R&D STATUS OF C-BAND ACCELERATING SECTION FOR SUPERKEKB

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Abstract

For the future upgrade of KEKB injector linac for SuperKEKB to raise its positron beam energy from 3.5 to 8.0 GeV, we have been developing C-band accelerating section. Prototype study has begun based on a half-scale design of the present S-band section. The first prototype has suffered from frequent breakdowns around the couplers. Then we started improving the coupler structure. The second prototype has completed recently and two more sections with different types of couplers are under fabrication. We report on an R&D status of these four prototypes of the C-band accelerating section.

INTRODUCTION

The KEKB injector linac supplies 8.0-GeV electrons and 3.5-GeV positrons to the B-factory storage rings. The KEKB has achieved its peak luminosity 1.5×10^{34} $cm^{-2}s^{-1}$ in 2005 and is planning an aggressive upgrade [1] (SuperKEKB) to increase the luminosity more than 20 times. In the SuperKEKB, charge switch in the energy-asymmetry between the electrons and the positrons is planned against the electron-cloud effect in the positron storage ring. Then, the linac will be required to inject 8.0-GeV positron. The present energy gain of the accelerator modules after the positron generation target is sufficient for 3.5 GeV but not for 8.0 GeV. A scheme we are considering to achieve 8.0-GeV positron injection is to double the acceleration field gradient from 21 to 42 MV/m by replacing present S-band accelerator modules with the C-band equivalents.

As shown in Fig. 1, a C-band accelerator module for SuperKEKB is designed to be composed of a 50 MW klystron [2], a compact pulse modulator [3], a SLED-type of pulse compressor [4] and four 1-m long accelerating sections. Microwave from the pulse-compressor is divided equally into two and fed to two pairs of tandem-connected two accelerating sections. In each pair, an accelerating section with larger aperture in the upstream and the other with smaller aperture in the downstream are connected with a waveguide. The aperture diameter decreases linearly along the two sections to achieve quasi-constant field gradient. According to the decreasing aperture, the group velocity (v_g/c) in the cavities changes from 3.0 to 1.9 % in the first section and further from 1.9 to 1.0 % in the second one. The length of accelerating section is limited to be 1 meter from the constraints of the apparatus used in fabrication and RF measurements. Thus the tandem connection of two sections is adopted to effectively achieve 2-m long section for efficient use of the RF power.

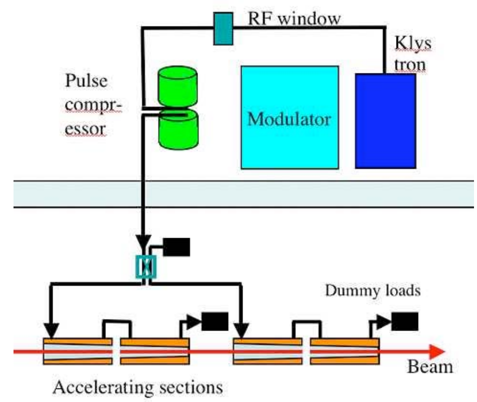

Figure 1: C-band accelerator module.

PROTOTYPES

We have been developing four prototype accelerating sections. They all have following features which are also common to the S-band accelerating sections presently used in the KEKB linac.

- Travelling wave, disk-loaded structure
- 54 regular cells of accelerating cavity which have 2/3-pi phase advance.
- Quasi-constant field gradient (except for 3rd prototype)
- Single-port couplers.
- Formed by copper electroplating

In the following chapters, the features and the status of each prototype are described.

1st prototype (CKM001)

As is already reported elsewhere [5], the first prototype of the C-band accelerating section was designed on a half-scale dimension of the present S-band accelerating section. It was fabricated in 2003 and installed in the KEKB injector linac in the summer of that year. It has been operated in the linac and achieved an accelerating field gradient of 42 MV/m that was measured from the beam energy gain. Though the field gradient was high, we suffered from frequent breakdowns around ten times an hour. After ten month operation in the linac, we observed inside of the accelerating section with a CCD microscope and found a small fraction of a metallic chip in the input coupler. It was then removed. After two years of RF processing during operation, a breakdown frequency now is approximately once a day. Though the chip certainly

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enhanced the breakdowns, we think the coupler structure itself is not sufficiently tolerant against breakdowns.

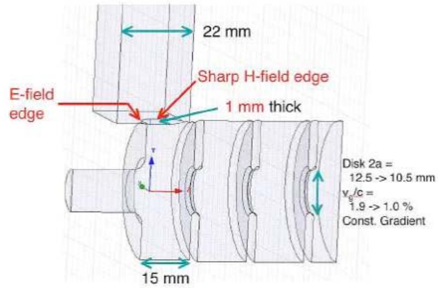

Figure 2: Coupler of 1st prototype.

As shown in Fig.2, the coupler has thin (1 mm thick), sharp-edged iris. It also has an E-field edge at the step between the waveguide and the coupler cell. It is because the height of the standard waveguide (22 mm) differs from that of the coupler cell (15 mm). In the following prototypes, the coupler shape is improved in these respects.

2nd prototype (CKK001)

In the second prototype, we adopt a coupler shape as shown in Fig. 3. To eliminate the E-field edge in the coupler, the length of the coupler cell is adjusted to be same as the height of the standard waveguide. The coupling iris is thicker (4 mm) than the 1st prototype to reduce the current density there. The iris edges should be rounded off by machining, but it cannot be applied for this coupler due to a constraint on a composition of the parts which form the coupler. Instead, the edges are rasped off and the curvature of the rounded edge is typically 0.1 mm.

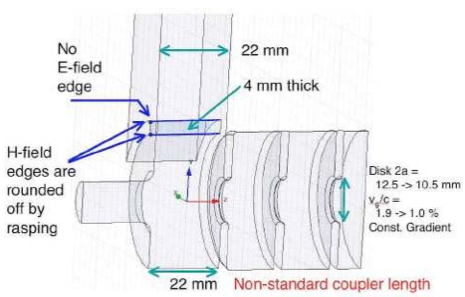

Figure 3: Coupler of 2nd prototype.

Since the length of the coupler cell differs from those of the regular cells, the ordinary Kyhl method cannot be applied in optimizing the coupler dimensions. We use nodal shift measurement as described in the reference [6]. We made certain quantification of the tuning process and also adjusted the diameter of the cell adjacent to the coupler. It finally took many trials of the coupler processing before reaching to the optimized dimensions as shown in Fig. 4.

While the coupler shape is changed in the 2nd prototype, the regular cells remain to have same dimensions as those of the 1st prototype.

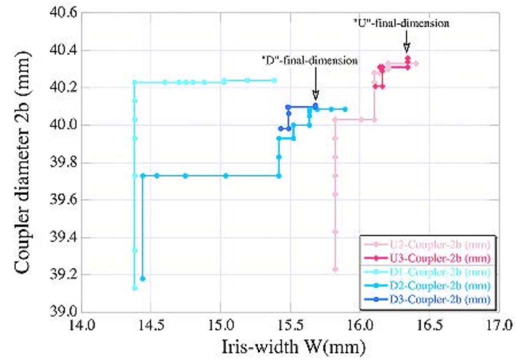

Figure 4: Coupler tuning history.

The regular cells, composed of disks and spacers, and the couplers are united by the copper electroplating. Subsequently, cooling-water jackets, RF flanges and the beamhole plunger were attached by welding as shown in Fig. 5. After the electroplating and the welding processes, a reflection of RF power from the accelerating section was increased. We considered that it came from a deformation of the couplers. The effect was partly compensated by adjusting the resonant frequency of the coupler with machining the edge of the beamhole in the coupler. In the next prototype, the structure of the coupler is changed to be more rigid to avoid such a deformation.

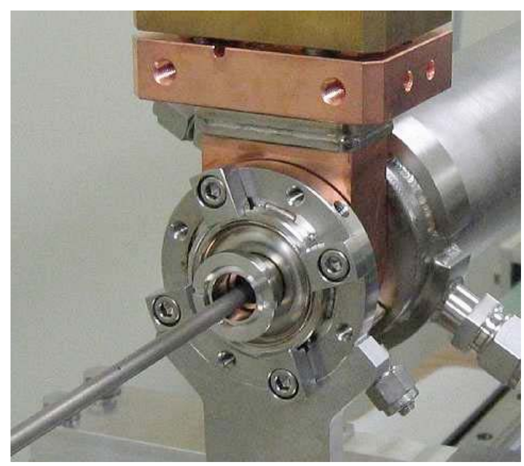

Figure 5: Welding of beamhole plunger.

After the fabrication is finished, RF processing of the accelerating section is performed at a test stand. The processing is finished after much less breakdowns compared to the 1st prototype. The 2nd prototype will be installed in the linac this summer. We expect that it can have less breakdown frequency in the operation.

3rd prototype (CKK002)

As described in detail in the reference [7], in the third prototype, we further improve the coupler to have smooth shape at the H-field edges as shown in Fig. 6. The tip shape is an arc of 2-mm radius in a cross-section and smoothly connected to the coupler-cell arc and to the end face of the waveguide.

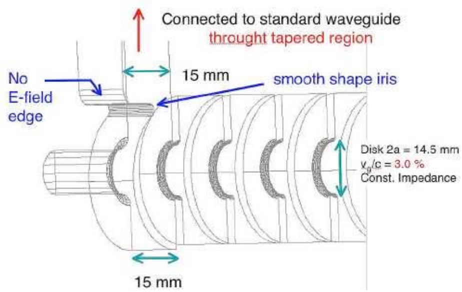

Figure 6: Coupler of 3rd prototype.

Furthermore, inner surface of the coupler is electropolished to get a surface with very small roughness. In the Fig. 7, we clearly see the difference between the surface after electropolishing and that is unpolished. The electropolishing has an uncertainty in a depth shaved by that. It amounts approximately to several micrometers which correspond to a frequency error of several hundreds of kHz. A problem in this method is that once the electropolishing process is finished, we cannot further process the coupler cavity for the resonant frequency adjustment because it deteriorates the surface roughness. As a solution to this problem, we adjust a dimension of the beamhole edge curvature to change the resonant frequency. Since the beamhole plunger is welded at the last stage of the fabrication, it can be used to compensate for the frequency shift caused by the electropolishing of the coupler surface, by the electroplating of whole the 1-m long structure and by the welding of other components like cooling-water jacket. As another improvement of this coupler, the field asymmetry due to the coupling hole is corrected by slightly shifting the central axis of the cavity.

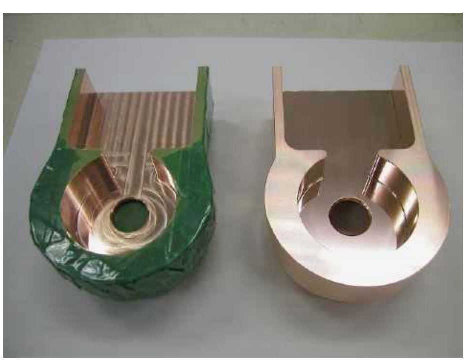

Figure 7: The couplers right is after electropolishing and that left is an unpolished one.

To use the Kyhl method in optimizing this coupler, the coupler cell length is adjusted to same as the regular cells. In order to keep eliminating the E-field edge, the coupler is connected to the standard waveguide through a tapered waveguide. As described in detail in the reference [7], the coupler dimension is determined by simulations and the RF measurement of samples of the low-power models of the coupler.

In contrast to the 1st and 2nd prototypes, the regular cells of the 3rd prototype have larger disk-iris aperture and have larger group-velocity (vg/c ~ 3 %). It corresponds to the most upstream part of the tandem-connected two sections.

The fabrication of the couplers is finished and the frequency tuning of the regular cells is ongoing.

4th prototype (CKM002)

The 4th prototype is a variant of the 1st prototype in which the coupler iris thickness is increased from 1 mm to 3 mm. The outside edges of the iris are machined to have rather smooth shape whose curvature is 1 mm. It is under fabrication in parallel to the 3rd prototype. Electroplating of the regular cells has just finished. It will be completed in June this year and will be installed in the linac.

SUMMARY AND FUTURE PLAN

We have been developing prototypes of the C-band accelerating section for SuperKEKB. The first prototype is in operation in the KEKB linac. The second with improved coupler shape has finished the RF processing. The third and the fourth, expected to be more tolerant against breakdowns, are in fabrication and to be completed in this June. All these four will be assembled this summer in the KEKB linac to form a quasi-complete C-band accelerator module for a full-power operation test.

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