THE C-BAND TRAVELING-WAVE ACCELERATING STRUCTURE FOR COMPACT XFEL AT SINAP *

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Abstract

R&D of a C-band (5712MHz) high gradient traveling-wave accelerating structure has been in progress at Shanghai Institute of Applied Physics (SINAP). Conceptual design of the accelerating structure has been accomplished, and verified by the cold test of the experimental model. Now the first prototype structure is ready for high RF power test. This structure is the type of constant impedance structure, and composed of 51 regular cells and 2 matching cells with about 1.1m long totally. This paper presents the fabrication, cold test, RF tuning and the matching results of this first structure.

INTRODUCTION

A compact hard X-ray Free Electron Laser (XFEL) facility is presently being planned, and some analytical and simulation research is ongoing at the Shanghai Institute of Applied Physics [1]. This facility will be located close to the Shanghai Synchrotron Radiation Facility which is a 3rd generation light source in China [2]. It requires a compact linac with a high gradient accelerating structure and high beam quality. At room temperature, linac, the C-band (5712 MHz) accelerating structure, is a compromise and a good option for this compact linac designed to operate at 40 MV/m [3]. In XFEL/SPring-8, the chock-mode-type C-band accelerating structure of 1.8 m is designed to operate at a high accelerating gradient of 35 MV/m (40 MV/m was achieved in 2009). This results in the 8 GeV linac of XFEL/SPring-8 being about 400 m in total length, which is a suitable size for a compact facility compared with similar machines in the United States and Europe [4, 5].

To verify the design, RF cold test and manufacture technology, an experimental model of a C-band accelerating structure of constant impedance with a 2π/3 mode was fabricated and tested, and to a large extent the cold test results confirm the feasibility of conceptual design and RF cold test principle [3], and also support the R&D of the C-band accelerating structure for high power test.

Based on the experimental results, a new model is ready for high power RF test. The new C-band accelerating structure of constant impedance comprises 51 regular cells and 2 matching cells with total length of 1.1 meter, which coupler is also the two ports electrically-coupled coupler, the same one as experimental coupler [3]. This paper introduces the general procedure of components machining and brazing, the RF cold test and tuning based on the Nonresonant Perturebation theory, and the baking.

MACHINING AND BRAZING

The whole Structure comprises of regular cells, couplers, high power waveguides and stainless steel flange, which is shown in Fig. 1. The regular cells are conventional disk-loaded type, and the coupler is a two ports electrically-coupled coupler, which can reduce the RF breakdown effectively [6]. The high power waveguides, which are the function of power divider and transmission, are connected by ADESY-type flange. ADESY-type flange performs excellently on microwave transmission compared with the conventional flange [7], and other flanges for beam tube connection are the CF35-type.

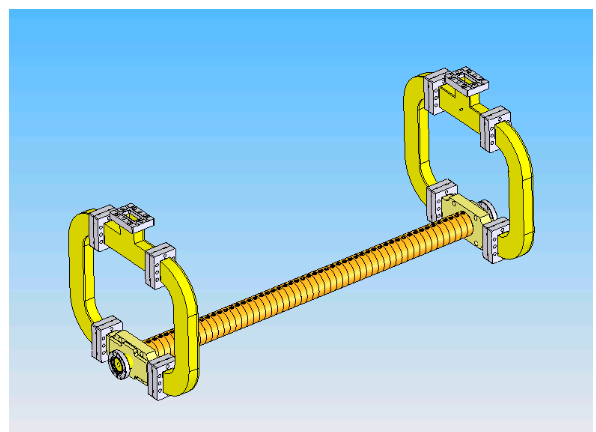

Figure 1: The drawing of the C-band accelerating structure.

All the identical disk-loaded cells are machined by diamond lathe with ±5 micrometers accuracy, and other components are maschined by milling. Some components are illustrated in Fig. 2.

All the components finally brazed together through 5 steps. Firstly three parts in Fig 2 are brazed independently, especially the regular cells are brazed into three identical sections; and then the flanges are brazed to the couplers and waveguides; After all the components are ready, two couplers first are brazed with two regular sections; and then all the couplers and regular sections are brazed together, Fig. 3 shows this step of brazing in the hydrogen furnace; after the four steps above, at last the water tubes are brazed to the accelerating structure.

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Figure 2: Components of C-band accelerating structure.

RF COLD TEST AND TUNING

After all the brazing step, the C-band accelerating structure is tested by low power RF, and tuned to eliminate the mismatch of couplers and regular cells, the setup for RF cold test and tuning is vertical type platform as shown in Fig. 4. Compared with the transverse setup in [3], the vertical setup can facilitate the installing process, and make sure the inner wall is clean relatively.

Figure 3: The structure brazing in the hydrogen furnace.

Figure: 4: The vertical setup for C-band accelerating structure RF cold test.

According to the non-resonant perturbation theory [6, 7], A tuning code based on LABVIEW 8.5 has been written. The software controls the RF cold test system composed of NWA Agilent 8363B, step motor and computer, and then acquires the measurement data from the system. The amplitude and phase of field distribution on axis are analyzed, and then the mismatch of each cell can be calculated cell by cell independently. According to the mismatch of each cell, the accelerating structure can be tuned cell by cell iteratively under the control of LABVIEW code.

Before the tuning of the C-band accelerating structure, the field distribution of amplitude and phase on axis and input S11 are shown in Fig. 5. From Fig. 5 the standing-wave rate (SWR) of both inner structure and input port is very large, and utilizing the analysis by LABVIEW code, all mismatch values of each cell are derived as shown in Fig. 6. There are mainly three parts of cells inducing remarkable mismatch in the red circle of Fig. 6, and next all the cells proceed to tune cell by cell depending on the real-time-control tuning system based on the LABVIEW code.

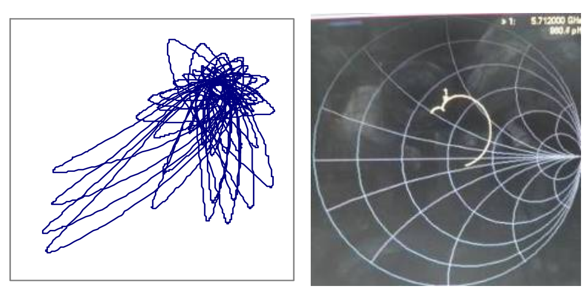

Figure 5: The mismatch status of accelerating structure Left: field distribution on axis; Right: S11.

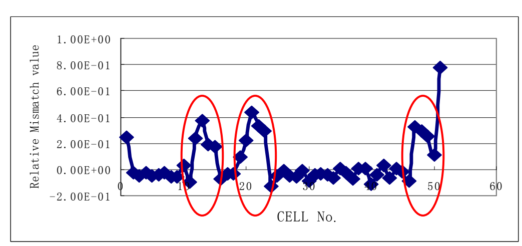

Figure 6: The mismatch distribution of each cell.

After tuning of all cells and two couplers, the C-band accelerating structure is matched. The field distribution on axis is smooth and the reflection of input port becomes slight as shown in Fig. 7, 8. The SWR in of input port is below 1.1 corresponding to 2MHz bandwidth, and on the point of center frequency 5712MHz the S11 is about -35dB, and also the same to the field distribution on axis. The results are thus reach the design target, and after the baking, the model can be ready for the high power RF test.

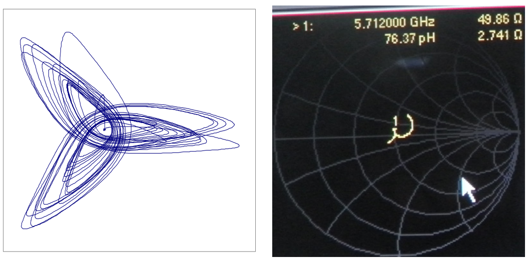

Figure 7: The match status of field distribution on axis and input port.

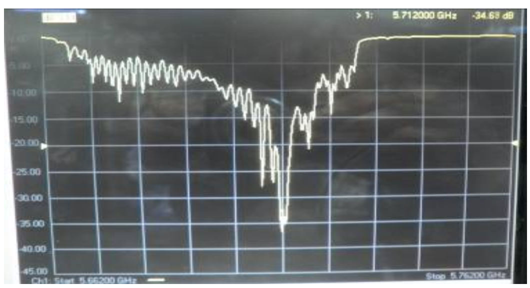

Figure 8: The S11 characteristic of full band (100MHz).

BAKING

After all the process of the machining, braking and RF cold test, we proceed the a long time baking to make sure the high level vacuum inner the C-band accelerating structure, and it can facilitate the following high power RF conditioning. The baking is proceeding for about 48 hours in the reach of the 480 Celsius Degree highest temperature, and the last vacuum level reach below 10^{-6} Pa. Fig. 9 illustrates the full baking process, which includes the temperature and vacuum level proceed in term of hours.

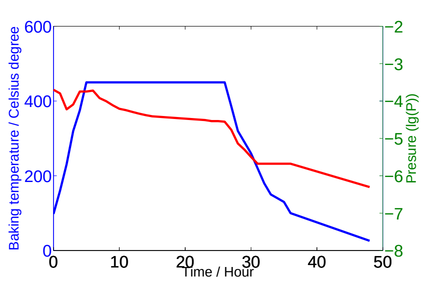

Figure 9: Vaccum level and temperature during baking

After 48 hours baking process, the C-band accelerating structure is vacuum-sealed, and ready for high power RF test. The accomplished model is shown in Fig. 10.

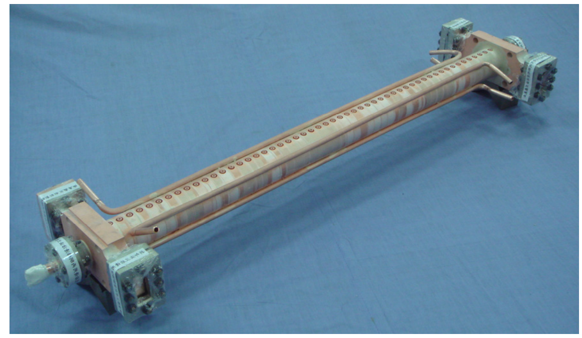

Figure 10: The model for high power RF test.

CONCLUSION AND FUTURE WORK

High gradient C-band traveling-wave accelerating structure is the key component for the compact XFEL facility. The model for high power test is accomplished, and in the process of R&D, and successfully the design, RF cold tuning and fabrication are carried out gradually. Future works are forced on the C-band high test setup building and a new C-band traveling-wave accelerating structure which is optimized on RF breakdown and beam quality [8]. At present the 50MW C-band klystron from KEK is ready, and other high power components will be accomplished soon.

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