THE ELECTRO-MAGNETIC FIELD SIMULATION AND CAVITY DESIGN OF RIDGETRON FOR HIGH POWER ELECTRON IRRADIATION ACCELERATOR

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Abstract

Ridgetron is designed with a frequency of 100 MHz and electron energy of 10 MeV and power of 50 kW. It used for disinfection and sterilization of medical appliers. The electro-magnetic field simulation and cavity design of the Ridgetron is carried out by CST code. The influences of the cavity length, accelerating gap and electrode head on electric field and effective shunt impedance are analyzed, and cavity structure is determined. After that, we calculate the energy gain, analyse influence of different acceleration times on shunt impedance and energy gain. The results show that with the same cavity length, the more the acceleration times, the greater the shunt impedance, but the cavity diameter is greater too. Finally according to the objective of the design requirements, we optimize the accelerating times to obtain electron energy of 10 MeV.

APPLICATION OF IRRADIATION PROCESSING

Irradiation processing is the application of low-energy charged particle beam or x-rays produced by irradiation facility to deal with material. At present, irradiation processing is widely used in sterilization of medical supplies, food irradiation, environmental science, and high polymer material modification, etc. Especially in terms of disinfection and sterilization of medical and health supplies, irradiation is replacing conventional chemical disinfection methods. Electron irradiation accelerator is one of the vital devices of irradiation processing. The higher of irradiation accelerator power, the stronger of processing ability. As growing about 18% one year of irradiation processing industry, high-power irradiation accelerator is in great demand. For high-power irradiation device, there are Rhodotron [1, 2], 10 MeV/20 kW electron linac. This paper made a design of a high power electron accelerator called Ridgetron with working frequency of 100 MHz, output energy of 10 MeV and beam power of 50 kW. Ridgetron is first proposed by Japan [3, 4] with output energy of 2.5 MeV and beam power of 6.5 kW. But there was no more research after that.

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RIDGETRON WORKING PRINCIPLE

Ridgetron is shown as Figure 1. The two same ridge are placed in a cylindrical cavity. Electron beam produced by electron gun is accelerated in the gap. After passing the channel, it is deflected 180 degrees by magnets and into another channel, accelerated again in the gap successively. it is extracted after passing the last channel. It is convenient to adjust output energy by controlling accelerating times.

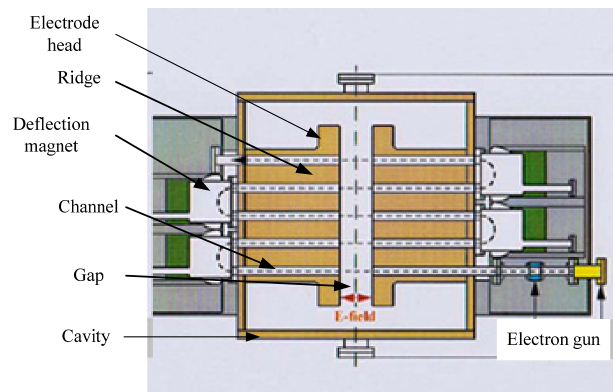

Figure 1: Working principle of Ridgetron.

Ridgetron's development is mainly divided into four parts including electromagnetic analysis, beam deflection system design, cooling system, and mechanical and electrical design, etc. This paper uses Microwave CST code to make electromagnetic analysis. Through simulation and analysis to determine structure parameters of cavity at the biggest shunt impedance, analyze influences of cavity structure on shunt impedance and optimize electrode head and acceleration times.

SIMULATION MODEL

The electric field distribution is shown as Figure 2, its excitation is TE110 mode. The electric field strength is the strongest in the gap and almost close to zero in other space. The magnetic field distribution is shown as Figure 3, it parallels round ridge board along the direction of the cavity length, and the magnetic field intensity is strong around ridge board and almost zero in the gap. Ridgetron working mode is π-π, so the length of trajectory between two adjacent gap is $\beta\lambda/2$.

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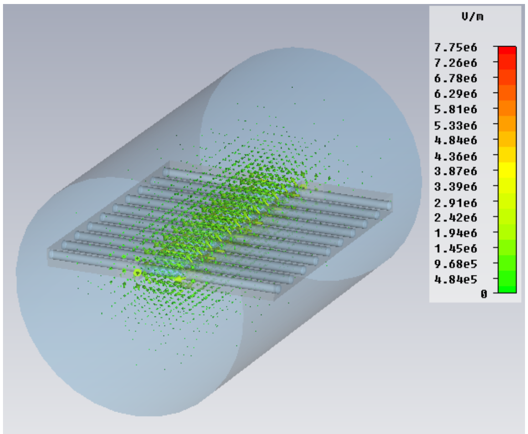

Figure 2: Ridgetron electric field distribution.

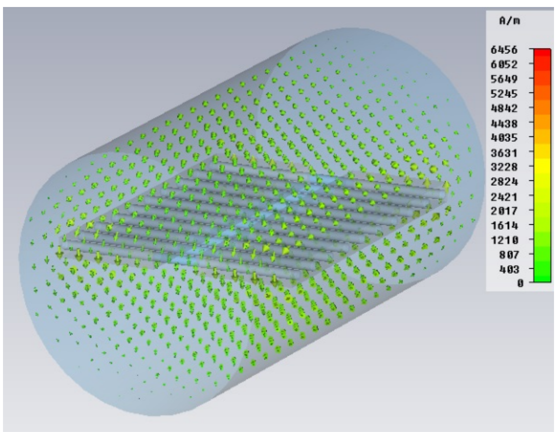

Figure 3: Ridgetron magnetic field distribution.

INFLUENT FACTORS' ANALYSIS OF SHUNT IMPEDANCE

There are several important factors that affect shunt impedance including cavity length, gap, electrode head. This section analyses influences of above factors on shunt impedance, to determine the cavity dimensions.

Figure 4 shows that as the length increases, shunt impedance increases and it is almost proportional with cavity length. Figure 5 shows that with the increase of gap, shunt impedance increases. But to meet the resonant frequency of 100 MHz, the greater the gap, the larger the cavity diameter. It is necessary to get a balance between shunt impedance and cavity dimension. Figure 6 shows that removing the electrode head can improve the shunt impedance at the same gap and cavity length. The electrode head helps to get uniform electric field in the gap [5, 6], to make sure the same energy gain per accelerating. If it has little influences on eventually energy gain, we can remove electrode head. So we have to analyse the influences of electrode head on energy gain.

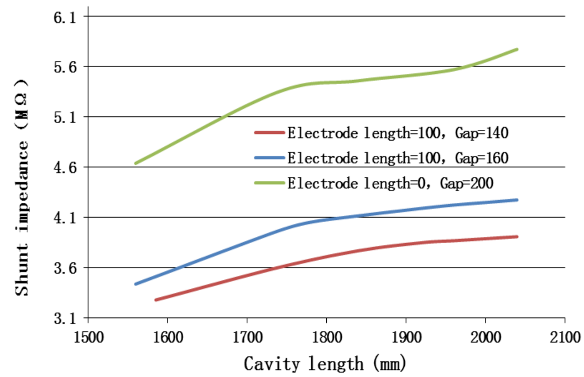

Figure 4: Influences of cavity length on the shunt impedance @f = 100 MHz.

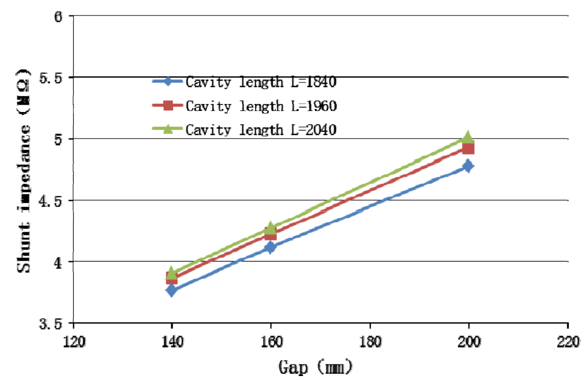

Figure 5: Influences of gap on the shunt impedance @f = 100 MHz, electrode length = 100 mm.

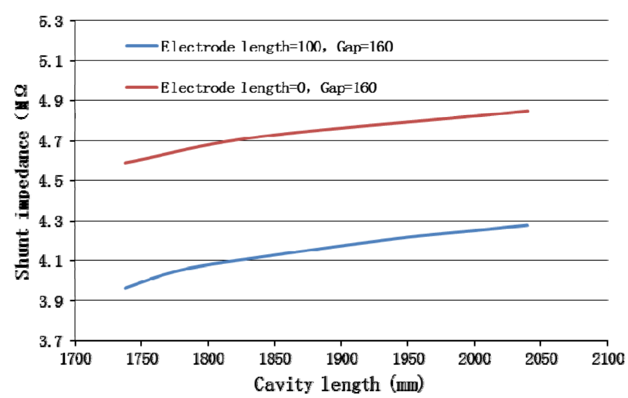

Figure 6: Influences of electrode head on the shunt impedance @f = 100 MHz.

Optimization of Electrode Head

This section makes a comparison of energy gain with electrode head and without. Electron beam is accelerated 10 times. The voltage in the gap is shown as Figure 7. It can figure out that with the same power loss, electron beam get more energy without electrode head. We make an integral of voltage in the gap, get the eventually energy gain of 5.2 MeV without electrode head and 4.74 MeV with electrode head.

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Though electric field uniformity in the gap is bad without electrode head, the eventually energy gain is good. So we remove electrode head in our design.

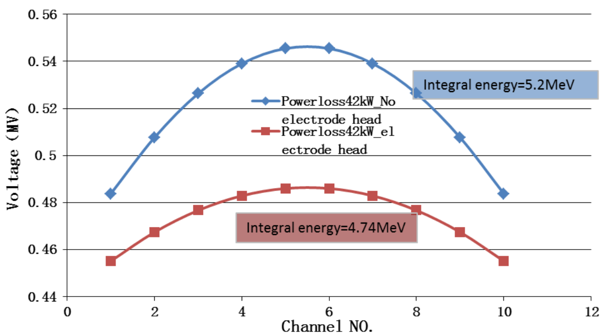

Figure 7: Voltage distribution in the gap in different channel @cavity length = 1960 mm, gap = 200, f = 100 MHz, power loss = 42 kW, distance_channel =120 mm.

Optimization of Acceleration Times

Through the above analysis, it shows that the shunt impedance is affected by cavity length with the same ridge length. Shunt impedance is larger with smaller proportion of ridge length to cavity, Ridge length is determined by acceleration times and distance between two adjacent channels. So we have to get short ridge as much as possible. Considering installing space and cooling structure, we set the distance between two adjacent channel 60 mm. Then we have to optimize acceleration times to make sure the final energy of 10MeV.

Acceleration times of 10, 14, 18, 20, 25 are taken into consideration. Power loss is 42 kW.

It can be figured out from Figure 8, when the cavity structure is determined, electron energy is higher with more acceleration times. We achieve 10.4 MeV after accelerating 20 times. So we set acceleration times to 20.

CONCLUSION

Shunt impedance is one of the important parameters. Large shunt impedance means low power loss. This paper gets Ridgetron structure with large shunt impedance by analyzing electromagnetic distribution, structure and energy. The largest shunt impedance is 5.77 MΩ with a cavity length of 2040 mm, gap of 200 mm, and an energy of 10.4 MeV at a frequency of 100 MHz

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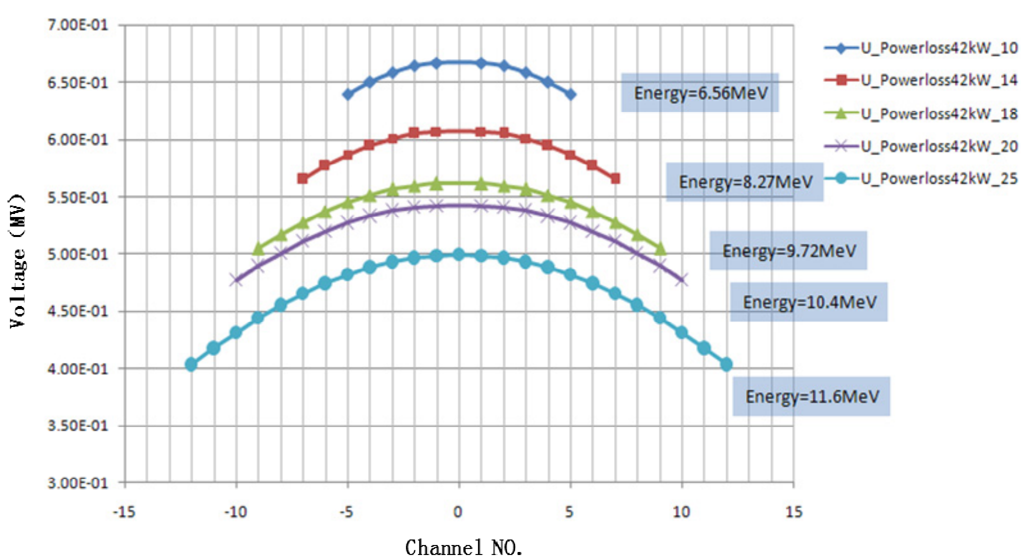

Figure 8: Voltage distribution at different acceleration times @cavity length = 2040 mm, gap = 200, f = 100 MHz, Total loss = 42 kW, distance_drift = 60 mm.

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