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FABRICATION, ASSEMBLY AND TEST OF THE 2×4-CELL SUPERCONDUCTING LINAC MODULE FOR THE CAEP FEL-THz FACILITY *

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Abstract

A 2×4-cell superconducting linac module for the THz-FEL facility has been developed at the China Academy of Engineering Physics, which is expected to provide 6~8 MeV quasi-CW electron beams with an average current of 1~5 mA. The module consists of two 4-cell cavities, two power couplers, two tuners and the cyromodule. The main components are tested before the module assembly. The cavity test includes microwave measurement at room temperature and vertical test at 2 K. The conditioning and test of the couplers are also finished. The performances of the main components and the whole module are presented in this paper. The horizontal test indicated that the effective field gradients of both cavities have reached 10 MV/m, which have satisfied our designed goal.

INTRODUCTION

The FEL-THz facility in the China Academy of Engineering Physics (CAEP) is under construction at Chengdu, China. It is expected to provide 1 ~ 3 THz FEL with average power greater than 10 W [1]. Because of the advantages on working at CW mode or long pulse mode with high accelerating gradient, RF superconducting technology is employed in this project. As shown in Fig. 1, the superconducting module is used to accelerate the CW 1~5 mA beam from 320 keV to 6~8 MeV. The design of the module is based on the requirement of CW mode operation, such as beam loading and HOMs issues [2]. Two 4-cell TESLA-type cavities are adopted instead of one original 9-cell cavity, because of the limit of coupler power tolerance.

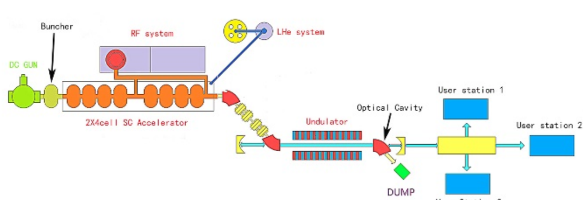

Figure 1: Layout of the CAEP THz-FEL facility.

Fig.2 shows the sectional view of the module. It consists of two 4-cell cavities, two power couplers, two tuners [3] and the cyromodule [4]. After the components are tested alone, the module are assembled and tested in Chengdu, China. The test technology and results are presented in this paper, as well as the components test.

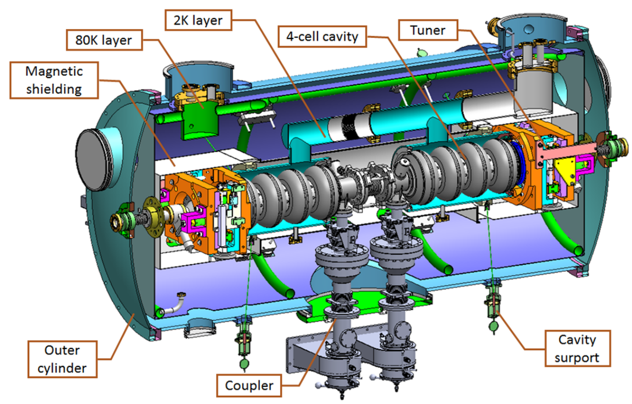

Figure 2: Schematic of the 2×4-cell module.

CAVITY PERFORMANCE

The 4-cell cavities are fabricated by Peking University. The RF character are measured by low power microwave test at room temperature. The frequency and electric field distribution of the fundamental mode and higher order modes are measured. After carefully adjust every cell length, the field flatness of each cavity reaches 95% (see Fig.3), and the fundamental mode frequency is adjusted to 1297.3 MHz, in order to make the frequency 1300 MHz after cooling down.

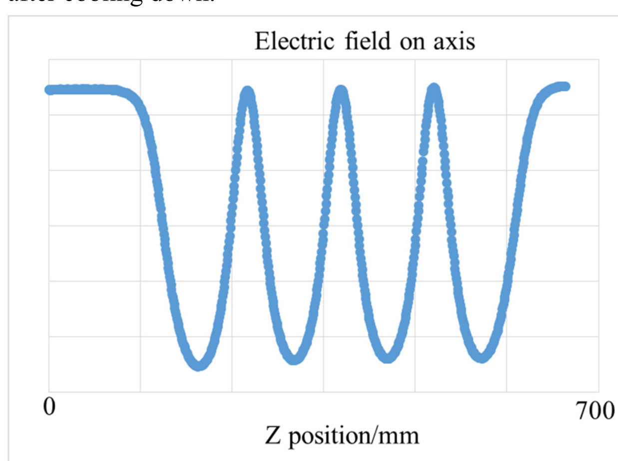

Figure 3: The electric field distribution of the fundamental mode in the 4-cell cavity.

The frequency and the field distribution of the HOMs are also measured. The modes type are identified by comparing with the simulation results before. The perfor-

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mance of the HOM coupler are measured by S-parameters. To avoid fundamental mode leak out from HOM couplers, the S_{21} of the fundamental mode is adjusted to lower than -100dB, as shown in Fig. 4. The Q_e of the HOMs are 10^3~10^6, which means the HOM couplers are able to damp HOM power effectively.

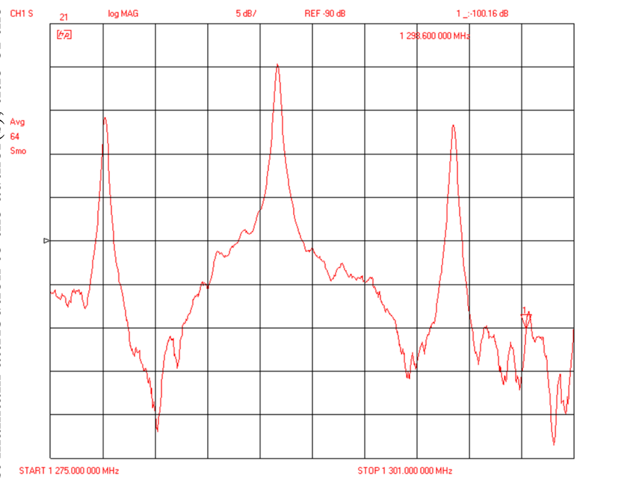

Figure 4: The S_{21} parameter of the HOM coupler.

In order to make sure the accelerating gradient can reach our target (10MV/m), one 4-cell cavity was transported to JLAB (USA) for 2K vertical test. A series of surface treatment were processed at JLAB, such as BCP, ultrasonic cleaning and drying, outgassing baking, HPR, etc. The Q_0 versus E_{acc} curve measured by VTA is shown in Fig. 5. Q_0 is larger than 2×10^{10} for gradients of 8~18 MV/m. The test is stopped at 30MV/m, due to the field emission effect.

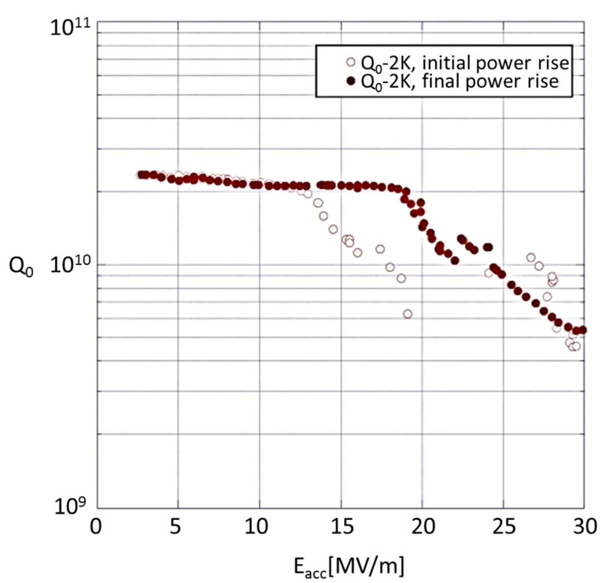

Figure 5: Q_0 versus E_{acc} for a 4-cell cavity at 2 K temperature.

COUPLER PERFORMANCE

The power couplers (CPI Company produced) are coaxial type with the presence of both warm and cold windows. They are fabricated by CPI company (USA) based on the design of the CORNELL ERL couplers [5]. The couplers are conditioned at Chengdu to get the maximum transfer power. Figure 6 shows the conditioning structure. Liquid nitrogen is used for cooling the dissipation power at cold window part. Temperature sensors and arc sensors are connected into interlock protect loop, in case that the power is too high. By about two months conditioning, the maximum power reaches 30 kW in CW mode (as shown in Fig.7), which was limited not by the coupler performance but by the power source.

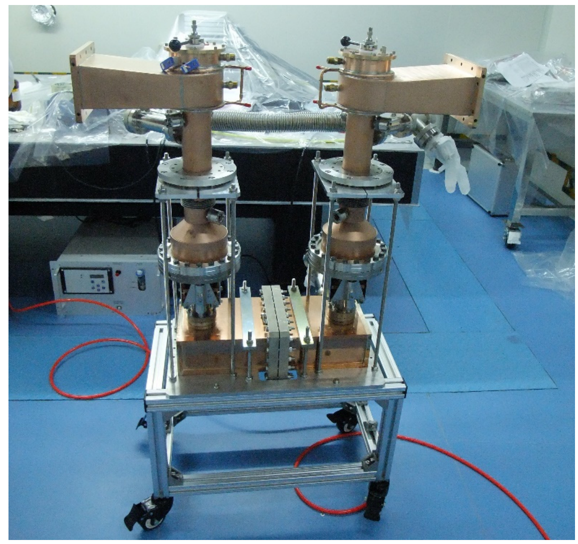

Figure 6: The conditioning structure equipped with couplers.

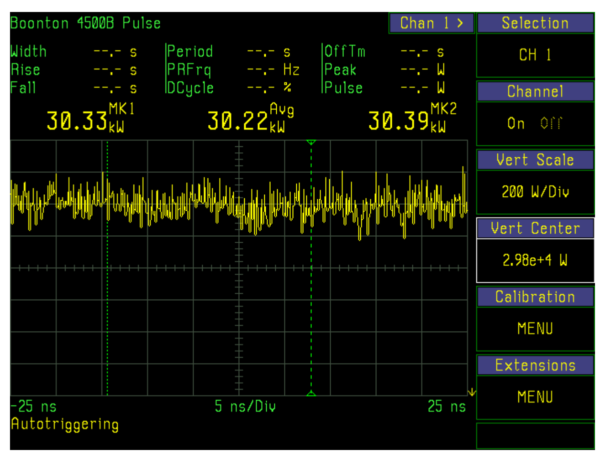

Figure 7: The max power reaches 30 kW in CW mode.

After power conditioning, the couplers were disassembled, and the cold parts were transported to Peking University to install on cavities.

ASSEMBLY

The assembly procedure is composed of two stage. Since there is no 100-class ultra-clean room in our lab in Chengdu, the cavity string assembly was done in Peking University. As shown in Fig. 8. The coupler cold parts, tuner planks and valves were installed on the jacketed cavities. And the string was carried back to Chengdu as a whole. Then the rest parts were assembled at the facility hall, such as 80K layer, magnetic shielding, coupler warm

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parts, sensors, and so on. Figure 9 shows the accomplished superconducting module which has been connected with the cryogenic system and the microwave system.

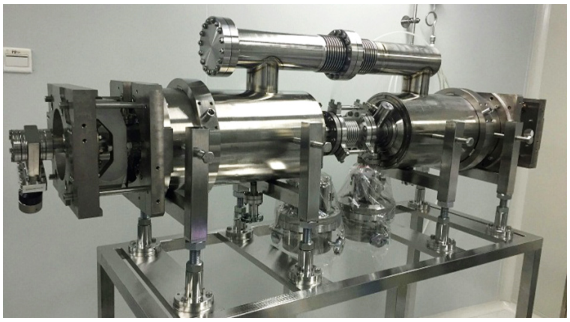

Figure 8: The cavity string assembled in 100-class ultra-clean room.

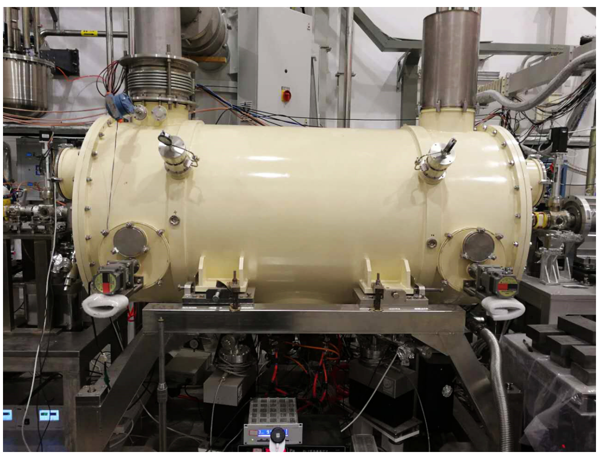

Figure 9: The superconducting module accomplished ssembly.

HORIZONTAL TEST

The cool down procedure from room temperature costs about ten days. All the components work well at 2K state. The vacuum of every layer can satisfy our requirement. The static heat loss is 17.4 W, including the heat loss along the helium transmission line (about 5 W).

The field in the cavity is build up and controlled by the LLRF system and protective interlock system. The forward and reflect signal is monitored by the power meter and the oscilloscope. The linear relation between the accelerating gradient E_{acc} and the amplitude of the pickup signal V_{pickup} are calibrated at 4 K state, by Eq. (1) and Eq. (2). The measured E_{acc} versus V_{pickup} at 4 K state is shown in Fig. 10.

$$E_{acc} = K \cdot V_{pickup} \tag{1}$$

$$E_{acc} = \frac{\sqrt{P_0 \cdot Q_0 \cdot \frac{R}{Q_0}}}{L_{cav}} \tag{2}$$

[6] K. Zhou *et al.*, “Progress of the 2×4-cell superconducting accelerator for the CAEP THz-FEL facility”, in *Proceedings of the 18th International* Conference *on RF Superconductivity*, Lanzhou China, July 17-21, 2017, paper MOPB037.

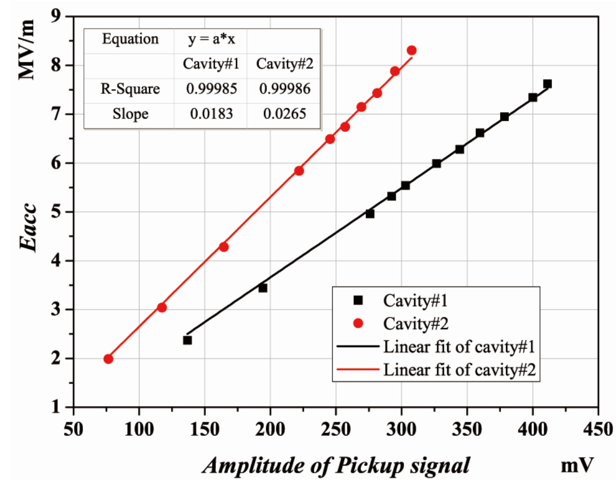

Figure 10: Eacc versus Amplitude of pickup signal at 4 K.

Then the module was cooled down to 2K, and the max E_{acc} are measured. The effective field gradients of both cavities have reached 10 MV/m, which have satisfied our designed goal. More detailed results of horizontal test can be seen in Ref. [6].

SUMMARY

The 2×4-cell superconducting accelerator for THz-FEL facility has finished its construction and horizontal test. The accelerating gradient of the 4-cell cavity reaches 18MV/m while Q_0 is 2×10^{10} in vertical test. And the max power of couplers reaches 30 kW after conditioning. The 2K horizontal test shows that the whole superconducting cyomodule works well and stably. The effective field gradients of both cavities have achieved our target, 10 MV/m.

ACKNOWLEDGEMENT

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