THE DESIGN AND DEVELOPMENT OF A 6 MEV X-BAND ON-AXIS COUPLING STANDING WAVE LINEAR ACCELERATOR*

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Abstract

On the basis of an X-band 2 MeV on-axis standing wave electron linear accelerator, we design and develop a 6 MeV X-band on-axis SW accelerating guide that has higher effective shunt impedance. The phase-focusing and asymmetrical cell geometry in the first cavity techniques are used. The non-linearity of RF fields in the accelerating guide is considered. The design parameters of the accelerating guide, magnetron and thermionic cathode are described. This accelerator system operates in $\pi/2$ mode and its frequency is 9300 MHz. A prototype 376 mm long structure has been machined, brazed and sealed, and tested.

1 INTRODUCTION

There are many advantages of using X-band accelerating structures which include small size, light weight, higher shunt impedance, short fill time, higher accelerating gradient and higher breakdown threshold level[1]. So X-band accelerating structure has the broad application in high energy linear colliders and portable accelerators. The portable accelerators can be used in nondestructive testing, radiation therapy, intro-operation radiation therapy, computerized tomography, FEL, et al[2, 3, 4, 5, 6, 7, 8]. Since 1991, the Accelerator Laboratory in Tsinghua University has been studying X-band on-axis standing wave accelerating guide. A 2 MeV accelerating guide (9300 MHz) had been developed[9] and beam tested[10].

Portable X-band linacs are mainly used in nondestructive testing and radiation therapy on-the-spot which energy range is from 2 to 9 MeV, especially above 6 MeV. We improved cell geometry design and considered the probable non-linearity of RF fields as a consequence. A prototype 6 MeV and 376 mm long structure has been designed, machined, brazed and sealed, and tested.

2 PHYSICAL DESIGN

A few types of X-band accelerating structures have been developed, disk-loaded structure[6], side-coupled structure[6], coaxially coupled structure[1, 11], $2\pi/3$ mode structure[7] and on-axis structure[9, 10]. Based on comparing these types of structures and our previous experience, we chose on-axis structure. This structure is convenient to machine and braze in addition small size and less weight.

2.1 Optimization of the Structure

According to the simulation of transverse particle dynamics, we decreased the beam aperture diameter to 3.5 mm and improved the effective shunt impedance to 152 MΩ/m in light speed cavities. It is available for machining and brazing. The designed parameters of a 6 MeV on-axis SW accelerating structure are shown in Table 1.

Table 1: A 6 MeV On-axis SW Accelerator Guide Specifications

Parameter	Specification
Mode	SW $\pi/2$
Frequency	9300 MHz
Structure	On-axis
Energy	6 MeV
Pulse Current	50 mA
Tube Length	376 mm
Input Power	1.2 MW
Beam Aperture Diameter	3.5 mm
Effective Shunt Impedance in light speed cavities	152 MΩ/m
Effective Shunt Impedance in total guide	134 MΩ/m
Spot Diameter	1.4 mm

2.2 RF Phase-focusing and Asymmetrical Cell Geometry in the Fist Cavity Techniques[12]

It is advantageous for portable accelerators without external magnetic focusing devices. So the RF alternating phase focusing is applied. By adjusting the phase velocity tape and the amplitude of the RF fields in the buncher region, the RF fields can provide transverse focusing as well as longitudinal bunching and accelerating. Designing the first cavity as an asymmetrical geometry can produce an asymmetrical electric and magnetic fields. Asymmetrical electric and magnetic fields makes the RF phase-focusing technique more effective. We used RF phase-focusing and asymmetrical cell geometry in the

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first cavity techniques in our design. We can get 1.4 mm spot diameter without external magnetic focusing devices.

2.3 The Non-linearity of the RF Fields in X-band Accelerating Structure

In low energy electron linacs, the RF fields are considered as linear when *r*/*a* is much smaller than 1, where *2r* is the transverse diameter of a bunch and *2a* is the beam aperture diameter. In order to get high shunt impedance and small size, higher frequency for linacs should be used (e.g. X-band) and *2a* decreases correspondingly. But *2r* does not decrease correspondingly due to the limit of the cathode emission ability in electron gun. Then *r*/a becomes large.

In order pursuing higher shunt impedance, we optimize cavities by decreasing *2a* and then *r*/a becomes larger. In the mean time, the magnetic focusing lens is not used to keep linac size small and *r/a* can not decrease further. The condition of paraxial beam is no longer satisfied in our case.

The non-linearity of RF fields will distort the emittance and contribute to the emittance growth in low current and low energy electron linacs. We considered the non-linearity of RF fields in our design. The transverse dynamics of particles is simulated including nonlinear RF fields, shown in Fig. 1.

2.4 Particle Dynamics Design

We designed a 6 MeV X-band (9300 MHz) SW accelerating guide using the software coded by the Accelerator Laboratory, Tsinghua University. The guide is approximately 376 mm and consists of 25 accelerating cells and 24 on-axis coupling cells. 5 accelerating cells and 4 coupling cells works as a buncher in the guide. It works in the π/2 mode and 9300 MHz. The effective shunt impedance of total guide is 143 MΩ/m. The input power is 1.2 MW and the pulse beam current is 50 mA. An injection voltage of 16 kV is applied on the thermionic cathode gun with a converging injection beam. Some design data is in Table 1. Fig. 1 to 3 show dynamics design results.

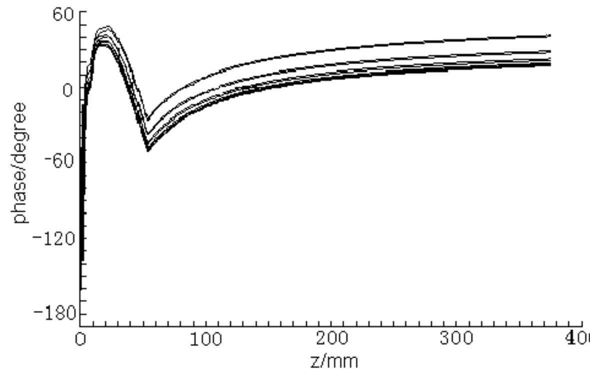

Figure 2: Simulation of Longitudinal Orbits.

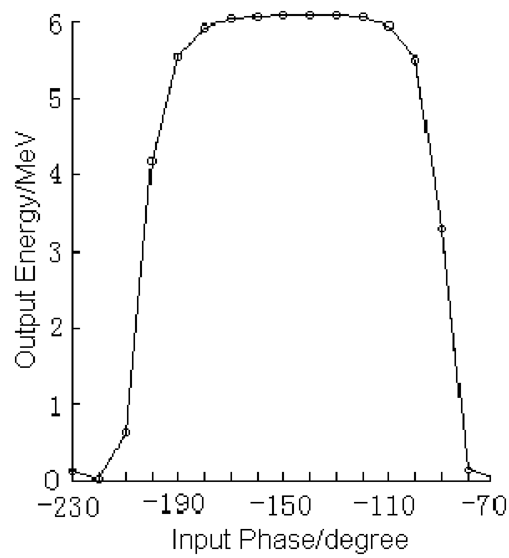

Figure 3: Energy Spectra as a Function of Input Phase.

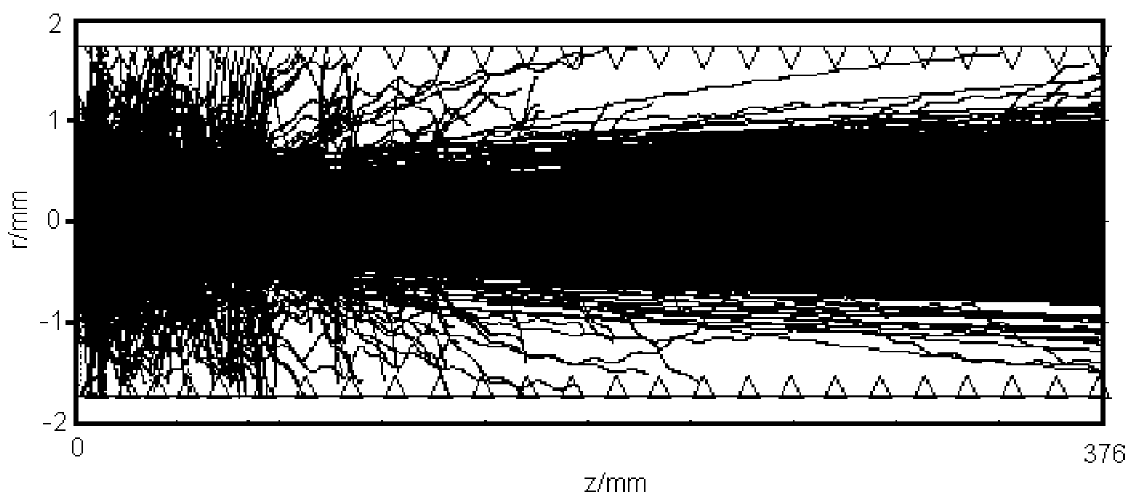

Figure 1: Simulation of Transverse Orbits.

3 TUNING AND TESTING

After being carefully machined, the 49 cavities were assembled and tuned. We got the on axis bead drop data and modules in the guide. The nearest neighbor coupling factors were measured and adjusted to meet the field configuration. The measured Q factor of the guide is 6832 and the coupling factor of the guide is 1.48.

The electron gun, RF waveguide and window, ion pump and magnetron were designed and fabricated in Beijing Institute of Electronics & Vacuum Technology (BIEVT). The over structure was then brazed, evacuated and sealed. Fig. 4 and 5 show the 6 MeV on-axis SW guide and 1.5 MW magnetron separately.

Figure 4: 6 MeV On-axis SW Guide Brazed Assembly.

Figure 5: 1.5 MW magnetron.

4 SUMMARY

On the basis of 2 MeV On-axis Standing Wave Accelerating Guide, we improved the effective shunt impedance by optimizing the structure. Without focusing external magnetic focusing devices, we still get the small beam spot size by RF phase-focusing and asymmetrical cell geometry in the First Cavity Techniques. The non-linearity of RF fields in the guide is considered. The 50 mA beam (pulse current) can be accelerated to 6 MeV in about 376 mm.

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