RESEARCH AND DEVELOPMENT PROGRAM ON SUPERCONDUCTING CRAB CAVITIES FOR KEKB

H. Nakai#, K. Hara, T. Honma, K. Hosoyama, A. Kabe, Y. Kojima, Y. Morita, KEK, Tsukuba, Japan
K. Nakanishi, M. MD. Rahman, GUAS (KEK), Tsukuba, Japan
K. Okubo, MHI Kobe Shipyard, Kobe, Japan

Abstract

Recent stable operation of the KEKB accelerator brings the highest integrated luminosity in the world and opens the new world of the particle physics. Then KEK has determined to install superconducting crab cavities into KEKB to obtain much more luminosity. Since no crab cavities have been operated in any accelerators so far, we had to started our research and development program on crab cavities for KEKB from the beginning literally. With 1/3-scale crab cavities made of pure niobium we had learned and experienced the fundamental characteristics of the crab cavities. As the second phase, we have fabricated two full-scale crab cavities and measured their performance. Beside these activities, various special parts to the crab cavities, such as coaxial couplers, notch filters, stub supports are under development. Also we have started to design the cryostats which accommodate crab cavities in KEKB.

INTRODUCTION

Since in the KEKB a high energy ring (HER) for electrons and a low energy ring (LER) for positrons intersect with a finite crossing angle, beam bunches may induce synchrotron-betatron coupling resonance [1,2]. To avoid this resonance and to increase luminosity, we employ the crab crossing scheme, as shown in Fig. 1. In this scheme, beam bunches in the two rings are kicked by RF deflectors, i.e., two crab cavities just before their collision at the interaction point of the KEKB to change their direction. Hence they can make the head-on collision at the point. After their collision beam bunches should be kicked back by another pair of crab cavities to be aligned to the beam lines again.

To realize this crab crossing scheme in the KEKB we have developed and studied the superconduting crab cavities made of pure niobium since 1994.

CRAB CAVITIES FOR KEKB

Conceptual Design of Crab Cavities

Different from accelerating cavities, axisymmetric shape of a cavity is not adequate to a crab cavity as an RF deflector. To generate the crab mode dominantly in the cavity, a squashed-cell cavity is proposed [3] as shown in Fig. 2.

#hirotaka.nakai@kek.jp

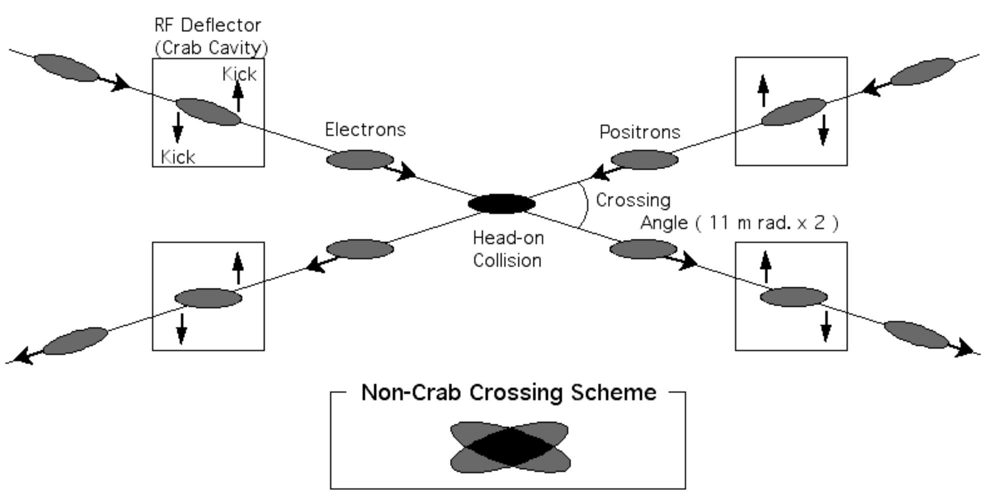

Figure 1: Crab crossing scheme for the KEKB.

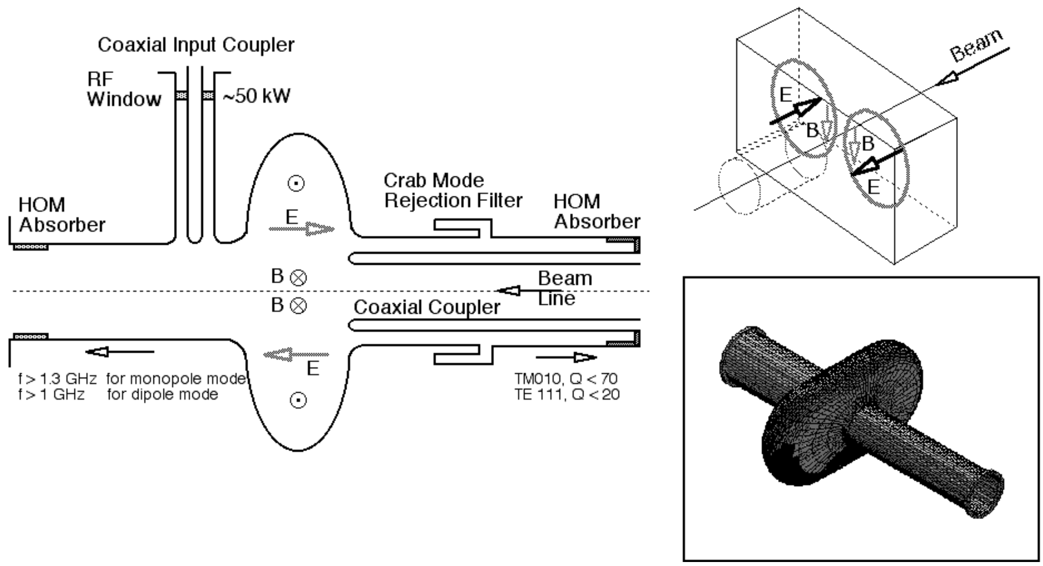

Figure 2: Concept of the squashed-cell crab cavity.

Fabrication and Surface Preparation

Our ordinary procedure of fabrication and surface preparation of crab cavities is block-diagrammed in Fig. 3. If the measured performance of crab cavities is not satisfactory, we may repeat high pressure ultrapure water rinsing, and electropolishing at the worst case.

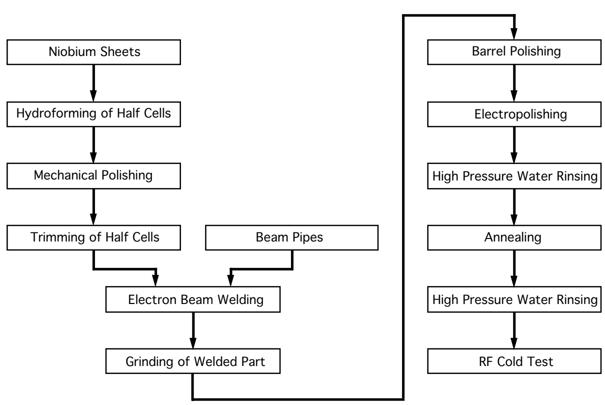

Figure 3: Fabrication and surface preparation procedure.

Performance of Crab Cavities

Performance of two full-scale crab cavities is shown in Fig. 4. The horizontal axis corresponds the surface peak field in the cavity, and the vertical axis does the Q-factor of the cavity. The performance of the cavity #1 was measured with or without a simplified coaxial coupler at 4.2 K to check the effect of the coaxial coupler to the cavity performance. At lower temperature, 2.8 K, the performance was also measured and it is clearly verified that the performance can be enhanced by decreasing the operation temperature.

The cavity #2 shows better performance than that of the cavity #1. Both of our two full-scale cavities show their performance better than design value. Then we can conclude that our procedure of fabrication and surface preparation is appropriate to fabricate superconducting crab cavities which satisfy the design specification.

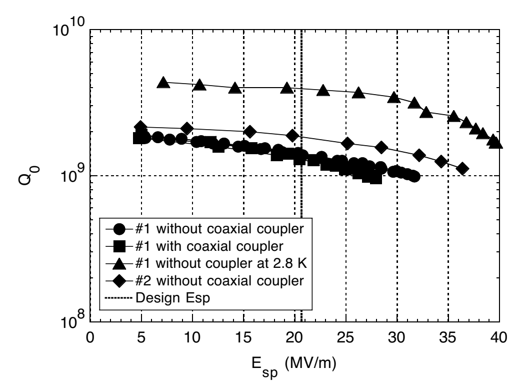

Figure 4: Performance of full-scale superconducting crab cavities with various configuration and at different temperature.

Performance Recovery by High Pressure Ultrapure Water Rinsing (HPR)

The major cause of the cavity performance degradation seems to be some dust on the inner surface of the cavity from outside which may be introduced during assembly stage. If the case, the cavity performance can be recovered by the high pressure ultrapure water rinsing. After the ordinary measurement of the cavity performance of the cavity #1, we introduced small amount of air into the cavity, and measured its performance again. As seen in Fig. 5, its performance degraded. Then we carried out the high pressure ultrapure water rinsing again, and we observed not only that the performance was recovered but that it became better than before contamination.

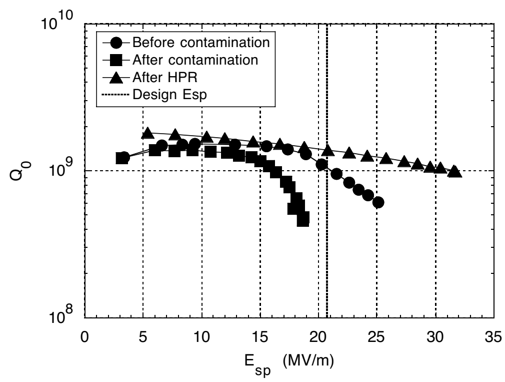

Figure 5: Effect of high pressure ultrapure water rinsing.

CRYOSTAT DESIGN

There remains only limited space for the crab cavities in the KEKB tunnel. Hence the cryostats for the crab cavities are requested to be as small and light as possible to avoid the interference with other accelerator units such as wiggler magnets. Since the crab cavity has a strange shape, we adopt a jacket-type liquid helium vessel, as shown in Fig. 6. If the cavity performance degrades after the final assembly of the crab cavity into the cryostat, high pressure ultrapure water rinsing can be applied to the cavity as housed in the liquid helium vessel.

Plates for the cryostat are needed to be strong enough and also thin to make the cryostat as light as possible. To meet these requirements for the cryostat, we carry out the structure analysis and development of thin plate forming for the end plates of the cryostat.

R&D ON SPECIAL PARTS TO CRAB CAVITIES

Coaxial Coupler and Stub Support

To withdraw unwanted modes from the cavity and to transmit them to RF absorbers, a long coaxial coupler is inserted into the beam pipe of the cavity (Fig. 6). This coupler is considered to be made of niobium-sputtered copper to utilize both of superconductivity of niobium and good thermal conductivity of copper. Stub supports should be equipped to support this long coupler adequately in the beam pipe. They have a function as liquid helium conduits to cool down the coaxial coupler tip.

The coaxial coupler has also a role of frequency tuner of the cavity. The coupler has to be movable along the beam line to adjust the frequency. Hence there should be bellows between the cavity and the stub supports of the coupler to allow the coupler to be moved in the cryostat.

We are now making our efforts to establish niobium sputtering technique, seamless copper bellows fabrication to fabricate the coaxial couplers and stub supports properly.

Notch Filters

The coaxial coupler may withdraw and transmit even the crab mode. A notch filter (crab mode rejection filter) returns the crab mode to the cavity. This filter is placed outside of the cryostat at room temperature. There is a need to develop the fabrication method of thin tubes to make these filters.

SUMMARY

- We have fabricated two full-scale crab cavities and measured their RF performance.
- With our fabrication and surface preparation procedure crab cavities can have better performance than design surface peak field.
- Even if a cavity is contaminated by dusts from air, its performance can be recovered by high pressure ultrapure water rinsing.
- A conceptual design of the cryostat for crab cavities is completed, and detailed design is in progress.
- Various special parts to crab cavities, such as coaxial couplers, notch filters, thin bellows, thin end plates etc. are now under development in KEK.

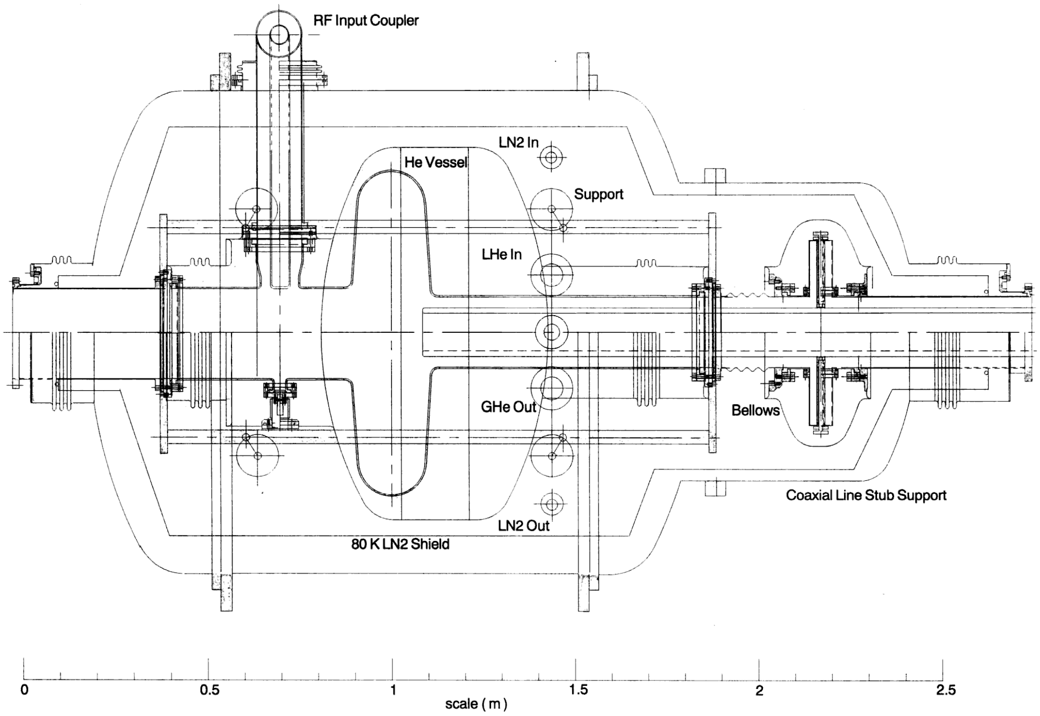

Figure 6: Cryostat design for crab cavity seen from the top.

REFERENCES

[1] R.B. Palmer, SLAC-PUB-4707 (1988)
[2] K. Oide and K. Yokoya, Phys, Rev. A40 (1989) 31
[3] K. Akai, J. Kirchgessner, D. Moffat, H. Padamsee, J. Sears, T. Stowe and M. Tigner, Int. J. Mod. Phys. A 2B (1993) 757