THE ELECTRON ACCELERATOR RIDGETRON

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1. INTRODUCTION

Many electron accelerators of DC or RF type have been widely used for electron beam irradiation (curing, crosslinking of polymers, sterilization of medical disposables, preservation of food, etc.). Regardless of the acceleration energy, the accelerators to be installed in industrial facilities have to satisfy the requires of compact size, low power consumption and stable operation. The DC accelerator is realized very compact in the energy under 300 keV, however, it is large to prevent the discharge of an acceleration column in the energy over 300 keV. The RF electron accelerator Ridgetron has been developed to accelerate the continuous beam of the 0.5-10 MeV range in compact space. It is the first example as an electron accelerator incorporated a ridged RF cavity. A prototype system of final energy of 2.5 MeV has been studied to confirm the feasibility at present.

2. ACCELERATION SCHEME

The Ridgetron is an accelerator of recirculating type and consists of a cylindrical cavity equipped with two hollow ridges and small bending magnets at its periphery. The schematic drawing is shown in Fig. 1. In the cavity, the opposite two ridges are extended axially and the electric field excited in the TE_{110} mode is concentrated in a gap between the ridges. By using this electric field, the Ridgetron accelerates beam in the radial direction through the inside of the ridges and performs beam deflection and focusing with the bending magnets for successive acceleration. Therefore, beam trajectory rounds as a wavy line and the trajectory length from one accelerating gap to the next one lengthens in proportion with the beam energy. The electric field distribution can be uniformed by adjusting the ridge configuration, and moreover, the Ridgetron is easily capable of increasing beam energy by extending the cavity length. The acceleration sequence is repeated every half period of RF frequency. When the magnetic field of arbitrary magnet is adjusted to zero, it is possible to extract beam before the final energy. The bending magnet also functions as a beam focusing device. The magnets with an edge angle and equipped with an active field clamp are devised to realize fine tuning of the fringing field and obtain a good focusing.

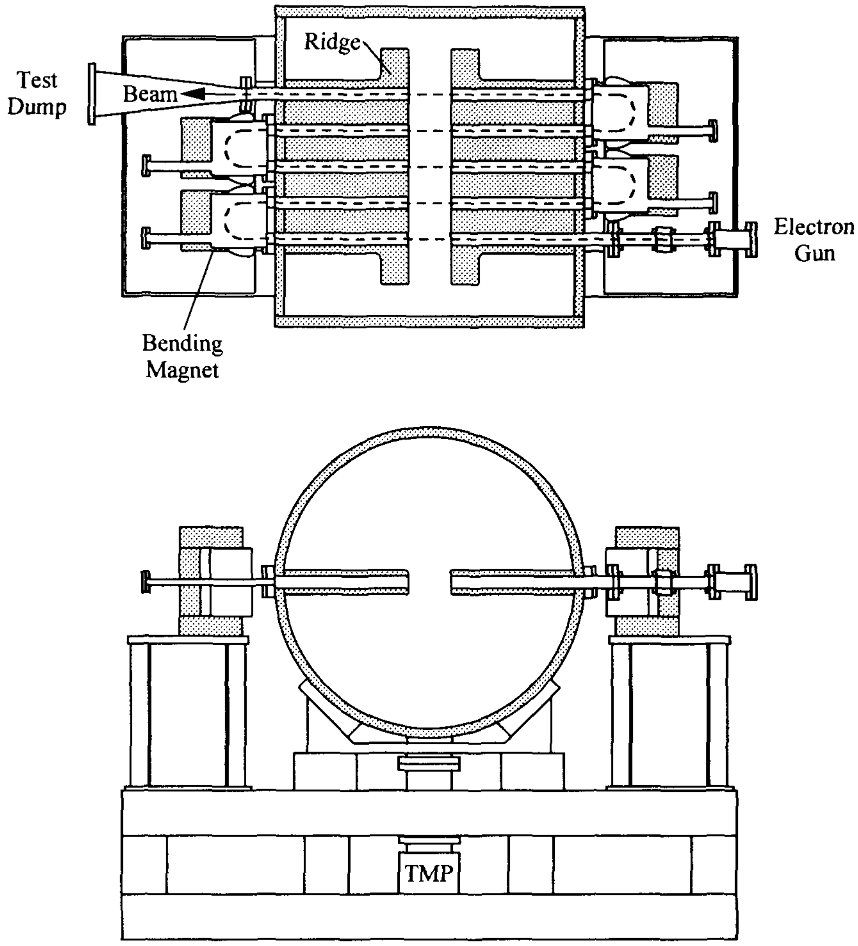

Fig.1 Schematic drawing of the Ridgetron prototype

3. DEVELOPMENT OF PROTOTYPE SYSTEM

System design

The prototype system of the Ridgetron has been studied to confirm the feasibility of the acceleration scheme. Its performance is at an average beam current of 2.5 mA and a final energy of 2.5 MeV. The size of a machine is defined by the operating frequency. The resonant frequency of a ridged cavity is lower than a normal cavity without a ridge. The operating frequency of 100 MHz was chosen by taking into account the handy size of the cavity and availability of power vacuum tube for cw operation. To estimate the resonant property of the cavity, calculations with the computer code MAFIA and analysis by a quarter scale model were performed. Consequently, the inner diameter of the cavity is 964 mm.

The number of beam passes is limited by the deflecting radius of magnets and the energy gain per pass. In the prototype, the beams have to pass the acceleration gap five times through the four bending magnets to reach the final energy because of the energy gain per pass being limited at 0.5 MeV to keep down the power consumption. The deflecting radius of bending magnets is 65 mm. Therefore, the inner length of the cavity is 990 mm. The design specifications of the prototype are shown in Table 1.

Table 1 Design specifications of the Ridgetron prototype

Operating frequency	100	[MHz]
Input energy	0.02	[MeV]
Output energy	2.5	[MeV]
Beam current	2.5	[mA]
Maximum gap voltage	0.5	[MV]
Cavity inner diameter	964	[mm]
Cavity inner length	990	[mm]
Gap length	140	[mm]
Ridge width	80	[mm]
Quality factor	27000	
RF power consumption	42	[kW]

Electron Gun

A triode type thermionic electron gun was designed for accelerating beams with low emittance. It is operated in cw or pulse mode by modulating the grid bias in synchronous to the RF electric field. The cathode material is LaB_6 with a diameter of 4 mm. The gun electrodes configuration was optimized with the computer code EGUN2e. The calculation was performed as a diode on the assumption that the interception of beam current at the grid is small. The shape of the adopted Wehnelt electrode was of the flat type without a slope. As a result, a average beam current of 2.5 mA and an emittance of 2.5 πmm·mrad were obtained at an anode voltage of 20 kV. The extracted beam is injected into the cavity through a solenoid lens.

Beam focusing

In the Ridgetron, beam focusing is performed by the edge angle of the bending magnet, however, the fringing magnetic field decreases the focusing force in the vertical plane, which is inversely proportion to the deflecting radius (1). Therefore, this effect arises severely for small magnets of the Ridgetron.

To achieve effective focusing in horizontal and vertical planes, we have found an active field clamp scheme is very effective where the fringing field is positively compensated by energizing coils wound around the field clamp to generate inverse field in the outer lobe of the fringing field. Effect of modification of the fringing field by the field clamp was studied by computer calculations. The electron beam trajectory in the Ridgetron was simulated with the computer code TRACE-3D. The fringing field region was divided in small segments transverse to beam trajectory and the field inside each segment was replaced by an uniform field. The calculated beam envelope is shown in Fig. 2. Consequently, the beam was accelerated successfully and stably up to the final energy.

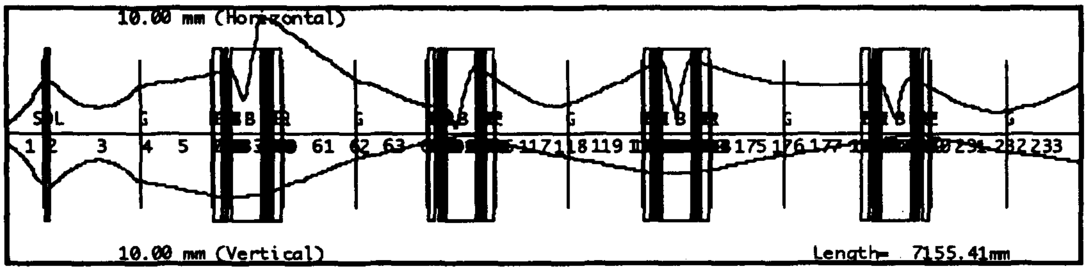

Fig. 2 The calculated beam envelope in the Ridgetron prototype. The block sections indicate the space where a magnetic field extends.

4. PRESENT STATUS

The fabrication of the prototype system was completed and the beam acceleration test is in wait for the permission of the government. However, the electrical property measurement of the cavity and the electron gun test have been performed already. In the resonant frequency of 101 MHz, the power consumption is 50 kW and the quality factor is 23300. The average beam current extracted from the electron gun is 3 mA.

5. CONCLUSION

The prototype system of the electron accelerator Ridgetron has been developed. The validity of its configuration has been proven by the computer simulation and the satisfactory results concerning the electrical property and the electron gun were obtained. We prepare or the beam acceleration test at present.

REFERENCE

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