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ELECTROMAGNETIC AND MECHANICAL DESIGN OF HIGH GRADENT S-BAND ACCELERATING STRUCTURE IN TTX

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Abstract

Thomson scattering x-ray source is an essential scientific platform and research tool in x-ray imaging technology for various fields. Upgrading plan that replacing the 3-meter S-band old linac with shorter high-gradient structure in Tsinghua Thomson scattering X-ray source (TTX) is undergoing so far, aiming to enhance accelerating gradient from 15 MV/m to 30 MV/m. Detailed parameters of couplers and electromagnetic simulation results of whole acceleration structure are presented in this paper. Finally, mechanical structure and further upgrading research on energy with X-band structures are also discussed.

INTRODUCTION

The Advanced X-ray sources, including X-ray free-electron-lasers facilities and Thomson scattering facilities, are widely used in molecular biology and material sciences research area. In Tsinghua University, we have built the compact Thomson x-ray scattering source, which is specialized in hard x-ray generating in china firstly [1]. The current beam line layout of TTX is presented in Fig. 1 (a).

In the latest proposal, we are planning to add two X-band accelerating structures and replace the S-band travelling wave (TW) tube with a shorter one in 1.5-meter, maintaining high-energy x-ray photos generation meanwhile. The layout of beam line after the upgrading is showed in Fig. 1(b).

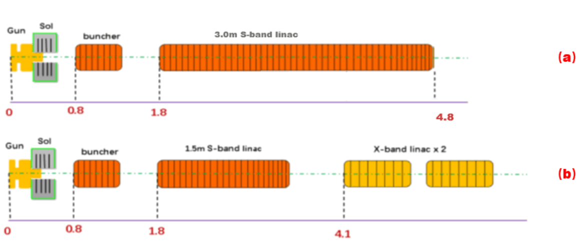

Figure 1: Present linac layout and upgrade proposal.

In the new acceleration structure, we have adopted the constant gradient design in chambers to achieve a higher acceleration gradient as well as a shorter distance. The S-band TW tube are supposed to working in 3π/4 mode through electromagnetic simulation. The method and the concrete parameters of the design of the cavity structure has been demonstrated previously [2-3]. The following section we will present input/output couplers design parameters and the whole integrated structure with acceleration chambers. The completely electromagnetic structure and mechanical structure of the S-band TW tube are also showed here.

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ELECTROMAGNETIC DESIGN

Completely single-cell design procedure of S-band TW tube has finished [2]. Continuous feedback brings adjustments dynamically between the electromagnetic design and realistic mechanical manufacturing procedure.

The simulated parameters of S-band TW tube without couplers are updated in Table 1.

Table 1: Completely Parameters of S-band TW Tube

Parameters	Value
Frequency	2856.00 MHz
Phase advance per cell	3π/4
Length	1.456 m
Cell numbers	37
Period	39.36 mm
Iris half aperture	10.22 mm~8.13 mm
Cell radius	42.53 mm~42.17 mm
Elliptical iris long axis	9.54 mm
Elliptical iris thickness	5.3 mm
Filling time	999 ns
Group velocity (v_g/c)	0.00724~0.00302
Shunt impedance	66.2 MΩ/m~72.0 MΩ/m
Input power	30 MW
Gradient	31.5 MV/m~29 9 MV/m

Separate design process of dual-feed coupler was simulated in working frequency of 2856MHz to match the chambers as microwave input/output port.

Coupler Design

The input and output couplers have been designed in order to implement the power feeding into structure. Dual-feed coupler structure and its separated model with four cells are showed in Fig. 2 [4]. One fourth of side coupler are showed in Fig.3 [4].

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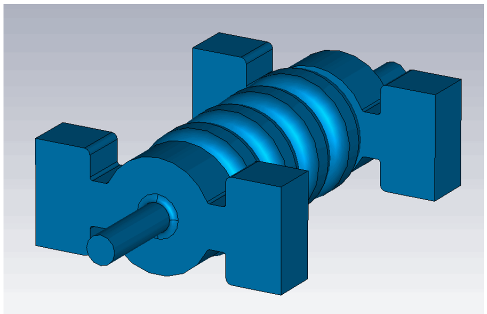

Figure 2: Model of coupler with four cells.

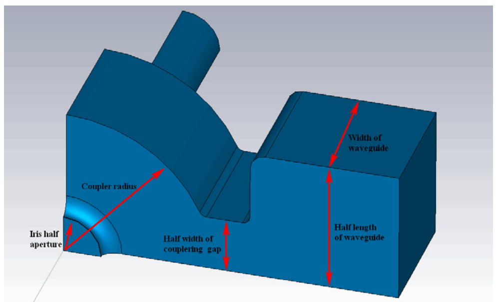

Figure 3: Symmetric split of coupler model in simulation.

We have optimized radius of coupler and width of coupling gap for lower reflection. Parameters of couplers working in 2856 MHz are listed in Table 2.

Table 2: Input / Output Couplers Parameters

Parameters	Input coupler	Output coupler
Iris half aperture	10.22mm	8.13mm
Coupler radius	39.46mm	39.52mm
Half-width of coupling gap	15.23mm	13.94mm
Half-length of waveguide	36.07mm	36.07mm
Width of waveguide	34.04mm	34.04mm

The input and output coupler convert TE mode to TM mode and transmit power through waveguide. The simulated reflection coefficient of individual input/output coupler with four cells are showed in Fig. 4.

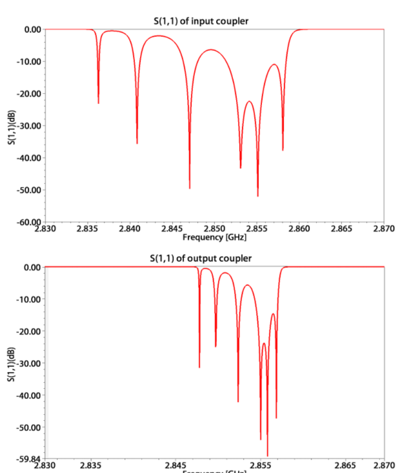

Figure 4: S (1, 1) parameter of input/output coupler.

Completely Electromagnetic Accelerating Structure

In the whole design process, feedback between the electromagnetic design and realistic mechanical design procedure has been necessary.

Combined cell-chains consists of each cell and power feeding couplers are integrated with beam pipe. The whole S-band accelerating structure are showed as Fig. 5 [4].

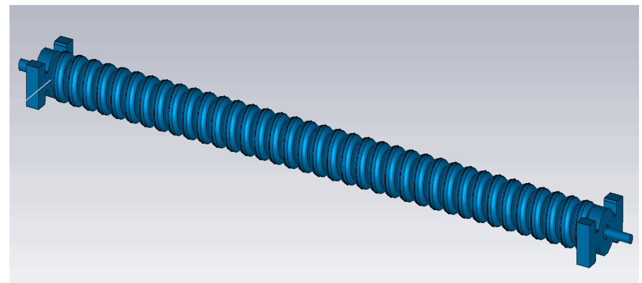

Figure 5: Completely electromagnetic model of S-band TW tube.

Initial tuning and simulation results shows that microwave reflection of whole structure is -14 dB.

Optimizing the radius for every cell and the size of coupling port is continuing in process to match the microwave working frequency in 2856 MHz.

Mechanical Design

The electromagnetic model of the vacuum area wrapped in the metal boundaries. Division of whole acceleration structure are cavities, input coupler and output coupler.

The cell design was split up in the middle position of cavity for the industrial manufacturing procedure consideration. The section chart of cavity has demonstrated as Fig. 6 [5].

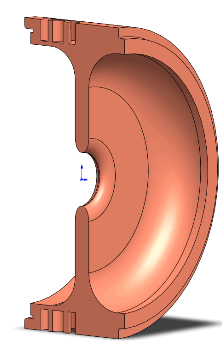

Figure 6: Mechanical model of individual cavity design.

Couplers was split into two parts for conventional milling process. Half of coupler component combined with one cell part to form the first cavity and the last cavity.

The accelerating structure is consisting of 37 vacuum chambers by adding input couples, output couples and 36 similar parts above combing. The completely mechanical design with flanges are showed as Fig. 7 [5].

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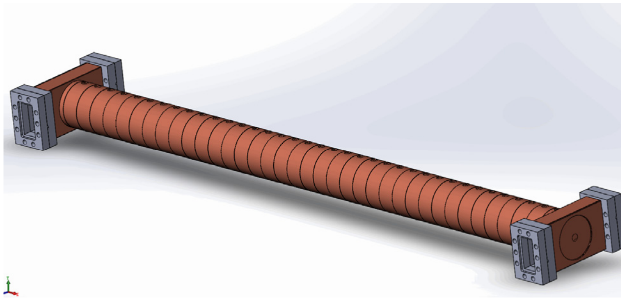

Figure 7: Completely mechanical model of acceleration structure.

Mechanical drawing is real-time adjustment with results of electromagnetic simulation process. Subsequent fabricating procedure will be carry out when the optimistic process finished.

CONCLUSION

The initial design of S-band TW tube with nearly 1.5m length is finished and overall parameters have mentioned previously. Mechanical drawing design are in progress depended on optimistic simulation results. Next several months, manufacturing procedure will carry out. After that, frequency measurement of cold test and high power test of the structure will proceed in platform. Final experiment results will characterize the performance of tube.

Structure optimization in upgrading proposals is aiming to improve electron energy into 150 MeV. Meanwhile, synchronically structure design of another two X-band accelerating tube is in progress. Furthermore, mechanical design of X-band acceleration structure keeps pace with the fabrication of X-band TW tube.

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