FABRICATION OF A FULL SCALE CRAB CAVITY FOR KEKB

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ABSTRACT

After R&D study of 1/3 scale 1.5 GHz non-axially symmetric squashed cell shape superconducting Nb crab cavities a full scale 508 MHz squashed cell shape superconducting Nb crab cavity for KEKB has been designed and fabricated at KEK. The full scale cavity was fabricated using the same fabrication techniques developed at the R&D studies of the 1/3 scale model. At the same time test stand for this cavity with RF measurement system and vertical cryostat has been constructed. The first cold test of this cavity in 4.2 K vertical cryostat was carried out and the surface electric peak field Esp could exceed its design value of Esp = 21 MV/m.

INTRODUCTION

KEK B-Factory (KEKB)[1], a high luminosity 8 x 3.5 GeV asymmetric electron-positron collider, which is now under constructing in TRISTAN tunnel at KEK, adopted a finite angle crossing scheme of 2 x 11 mrad at the interaction point to reduce the background rates and to simplify beam optics at interaction region. By this scheme the luminosity reduction due to geometrical effect and the possibility of beam-beam instability by synchrotron-betatron coupling resonances will be anticipated. The crab crossing scheme shown in Fig.1 was proposed to eliminate these effects[2,3]. In this scheme electron and positron bunches to the interaction point are tilted by time-dependent transverse kick in RF deflectors (crab cavities) and head-on collide. After the collision these bunches are kicked back to the original orientations by another crab cavties. The selected parameters for KEKB crab crossing are listed in Table 1. The required deflecting voltages for the 3.5 GeV low energy positron ring LER and 8 GeV high energy electron ring HER are 1.41 and 1.44 MV, respectively.

Figure 2 (a) shows conceptual picture of a crab cavity with damping scheme for all lower and higher frequency modes. We have adopted non-axially symmetric squashed cell shape crab cavity which was designed and studied extensively at Cornell[4] for CESR-B under KEK-Cornell collaboration. In this schame the TM110 like crab mode shown in Fig. 2 (b) is used to get time-

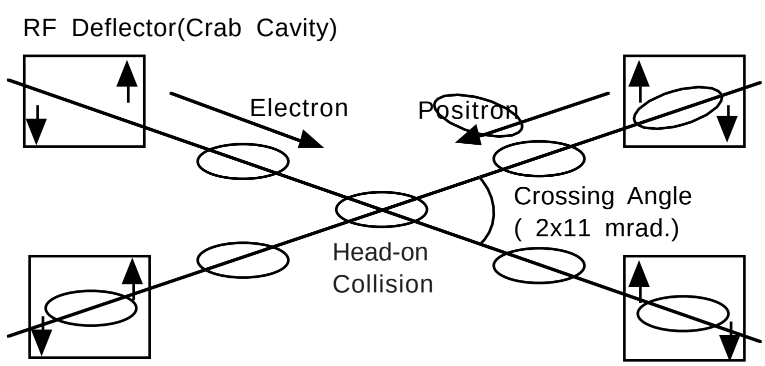

Fig. 1 Crab crossing scheme for KEKB

Table 1. Selected Parameters for KEKB

	LER	HER
Beam Energy [GeV]	3.5	8.0
RF Frequency [MHz]	508.887	
Crossing Angle [mrad]	2 x 11	
βx	0.33	0.33
$\beta crab$	20	20
Kick Voltage [MV]	1.41	1.44

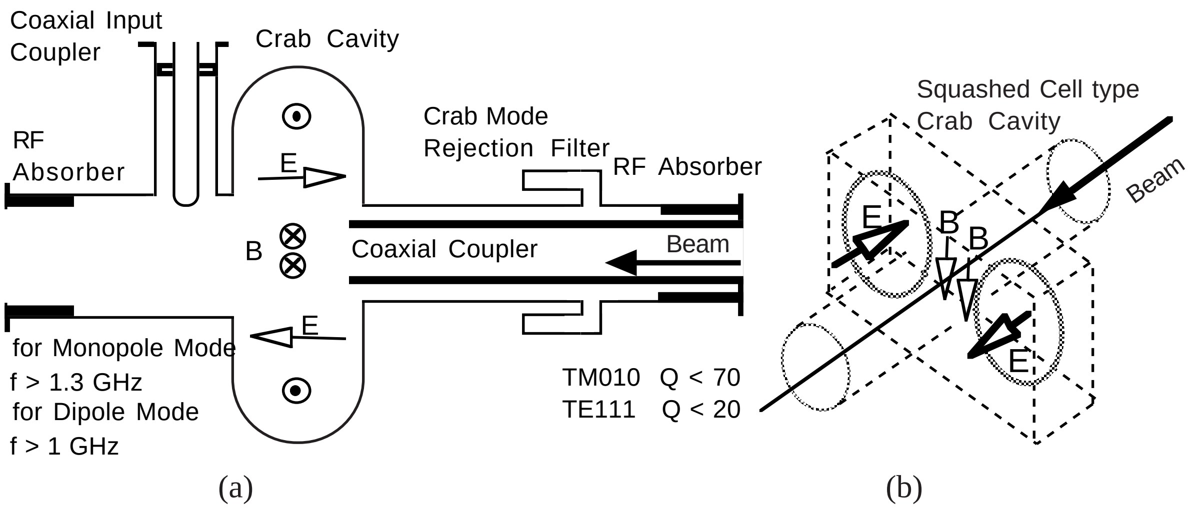

Fig. 2 (a) Conceptual design of a crab cavity with damping for all lower and higher frequency modes.
(b) Electric and magnetic field patterns of crab mode in squshed cell type cavity

dependent transverse kick for the crab crossing. Unwanted higher and lower modes are extracted from the cavity through a large aperture beam pipe and a coaxial beam pipe on both ends and absorbed by RF absorbers attached on the beam pipes placed at room temperature.

DESIGN OF KEKB CRAB CAVITY

Figure 3 (a) and (b) shows dimension of the 508 MHz non-axially symmetric squashed cell type cavity for KEKB. By this squashed cell type design, an unwanted polarized crab mode can be pushed upward higher enough easy to extract outside of the cavity[4].

The RF characteristics of the crab cavity is calculated by computer code MAFIA. The calculated results are shown in Table 2. Because the ratio of maximum surface electric field to deflecting voltage Esp/Vkick for the KEKB squashed cell cavity design is 14.4 (MV/m)/MV, the required maximum surface electric field Esp for the KEKB crab cavity is about 21 MV/m.

The mechanical design for the 508 MHz KEKB crab cavity was performing using the finite element softwares ANSYS and MARC. The required cavity wall thickness of more than 4 mm was determined by this stress analysis under the conditions of external presser 0.13 MPa at room temperature[5]. In this design four ribs for reinforcement are attached to the neck part of the cavity to reduce the localized stress concentration due to non-axially symmetric squashed cell shape.

Table 2. RF properties of 508 MHz KEKB crab cavity

	Without / With Coaxial Coupler
R / Qo [Ω]	48.9 / 46.7
Γ	227 / 220
Esp/Vkick [MV/m/MV]	13.9 / 14.4
Hsp/Vkick [Oe/MV]	384 / 415

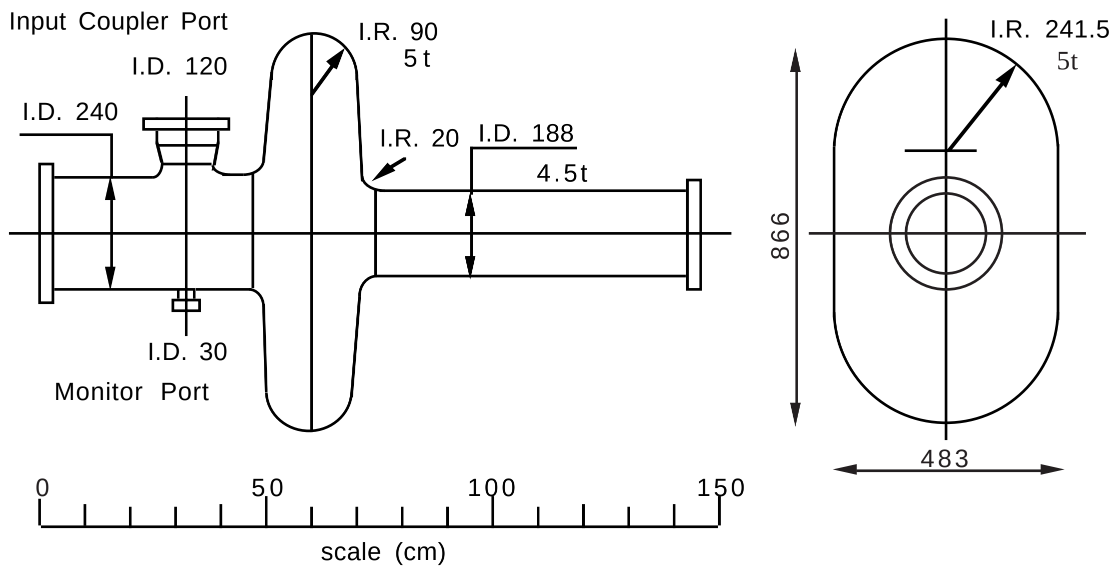

Fig. 3 Dimension of squshed cell type crab cavity for KEKB

FABRICATION OF THE FULL SIZE KEKB CRAB CAVITY

Before fabrication of the 508 MHz full scale Nb crab cavity, we have designed and fabricated three 1.5 GHz 1/3 scale squashed cell model cavities[6] to establish the fabrication and surface treatment techniques for non-axially symmetric Nb cavity. One of these cavities has been carried out the cold tests in 1.8 K vertical cryostat. The maximum surface electric field of 43 MV/m was attained by this 1/3 scale model cavity[6]. The 508 MHz full scale KEKB Nb crab cavity was made by using the same fabrication methods and surface treatments developed at the R&D studies of the 1/3 scale model.

The fabrication and surface treatment procedure of the 508 MHz full scale KEKB crab cavity is summarized in Fig. 4. The half-cells of the Nb cavity were hydro-formed out of 5 mm thick Nb sheet with RRR=190 supplied from the Tokyo Denkai. Inner surface of the half cell were buff-polished to remove the scars on the surface. After the equator and the iris parts were trimmed

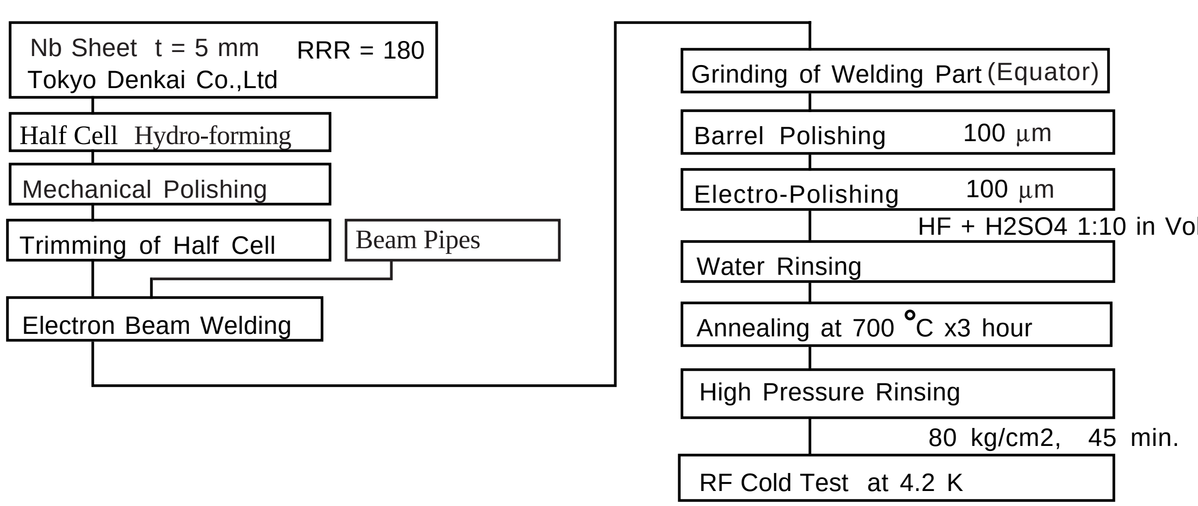

Fig. 4 Fabrication and surface treatment of KEKB crab cavity

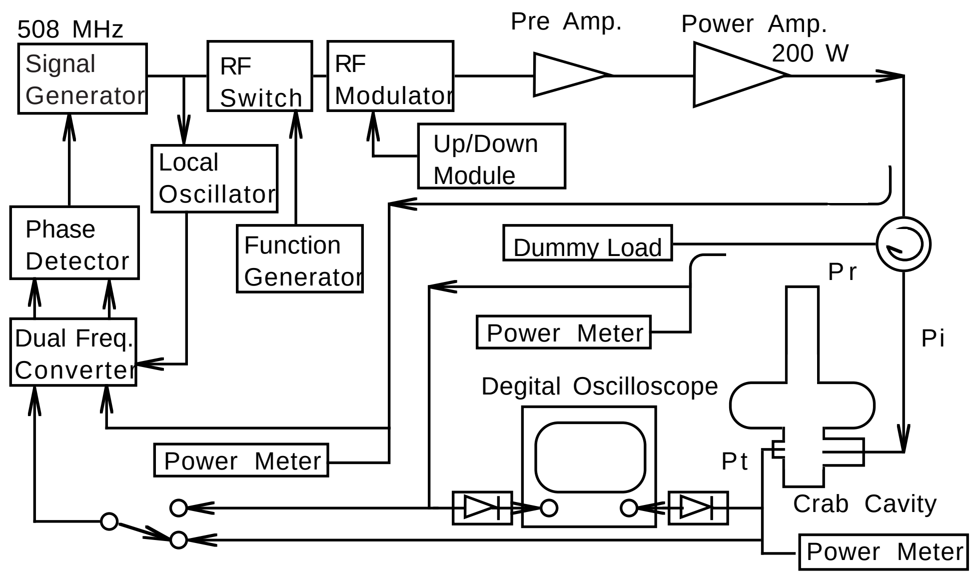

Fig. 5 508 MHz RF measurement system for KEKB crab cavity

mechanically, the cell and beam pipes were assembled into a cavity by electron beam welding. The electron beam welded equator part was ground by specially designed grinding machine. Inner surface of the cavity especially equator part was barrel polished[7] about 100μm and then the inner surface of the cavity was electropolished about 100μm by horizontal rotational electopolishing system developed and used for TRISTAN superconducting cavity[8]. After rinsing by ultra pure water the cavity is annealed in vacuum furnace at 700 ^{o}C for about 3 hours. Before the cavity was assembled into vacuume sytem for the cold test, inner surface of the cavity was rinsed by 8MPa high pressure ultra pure water for about 45 mimutes.

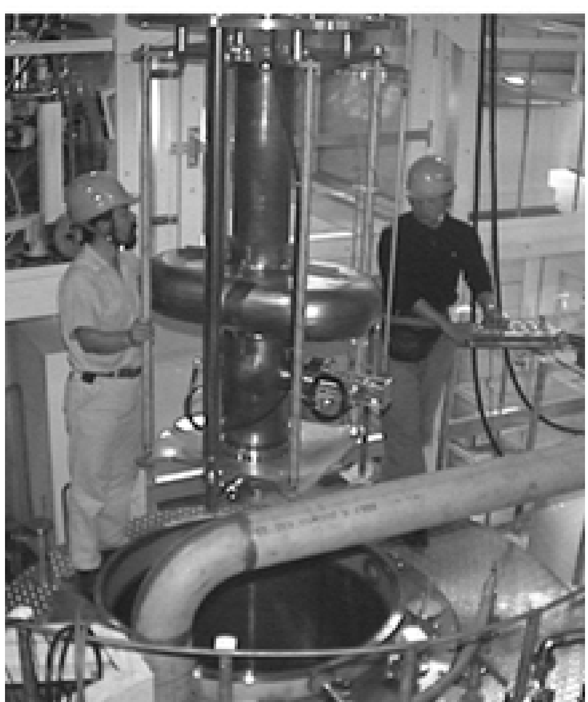

Fig. 6 KEKB crab cavity just before the installation into the virtical cryostat for cold test

RF MEASUREMENT AT 4.2 K VERTICAL CRYOSTAT

For the cold test of the 508 MHz full scale KEKB crab cavity we have constructed its test stand with a RF measurement system and a vertical cryostat. Figure 5 shows the 508 MHz RF measurement system. In this measurement system we use the phase detector and the dual frequency converter which were designed and extensively used in TRISTAN RF system for the phase lock system. The RF measurements of the crab cavity and its display are performed with a Labview language program. A high performance large vartical cryostat with 1.1m in diameter and 3.5m in height has been constructed for the cooling of the 508 MHz full scale KEKB crab cavity. This cryostat was constructed beside the existing cold box of the large helium refrigeration system with 8kW cooling capacity at 4.4K which was used for cooling of TRISTAN superconducting acceleration cavities[9]. Liquid helium of more than 5000L required for the cold test of the crab cavity was fed directly from 12000 L liquid helium Dewar. Figure 6 shows the picture of the crab cavity just before the installation into the vertical cryostat for cold test.

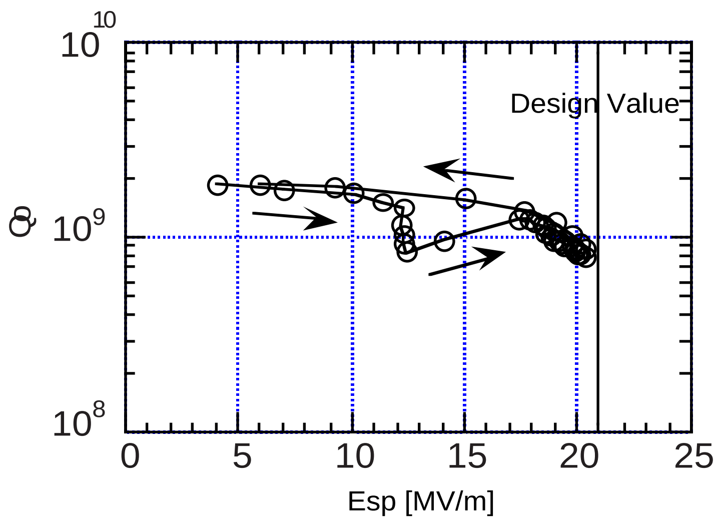

Fig. 7 Cold test results of 508 MHz KEKB crab cavity

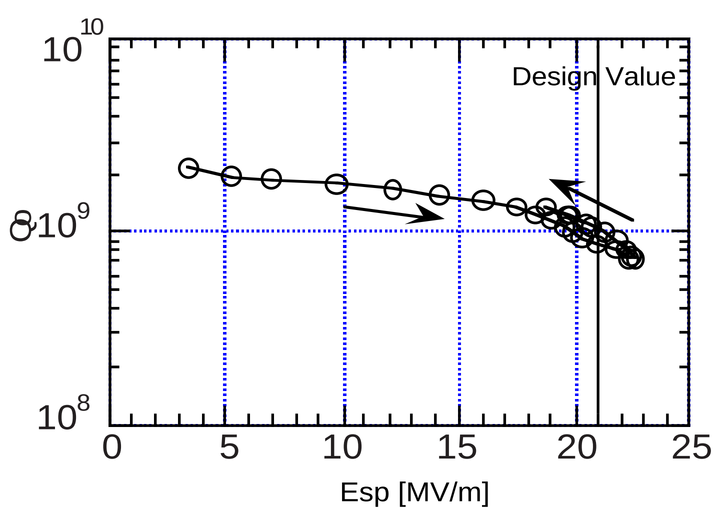

Fig. 8 Cold test results of 508 MHz KEKB crab cavity after helium processing

We have carried out the cold tests of 508 MHz KEKB crab cavity in the 4.2 K vertical cryostat. Figure 7, 8 show the results of the cold tests. In the first RF test Qo values degraded at around Esp = 13 MV/m as shown in Fig.7, this was overcome by short duration of the RF processing and reached maximum values of about 20 MV/m with field emmission loading but unfortunately at this field level we could not continue the RF processing by the limitation of the x-ray radiation due to poor radiation shield. We carried out helium processing for about 20 minutes. By this processing the maximum Esp exceed design value of 21 MV/m and reached about 23 MV/m as shown in Fig.8. This value was limited by the capacity of RF power source.

SUMMARY

We have designed and constructed a 508 MHz full scale KEKB Nb crab cavity and at the same time we have completed its test stand with a RF measurement system and a vertical cryostat. We are now ready for the regular processings and measurements of the 508 MHz KEKB crab cavity for extensive study of it.

We could exceed the design surface peak field of Esp = 21 MV/m but if we take into account the degradation of the superconducting cavity during installation into the horizontal cryostat required Esp at the vertical test must be around 30 MV/m. We need more efforts to improve the performance of the cavity.

In the surface treatments of the KEKB crab cavity we skipped high pressure rinsing just after the electropolishing. We consider this caused low maximum Esp. In the next step we want to carry out slight electropolishing of this cavity followed by high pressure rinsing to improve the performance of the cavity.

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