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DESIGN OF AN X-BAND 3MeV STANDING-WAVE ACCELERATOR WITH NOSE-CONE STRUCTURE MADE FROM TWO HALVES*

Focheng Liu[1], Hao Zha[1], Jiaru Shi[†,1], Huaibi Chen[1], Chuanxiang Tang[1]
Department of Engineering Physics, Tsinghua University, Beijing, China
[1]also at Key Laboratory of Particle and Radiation Imaging of Ministry of Education, Tsinghua University, Beijing, China

Abstract

This work presents an X-band 3MeV standing-wave accelerator with nose cones made from two halves. To qualify the processing capacity of machine tools, a single cell accelerating structure is designed, optimized and manufactured, whose simulated shunt impedance is 144 MΩ/m. The X-band linear accelerator includes 4 bunching cavities and 4 accelerating cavities, the total length is 11 cm. The shunt impedance of whole linear accelerator is 108 MΩ/m. A technical prototype is under fabrication to bring two milled halves manufacture way into industrial low energy accelerating application.

INTRODUCTION

The traditional normal conducting accelerating structures are manufactured to individual cell disks by precision turning and milling. Then these disks, usually with a large amount, are joined together by diffusion bonding.

An alternative method of milling two longitudinally split halves has aroused extensive attention [1-3]. Compared to traditional disk structures, half structures can reduce the number of pieces. Microwaves are cut off at the joint gap between two halves, so it is better for cold test before brazing and brazing itself. These two advantages make this method a more economic method. What's more, half structures show a great potential in high frequency accelerating structures manufacture [3].

However, more requests on half structures processing have been brought forward, especially on milling. As a result, half accelerating structures mentioned above have few numbers of cells [3] or just have accelerating cells with similar geometry [1, 2]. There is no nose cone structure [1, 3] or short nose cones in cells [2]. Besides, the way to use this novel method on standing wave accelerators and coupling structures is not discussed before.

The purpose of his work is to apply the half structure method to low energy standing-wave accelerators with normal nose-cone structures, which means bunching cells, accelerating cells, and coupling structures between cells should be taken into consideration, and the length of nose cones in cells is similar to the traditional way.

In this work, a single cell accelerating structure is designed and optimized. The rough machining and the first annealing have been completed, and the finishing machining is in progress. On the fundamental of the single cell structure, this paper presents an X-band 3 MeV standing-wave accelerator with 8 cells.

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† shij@tsinghua.edu.cn

DESIGN OF THE SINGLE CELL STRUCTUER

An accelerating single cell structure working at 9.3 GHz is presented in this work. As shown in Fig. 1(a), it is a diagram of single accelerating cell. The earthy yellow area stands for the copper cavity and the blue area stands for the vacuum part. For simplicity, cylindrical cavity is chosen rather than the racetrack design. The most important three parameters are the length of the nose cone structure L_n, the angle of the nose cone structure A_n, and the radius of the accelerating cell b, which are marked with red colour in Fig. 1(a). Other parameters stay the same value with the traditional disks. To manufacture the accelerating cell with nose cone, 5-axis machine tools are required, and the geometrical relation during processing should be considered in design. Figure 1(b) shows one simple situation where the milling cutter and nose cones are tangent on the vertical symmetry plane. Therefore, there is a constraint between L_n and A_n. It is noteworthy that the geometrical relation on 5-axis machine tool is complex and whether interference happens in processing should be verified by tool dynamic simulation programs, and Fig. 1(b) just give a rough relation.

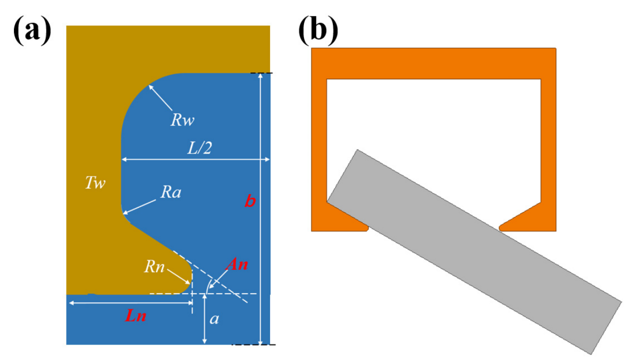

Figure 1: (a) The diagram of single accelerating cell; (b) The tangent relation of the milling cutter (grey) and the copper cell (orange) on the vertical symmetry plane.

Because of the geometrical limit of L_n and A_n, A_n is selected to do parameter sweep. The radius of the accelerating cell b changes during the sweep to keep the working frequency stable. The quadrant model of single accelerating cell in HFSS is shown in Fig. 2(a), and the simulation result of the shunt impedance of single accelerating cell versus the angle of the nose cones A_n is shown in Fig. 2(b).

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According to the results, the best value of A_n is 29°, the length of the nose cone structure L_n is 3 mm, and the shunt impedance of the single accelerating cell is 144 MΩ/m.

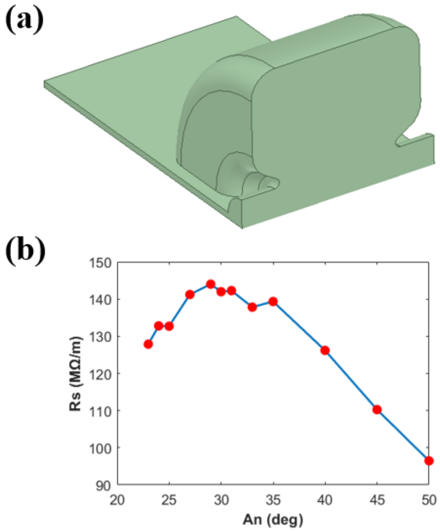

Figure 2: (a) The quadrant model of single accelerating cell in HFSS; (b) The simulation result of the shunt impedance of single accelerating cell versus the angle of the nose cones.

A protype of the single cell structure has been designed and manufactured to test the processing capacity of machine tools and the effect of the tuning structures on two halves. Figure 3 shows the picture of the single cell structure after rough machining and the first annealing, and the finishing machining is in progress.

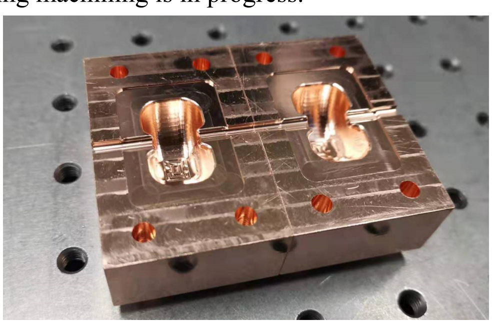

Figure 3: The picture of the single cell structure after rough machining and the first annealing.

DESIGN OF THE 3 MEV ACCELERATOR

Standing wave accelerators usually work at $\pi/2$ mode for mode stability, especially with numerous cells. To increase accelerating efficiency, the coupling cells, with no or little electromagnetic field, are much shorter than accelerating cells or move to the off-axial position, known as biperiodic accelerating structures and side-coupling structures. The biperiodic accelerating structures are easy to process through traditional disk method, but it is difficult to apply biperiodic structures in half method because of the short coupling cells' length. Side-coupling structures have higher shunt impedance and are easy to process at the symmetric plane with well-modified designs.

These two coupling structures are not considered this time, because the main purpose is to apply nose-cone structures in low energy accelerators. For simplification, the working mode is set as π mode with one coupling hole between cells. The HFSS mode is shown in Fig. 4(a). It has one pre-bunching cavity without nose cone, three bunching cavities with short nose cones, and four accelerating accelerating cavities with similar geometry described in last part "Design of the single cell structure". The electronic field distribution at the axis is shown in Fig. 4(b).

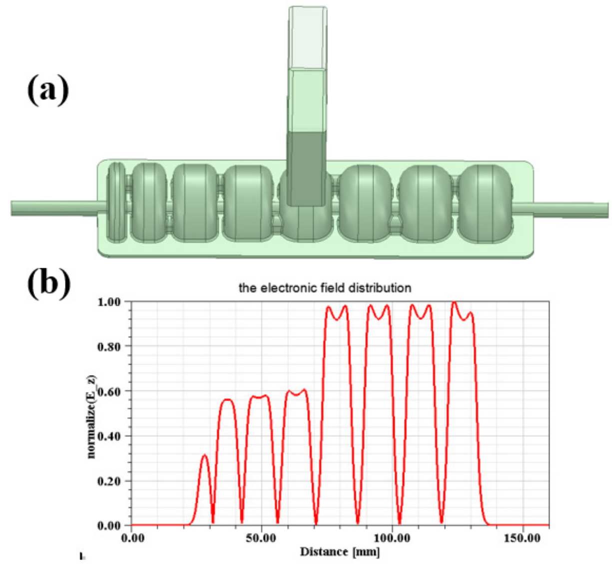

Figure 4: (a) The HFSS model and (b) simulated electronic field distribution of the 8 cells standing-wave accelerator.

The average shunt impedance of the whole accelerator is 108 MΩ/m. The final energy of electrons is 3.5 MeV, with designed current 30 mA and 1.5 MW input power. As seen in Fig. 5, the final energy of electrons injected at different phase shows the good performance of capture efficiency and low energy spread. The longitudinal accelerating process is shown in Fig. 6. The inject phase of plotted results is -100 ° to 50 °, according to Fig. 5. The designed parameters of the SW accelerator are shown in Table 1.

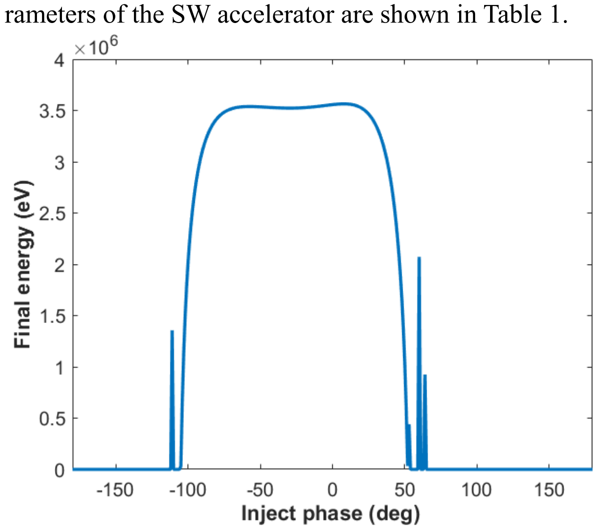

Figure 5: The final energy of electrons injected at different phase of the 8 cells standing-wave accelerator.

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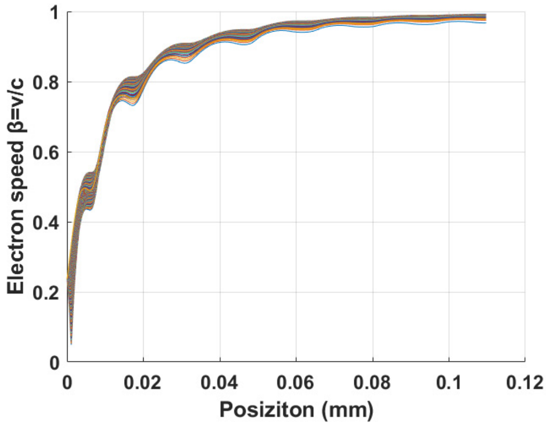

Figure 6: Longitudinal accelerating process. The inject phase of beams is $-100\,°$ to $50\,°$.

Table 1: Designed Parameters of the SW Accelerator

Parameter	Specification
Mode	SW π mode
Frequency	9300 MHz
Coupling	Coupling hole
Whole Length	110 mm
Input Power	1.5 MW
Energy	3.5 MeV
Pulse Current	30 mA
Effective Shunt Impedance in total guide	108 MΩ/m

The mechanical design of the 8 cells SW accelerator is shown in Fig. 7. After the finishing machining and cold test of the single cell structure completed, the fabrication of a technical prototype of 8 cells accelerator would follow.

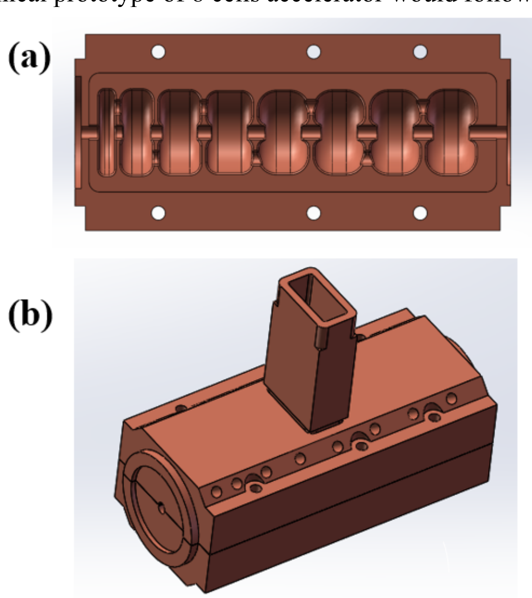

Figure 7: The mechanical design of (a) the half structure and (b) the 3 MeV SW accelerator made from two halves.

CONCLUSION

This work is a technical attempt to bring two milled halves manufacture way into industrial low energy accelerating application. A single cell structure with 144 MΩ/m shunt impedance is designed and under fabrication. An 8 cells X-band standing-wave accelerator has been designed. A standing-wave $\pi/2$ mode accelerator with side-coupling structures made from two halves would be developed as the further plan.

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