

HIGH POWER TEST OF X-BAND SINGLE CELL HOM-FREE CHOKE-MODE DAMPED ACCELERATING STRUCTURE MADE BY TSINGHUA UNIVERSITY

Xiaowei Wu^{*1,2}, Jiaru Shi^{†1,2}, Hao Zha^{1,2,3}, Huaibi Chen^{1,2},
Toshiyasu Higo³, Tetsuo Abe³, Walter Wuensch⁴,

¹Department of Engineer Physics, Tsinghua University, Beijing 100084, China

²Key Laboratory of Particle & Radiation Imaging (Tsinghua University), Beijing 100084, China

³KEK, Tsukuba, 305-0801, Japan

⁴CERN, Geneva, Switzerland

Abstract

As an alternative design for CLIC main accelerating structures, X-band choke-mode damped structures had been studied for several years. However, the performance of choke-mode cavity under high power is still in lack of research. Two standing wave single cell choke-mode damped accelerating structures with different choke dimensions which worked at 11.424 GHz were designed, manufactured and bench tested by accelerator group in Tsinghua University. High power test has started on it to study the breakdown phenomenon in high gradient. A single cell structure without choke which almost has the same inner dimension as choke-mode cavity will also be tested to make a comparison and study how the choke affects high-gradient properties.

INTRODUCTION

The CLIC-G waveguide damping design is the baseline accelerating structure design for the Compact Linear Collider (CLIC) main linac [1]. It is an X-band accelerator which works in the $2\pi/3$ mode at an accelerating gradient of 100 MV/m. In order to avoid beam instability, the transverse wakefield created by the beam in the cavity needs to be suppressed. The choke-mode accelerating structure was first proposed by Tsumoru Shintake [2] and applied in SACLAL which has been working at C-band. The choke reflects the accelerating mode back to the main cavity while the higher order modes (HOM) can pass the choke and will be absorbed in the load, as shown in Fig. 1. The choke-mode design has lower surface magnetic field and lower pulsed temperature rise compared with waveguide damping design. It can be manufactured easily by turning because of its axially symmetrical shape [3]. As an alternative design for CLIC main accelerating structures, X-band choke-mode structures had been studied under the collaboration between Tsinghua University, CERN and KEK. Three X-band single cell standing wave structures including two choke-mode cavities and one reference cavity without choke were designed, fabricated, assembled, bench tested and tuned by Tsinghua University. The high power test which aims at studying the high gradient properties of X-band choke-mode structure is ongoing at Nextef [4] in KEK.

* wuxw12@mails.tsinghua.edu.cn

† shij@mail.tsinghua.edu.cn

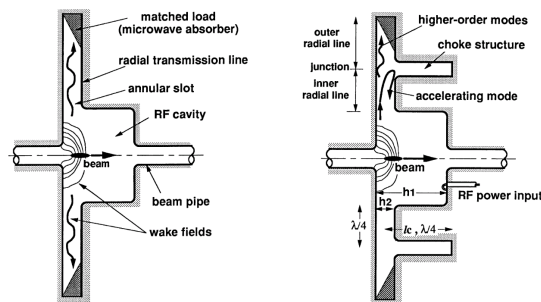


Figure 1: Radial line damper (left) and choke-mode cavity (right).

RF DESIGN

Three single cell standing wave structures including two choke-mode designs and one reference design were proposed by Tsinghua University, as shown in Fig. 2. The first choke-mode structure which is called THU-CHK-G1.68 comes from the choke design of CDS-C in [3]. The reference structure called THU-REF is an ordinary single cell standing wave structure whose test cell has the same dimension as THU-CHK-G1.68. These two structures will be compared to study how the choke affects high power performance.

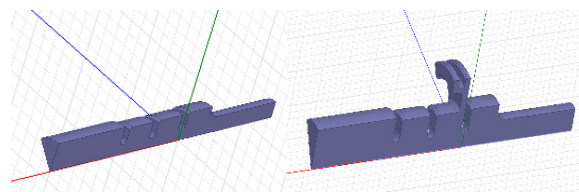


Figure 2: One eighth of 3D model of reference design (left) and choke-mode design (right) in HFSS [5], input power is fed from the left side.

In addition to THU-CHK-G1.68, another choke-mode design called THU-CHK-G2.1 was also proposed. It has a different choke dimension compared with THU-CHK-G1.68. “G2.1” means that the gap of the choke is 2.1 mm, shown as $d1$ in Fig. 3. SLAC High gradient experiments with 11.4 GHz choke accelerating cavities demonstrated that cavities with gap of 1 mm had inferior performance to the no-choke cavities and the cavities with 4 mm gap had

the same performance as the no-choke cavities [6, 7]. As larger choke gap may give us a better high gradient performance, 2.1 mm was chosen for the new choke design to compare with the CDS-C design whose gap is 1.68 mm. In order to keep the HOM damping property, c_1 , c_2 , g_{23} shown in Fig. 3 were tuned to optimize the choke. The radii of the coupling cells, shown as b_{in} and b_{end} in Fig. 3, were also optimized to obtain a better coupling.

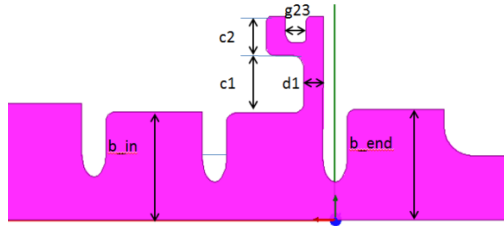


Figure 3: Dimension optimized in new choke-mode structure design.

FABRICATION

The mechanical design of THU-CHK-G1.68 was made of 6 disks, as shown in Fig. 4. The middle cell with choke was achieved by two disks together. All of these disks were manufactured by turning because of the symmetrical design of choke-mode structure.

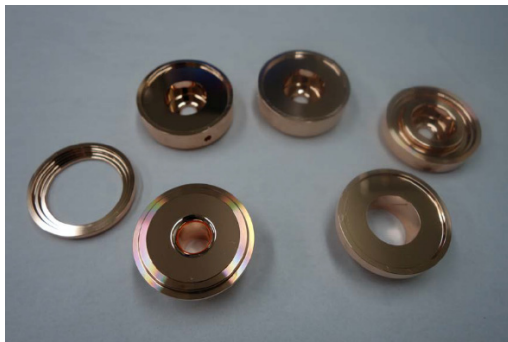


Figure 4: Disks of THU-CHK-G1.68 before bonding.

The assembly was done by diffusion bonding in a hydrogen furnace at Tsinghua University. As the contact areas of each choke-mode structure disks are not consistent vertically, a diffusion bonding test for choke-mode structure was carried out to check whether there was any deformation occurred during the bonding. We measured the inner dimension of the test cavity after cutting it into two pieces. Test cavity after cutting was shown in Fig. 5. The test showed a good result and no obvious deformation was observed. Then we went to the final diffusion bonding for the three single cell standing wave structures.

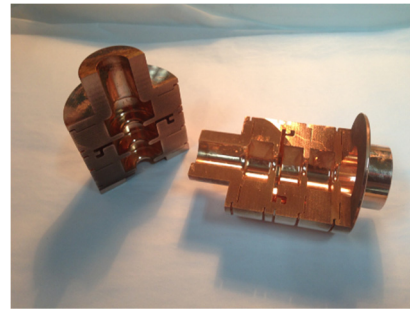


Figure 5: Cut pieces of choke-mode structure, the choke can be seen in the middle cell.

BENCH TEST

Bench tests were done before and after diffusion bonding and no frequency shift was observed which indicated that disks were not deformed during the assembly. Operating frequency of three structures was tuned to 11.424 GHz at 30 degC which is the cooling water temperature of Nextef. Three structures were vacuum baked at 500 degC for 5 days and then shipped to KEK for high power test after being closed by vacuum valves to keep vacuum environment inside. The final bench test was done in KEK after carefully purged with keeping nitrogen gas flow. Results are shown in Fig. 6. The operating frequency stayed consistent with the results tested at Tsinghua University while the loaded Q factor and coupling factor changed because mode launchers used in Tsinghua and KEK were different.

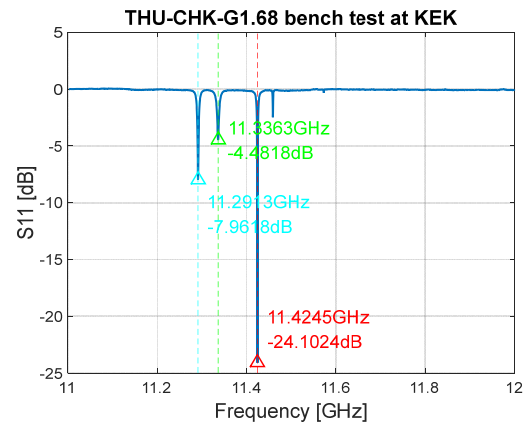


Figure 6: Bench test result at KEK.

HIGH POWER TEST

The high power test of THU-CHK-G1.68 started from 2016.4.15 after the cavity was installed in shield-B [4] of Nextef. The cavity equipped with cooling blocks, water pipes and thermal couplers is shown in Fig. 7. RF power was transferred to shield-B via WR90 waveguide and circular low-loss wave guide and then fed into the cavity from the mode launcher seen in the right side. The reflection rf signal and the dark current signals were monitored and used for breakdown detection. Once breakdown occurred, we stopped the next rf pulse and waited for several tens of

seconds. The operation would restart at a lower rf power level and ramped to the origin set value.

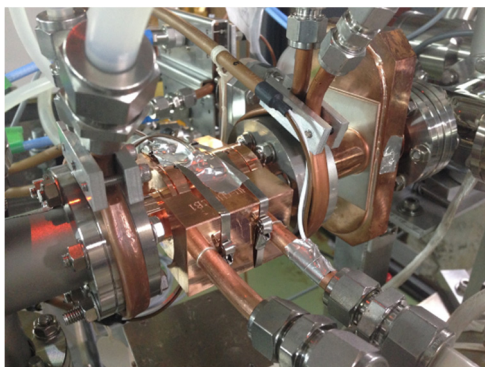


Figure 7: THU-CHK-G1.68 under high power test.

The initial high power test results are shown in Fig. 8. The structure ramped to a maximum Eacc of 90 MV/m successfully in 100 ns pulse width operation. However, the input power could not be easily increased further after reaching 90 MV/m due to the frequent rf breakdown events. The rf breakdown events recorded in our system also showed a big difference between the operations before and after reaching 90 MV/m. There is an increase of the reflection wave accompanied with dark current flash for the breakdown events in the operation before reaching 90 MV/m while almost no dark current flash was observed for the breakdown events afterwards. During the operation, multiple chain breakdowns occurred frequently and numerous vacuum trips were observed. Similar experimental results of choke-mode structure were reported in [8]. All of the recorded events need to be checked again and carefully studied. Now the structure is still under high power testing and running at the two-step pulse shape which will keep the constant electrical field. The other two single-cell structures will be tested soon to make a comparison with the first one.

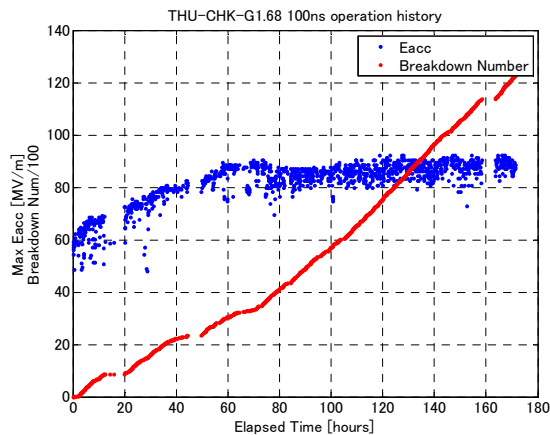


Figure 8: Initial results of THU-CHK-G1.68 high power test.

CONCLUSION

In this work, three X-band single cell standing wave accelerating structures including two choke-mode structures and one reference structure were designed, fabricated, assembled, bench tested and tuned by Tsinghua University. Bench tests at Tsinghua University and KEK showed consistent with each other. The initial result showed that THU-CHK-G1.68 could reach a maximum gradient of 90 MV/m at 100 ns pulse width easily but higher gradient could not be achieved in a short time. The other two structures will be high power tested and compared to study the performance of choke in high gradient.

REFERENCE

- [1] A. Grudiev and W. Wuensch, "Design of the CLIC Main Linac Accelerating Structure for CLIC Conceptual Design Report", Proceedings of LINAC10, Tsukuba, Japan, 2010.
- [2] T. Shintake, "The Choke-mode Cavity", Jpn. J. Appl. Phys. 31, L1567 (1992).
- [3] H. Zha, "Choke-mode Damped Structure Design for the Compact Linear Collider Main Linac", Phys. Rev. ST Accel. Beams 15, 122003 (2012).
- [4] S. Matsumoto, T. Abe, Y. Higashi, T. Higo, and Y. Du, "High Gradient Test at Nextef and High-power Long-term Operation of Devices", Nucl. Instrum. Methods Phys. Res., Sect. A657, 160 (2011).
- [5] Ansoft HFSS, www.ansoft.com.
- [6] V. A. Dolgashev, Standing Wave Structure Design, ISG meeting, SLAC, June, 2002.
- [7] A. D. Yermian, V. A. Dolgashev, S. G. Tantawi, Choke for Standing Wave Structures and Flanges, SLAC-PUB-15145, Proceedings of IPAC'10, Kyoto, Japan.
- [8] V. A. Dolgashev, et al., "Status of High Power Tests of Normal Conducting Single-cell Structures", EPAC08, Genoa, Italy, 2008.