TEST OF 700MHz, 1MW PROTO-TYPE KLYSTRON FOR PEFP*

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Abstract

High power and RF source of 700MHz and 1MW klystron, which has been designed and constructed by Korean Accelerator and Plasma Research Association, has been being tested. To test the primary performance of the klystron, a pulse power supply was used to manipulate a negative high voltage. We are currently reinforcing the protection circuit, and it is going on without much trouble as originally planned. In addition, a baking furnace for the klystron is under fabrication for the ultra high vacuum of better stability. We constructed various infrastructures such as baking furnace for the development of Klystron.

INTRODUCTION

The main linac was designed to supply 100 MeV proton beam in the Proton Engineering Frontier Project (PEFP)[1]-[2]. In the 2nd phase the linac above 100 MeV is designed and constructed with 700 MHz components [3]-[4]. The 700 MHz klystron study had been launched for the phase. Another purpose of this study was to develop new method to repair and maintain the 350 MHz klystrons. For the design of the klystron tube, several computer codes were incorporated to predict the performance of the tube [5]. The overall layout was finished using both the previous studies and the pre-prototype experience [5]-[6]. The parameters of the 700 MHz Klystron designed are presented in Table 1.

The main components of the Klystron tube such as the electron gun, RF cavities, the collector, the focusing magnet, and the supporting structure, were assembled.

Table 1. Specifications of the PEFP prototype Klystron

Operating Frequency (MHz)	700
Output RF Power (kW)	1,000 (CW)
Anode Voltage (kV)	95
Modulating Anode Voltage (kV)	51
Beam Current (A)	16.6
Efficiency (%)	~ 60
Power Gain (dB)	43 (minimum)
Focusing Field (Gauss)	~250
Bandwidth (MHz)	±1.5 (-1 dB)
Number of Cavities	6

DESIGN

RF Interaction

The prototype is a six-cavity Klystron to examine the RF interaction. The 3rd cavity is a second harmonic cavity for the high efficiency. Figure 1 shows the interaction between RF and the distance from the cathode. The data were simulated using the computer codes (FCI). The highest RF Power is obtained at the point of 1,800mm away from Cathode. Each line is corresponded to the cavity mode. To secure the specifications, the cavities were tuned to keep higher output power than without the tuning

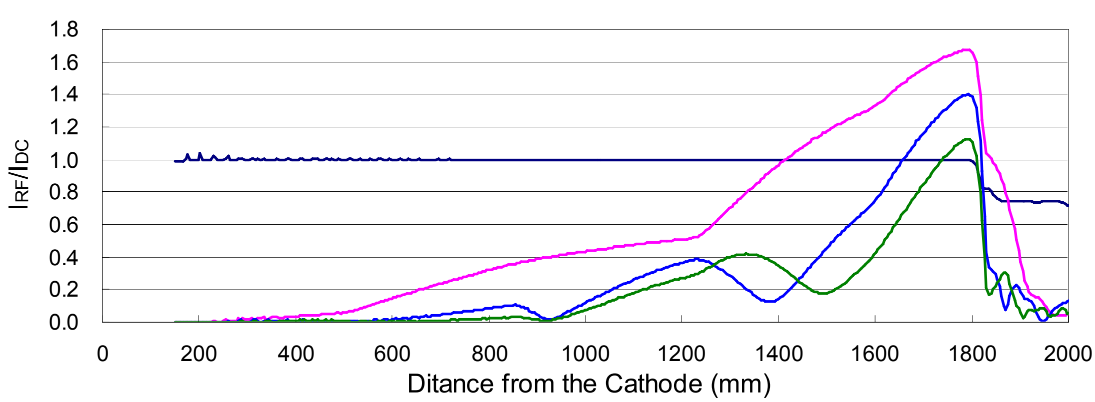

Figure 1. Simulated interaction between RF and the distance from the cathode

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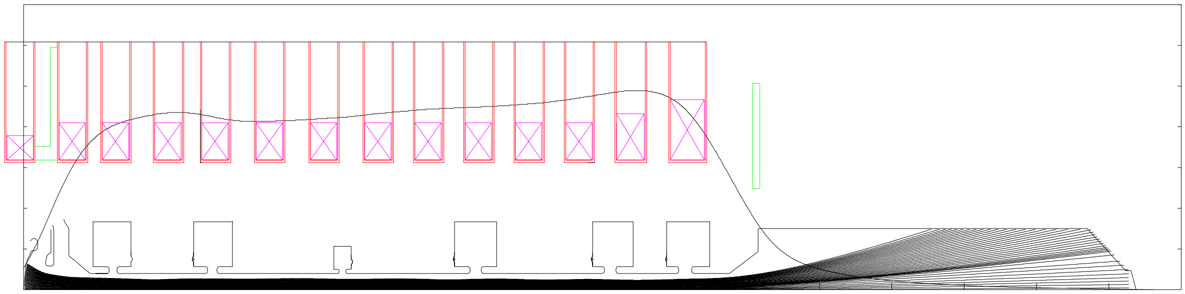

Figure 2. Focusing magnet and beam transport

Electron Gun

The electron gun with an M-type cathode was a triode type with a modulating anode. The gun was designed with the cathode-loading peak less than 0.6 A/cm2 and the electric field peak less than 70 kV/cm. Figure 2 presents the simulated data by E-gun. This shows that beam withdrawn from Cathode spread uniformly and then reaches the collector. The magnetic field on the cathode surface was about 31 Gauss and the one on the main drift region was about 250 Gauss. The latter was 2.3 times to the Brillouin value and could reach up to 300 Gauss in order to compensate to the increased space charge effects.

Output Circuit

The output circuit was incorporated with a pillbox type alumina window, a cascade step waveguide transformer, and the 6th cavity as shown in Figure 3. The coupling slot size was optimized on the data resulted from the RF interaction simulation. An iris coupling scheme was chosen for the extraction of the output power. The crossing part presented in the right side of the Figure 3 corresponds to the region satisfies the requirement. Both of the window and the transformer were optimized to the minimum and ensured the required bandwidth.

Collector

The collector was made of the Oxygen Free High Conductivity Copper (OFHC). The peak power dissipation density of the collector surface was designed to have the maximum capacity 200 W/cm2 under the nominal operating condition.

FABRICATION AND PROCESSING

All parts of the Klystron were fabricated and tested to examine the desired quality. The cathode firing of the gun was done in the high vacuum chamber of a quartz bell jar reached up to 950°C. In the firing procedure, the vacuum was kept under 10-7 torr and the final pressure at the end of the firing was 9 x 10-9 torr. The external Q (Qex) of the 1st cavity was measured 538. The designed value was 550. The tuning range of all cavities was between about -15 and +15MHz. It was sufficient to the klystron tuning. The capacitive tuning mechanism was used to adjust the gap of the re-entrant cavity. After eight parts, such as six cavities, the electron gun, and the collector, were welded as presented in Figure 4, the vacuum and the RF tests were finished. The soft baking was performed for 2 weeks at 250°C.

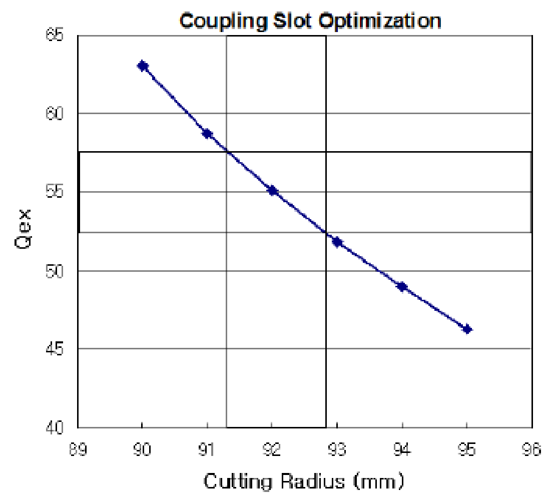

Figure 3. Schematics of the RF output circuit and dependencies of Qex on the size of the coupling slot

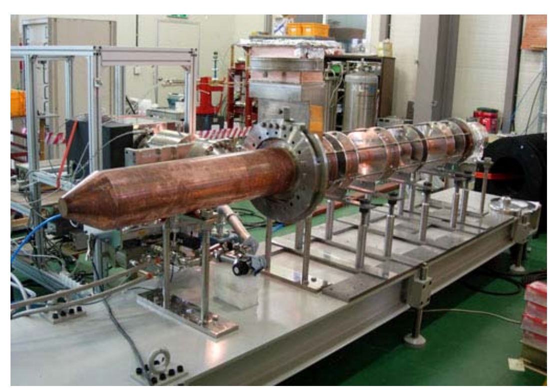

Figure 4. 700 MHz PEFP prototype klystron tube after the final welding

OPERATION TEST

In parallel to the tube development, a long pulse power supply was developed for the RF performance test by KAPRA. The pulse length was up to 2 ms and its power was 1.8 MW. Two energy storage capacitors, two high power spark gaps, current limiting resistances, and trigger circuits were incorporated. Each energy storage capacitors was 100 kV and 3μF. 1 MW RF dummy load and its related waveguide circuits were equipped for the test.

Klystron amplifier system has been operated up to -95kV anode voltage. The RF output power reaches up 950kW as shown in Figure 5. When the beam was emitted from the cathode at over -95kV, an arc occurred at the power supply due to rapid decrease of vacuum by processing only soft baking. The power supply was repaired from the arc problem.

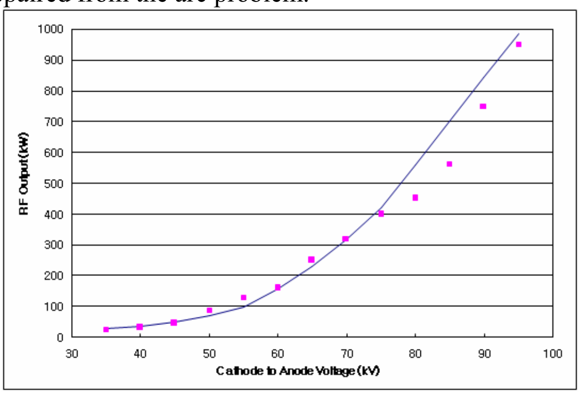

Figure 5. Anode Voltage and RF Power

The baking furnace is manufacturing to bake at 550°C as keep the vacuum under 10^{-3} torr using mechanical pump. The height of the baking furnace was compared to the human size in the figure11. The data were collected from the out-gassing of the OFHC using Residual Gas Analyzer (RGA). The surface roughness was examined by surface illuminometer.

SUMMARY

The prototype Klystron has been designed and constructed by the KAPRA. Even though there is a little difference between simulation data and capability of this Klystron, this has been tested in high voltage. However, now that baking work was carried out in low temperature, vacuum tends to be destabilized as beam testing is conducted. The assembling for the machine parts has been finished under high vacuum. The completed klystron was operated up to -95kV anode voltage.

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