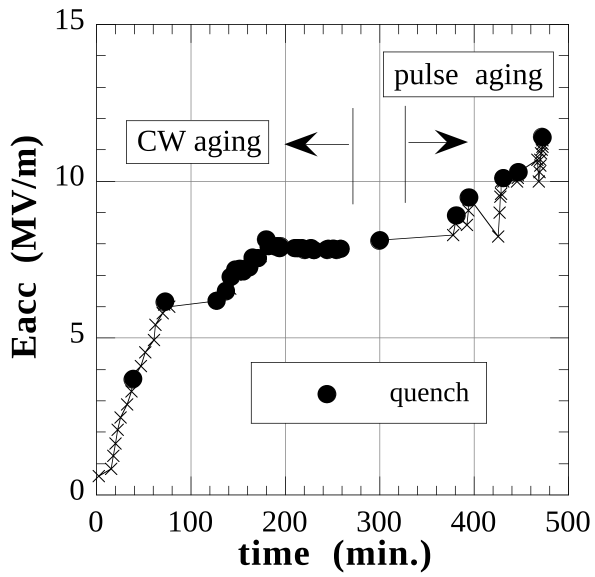

Figure: 2 Aging process in horizontal cold test.

New cryostat has fundamentally the same style as that for TRISTAN cavities, except for magnetic shielding. A vacuum vessel made of pure iron was used as well as a permalloy shield. The flux penetration from large holes for the beam pipes gave the residual field of 50mGauss at the center of the He vessel.

The cavity was aged up to 11.4MV/m by CW and pulse aging processes. The field was improved by the CW aging to 8MV/m but came to a standstill. The pulse aging, in which the pulse power of a 5% duty was added to CW power just below the quench level, broke the deadlock and improved the field to 11.4MV/m(Fig.2). During this test, the maximum input power was limited to 200kW, because the input coupler had been aged up to this power level before cooling.

Mechanical proper vibration of the cavity was observed at 65Hz giving the forced vibration by a piezo tuner. To avoid the resonance, the response of a frequency feedback loop was limited to 20Hz. The parameters of the cavity are listed in Table1.

Table: 1 Parameters of the module.

R/Q of acc. mode	93 ohm/cavity
gap length	0.243 m
loaded Q	8.9 x 10^4
tuner stroke (motor tuner)	508.48 - 508.88 MHz
(piezo tuner)	6.7 kHz
cryostat LHe volume	290 liter
static loss	30 Watts
max. acc. voltage	2.8MV (11.4MV/m)

3 BEAM TEST IN TRISTAN AR

The test module was installed in the east RF section of TRISTAN AR. The first two days were spent for the HOM study of the SC cavity using normal conducting APS cavities in the west RF section. No serious mode was observed in the study, where the frequency of the SC cavity was scanned by 400kHz and the beam was bumped in both x and y directions.

The summary of the beam currents accelerated by the SC cavity alone is as follows.

(single bunch study)

- 60mA for 10hours with the voltage of 2MV.
  This voltage corresponds to the gradient of 8.2MV/m. No RF trip has happened during this operation.
- 90mA for 30 min. with 2MV.
- 70mA for 50 min. with 2.5MV(10.3MV/m).
- 110mA for 10 min. with 2.33MV(9.6MV/m).
  The current was limited by heating up of HOM dampers of APS cavities and other ring components.

(multi bunch study)

- 100mA in 32 bunches with 2.33MV.
  The limitation of the current was caused by the instability due to the APS cavities.

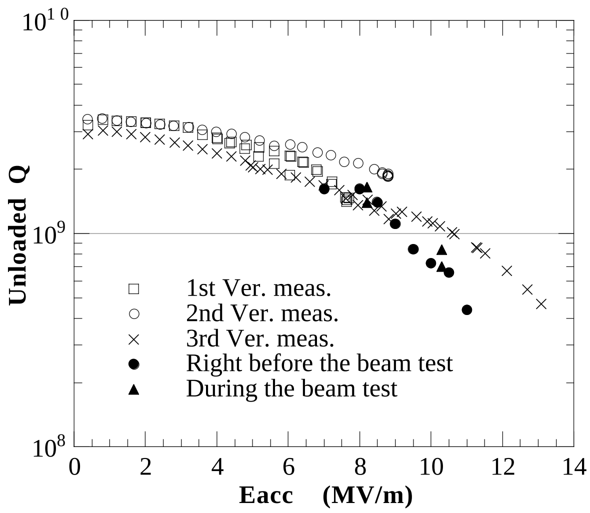

Figure: 3 The Q vs accelerating gradient (Eacc).

The maximum power absorbed by the HOM dampers was 760W for a single bunch of 110mA. Though the bunch charge of 1.4 x 10^{7}C was 64 times higher than that of KEKB-HER, the low loss parameter due to a long bunch length(8-9cm) reduced the HOM power.

RF power up to 230kW was supplied to the cavity under perfect reflection for aging. The maximum power transferred to the beam was 47kW at 110mA. Input power of 165kW was fed to the cavity with the reflection of 117kW. After the HOM study of two days, RF trips due to coupler arcing happened frequently. This was caused by a large amount of condensed gas from the ring duct. After warming the cavity up to 70K, the cavity field was recovered.

The Q value as the cavity field is summarized in Fig.3. Additional loss of the cavity related to the beam current was observed(Fig.4). This loss will be measured in detail at the next beam test.

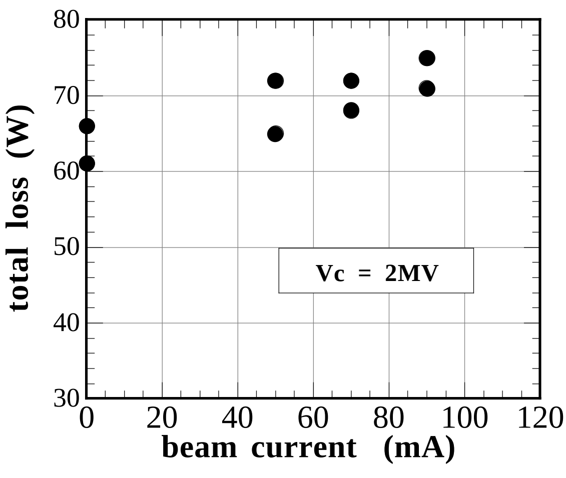

Figure: 4 Total loss measured by Lhe consumption at 2MV. The loss increases as the beam current.

4 SUMMARY

A prototype module of an SC damped cavity for KEKB has been constructed. No serious problem has been observed in a preliminary test in TRISTAN AR. The maximum current of 110mA in a single bunch has been limited by heating up of other components in the ring and a current of 100mA in 32 bunches was limited by the instability due to APS cavities. The cavity voltage of 2.5MV(10.3MV/m) was kept stably under the beam. The maximum HOM power absorbed by ferrites was 760W. This small power was due to a long bunch length.

The next beam test is scheduled for this July. All APS cavities, which are the main component of a ring impedance, will be removed for upgrading the beam intensity. This will also has an effect to reduce the bunch length. We will make a challenge of the beam current of 0.5A and the HOM power of 5kW in the next test.

Figure: 5 Prototype module in TRISTAN AR.

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