R&D STATUS OF THE 700 MHZ, 1MW KLYSTRON FOR PEFP*

Sang-ho Kim, Bo-hyun Chung, Jai-ha Jeon, Jin-suk Hong,
Kang-ok Lee, S.J. Noh, Seung-kook Ko, Kie-hyung Chung
Korea Accelerator and Plasma Research Association, Cheorwon, Korea

Abstract

KAPRA (Korea Accelerator and Plasma Research Association) are undertaking the first phase R&D for the 1 MW, CW 700 MHz klystron, which is targeting the future stage of the PEFP (Proton Engineering Frontier Project) accelerator at KAERI (Korea Atomic Energy Research Institute). The objectives of the first phase R&D are 1) setting up infra structures/procedures for the design and fabrication, 2) developing a prototype klystron for proofs of principles, and 3) making a performance test of the prototype at a reduced duty. The second phase R&D is supposed to cover full power, CW operation and reliability issues. In this paper, a summary of the R&D status during the first phase for PEFP 1 MW, 700 MHz klystron is reported.

INTRODUCTION

The main linac of the PEFP in the first phase is designed to supply 100 MeV proton beam with 350 MHz RF [1]-[2]. In the future phase the PEFP linac above 100 MeV is supposed to be designed with 700 MHz. In order to make necessary preparation for this future phase 700 MHz klystron R&D has been launched, in parallel this R&D is aimed to have capability for repairing 350 MHz klystron. For the design of the klystron tube, several computer codes were incorporated to predict the performance of the tube [3]. Based on the previous R&D works and the pre-prototype experiences [3]-[4], an overall layout is fixed. The design parameters of the klystron are summarized 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 fabricated and the final assembly was done. Presently the klystron tube is under baking process after which tests at a reduced-duty will be carried out.

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

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DESIGN

RF Interaction

The prototype is a six-cavity klystron where the 3rd cavity is a second harmonic cavity for the higher efficiency. Figure 1 shows developments of the modulated RF currents in which each line is the corresponding cavity mode. At this condition the gain and the transfer characteristics are calculated, which is shown in Figure 2 and 3. To secure the specifications cavities are tuned to have higher output power.

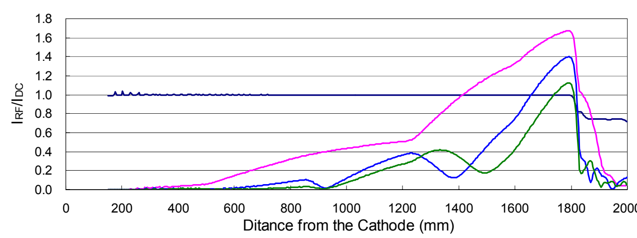

Figure 1: Simulation of the RF interaction. Lines show modulated RF currents of the corresponding cavity modes.

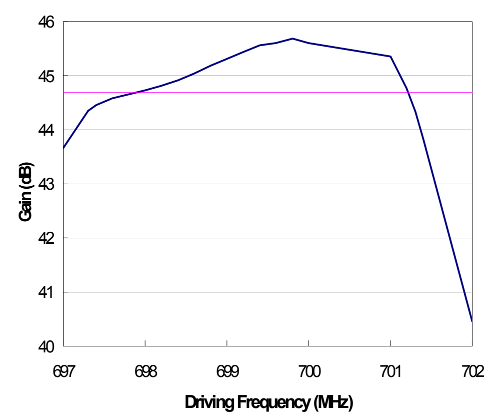

Figure 2: RF gain characteristics.

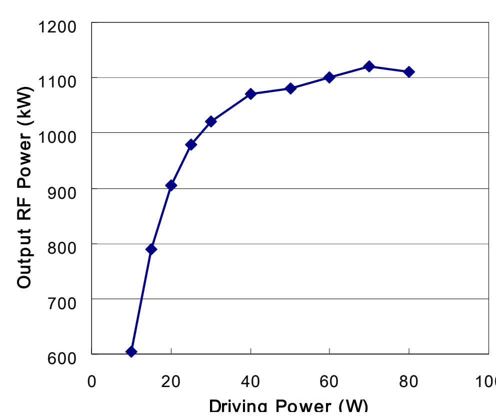

Figure 3: Transfer curve at Qex=55.

Electron Gun

The electron gun is a triode type with a modulating anode (figure 4). An M-type cathode is adopted and the gun is designed to have a peak cathode-loading less than 0.6 A/cm^2 and a peak electric field less than 70 kV/cm. Figure 5 shows the beam trajectories where the magnetic field on the cathode surface is 31 gauss. The magnetic field of the main drift region is about 250 Gauss that is 2.3 times of the Brillouin value and increases up to 300 Gauss in order to compensate the increased space charge effects.

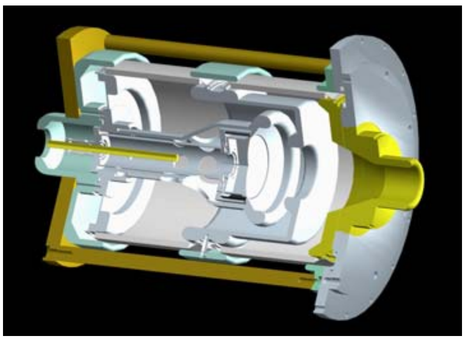

Figure 4: Electron gun.

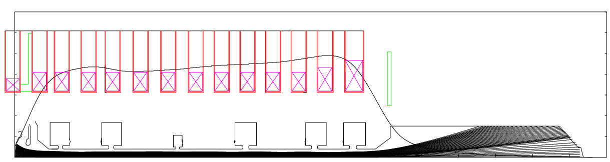

Figure 5: Focusing magnet and beam transport.

Output Circuit

An iris coupling scheme is chosen for the extraction of the output power, which is incorporated with a cascade waveguide step transformer and a pillbox type RF window as can be seen in Figure 6. The slot size is optimized to have the requirement, according to the RF interaction simulation. The crossing part in the right side of the Figure 6 corresponds to the region that satisfies the requirement. The window and the step transformer is optimized together to have a minimum VSWR and ensure the required bandwidth (Figure 7). The major specifications of the output window are summaries in Table 2.

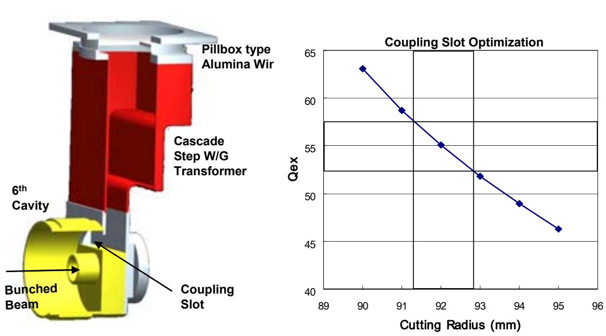

Figure 6: Schematics of the RF output circuit and dependencies of Qex on the size of the coupling slot.

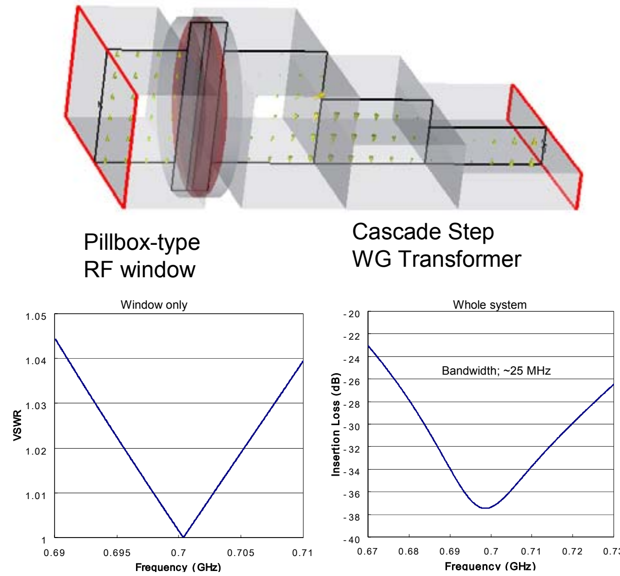

Figure 7: RF characteristics of the RF output circuit.

Table 2: Specifications of the Output Window.

Frequency (MHz)	700
Mode	TE11
Average Power (kW)	1,000
Window Diameter (mm)	220.8
Window Thickness (mm)	7
Window Material	Alumina, >99.5 %
Peak DT (K)	50
Power Loss in Window (W)	100
Peak Tensile Stress (MPa)	60
Alumina Tensile Strength (MPa)	250
Safety Factor	~5

Collector

The peak power dissipation density on the collector surface is designed to have less than 200 W/cm^2 at the nominal operating condition.

FABRICATIONS AND PROCESSINGS

All parts are fabricated and tested along with the infra structures while training domestic companies to have required qualities for klystron fabrication. The cathode firing is done in the high vacuum chamber made of a quartz bell jar up to 950 C. During the firing procedure vacuums are kept not to exceed 10^{-7} torr and the final pressure at the end of the firing is 9 10^{-9} torr. Figure 8 was taken at the end of the firing. Figure 9 shows the cavities waiting for the final welding. The Qex of the first cavity is measured to be 538 (the design value; 550) and the tuning range of all cavities is about +/- 15 MHz that is enough for the klystron tuning. The capacitive tuning mechanism is adopted, which is adjusting the gap of the re-entrant cavity. After having the vacuum and RF tests of all cavities and parts, the parts are welded together as can be seen in Figure 10. Presently the soft baking is in progress at about 250 C.

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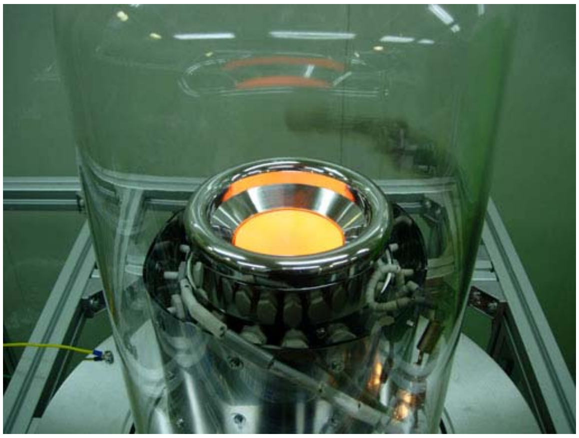

Figure 8: Gun firing.

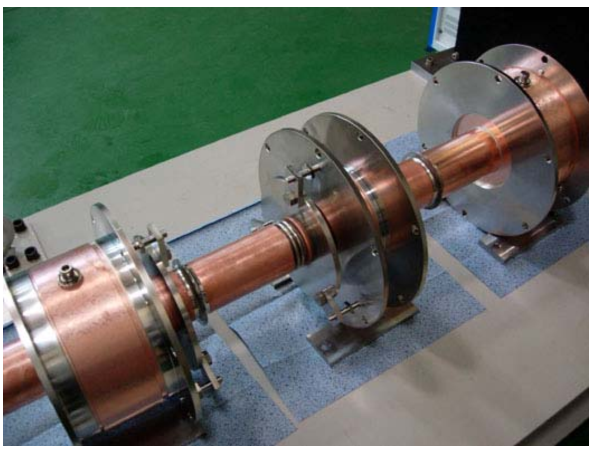

Figure 9: Cavities before the final welding.

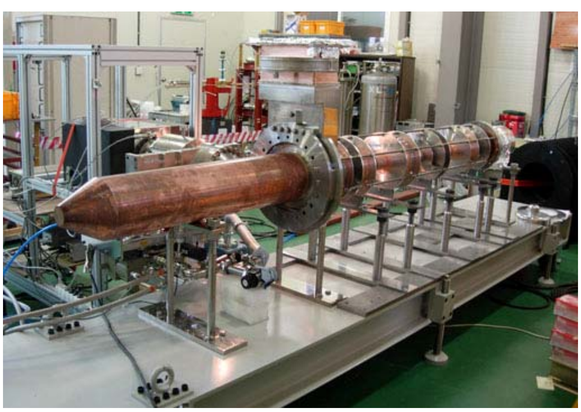

Figure 10: 700 MHz PEFP prototype klystron tube after the final welding.

TEST SETUP

In parallel with the tube development, a long pulse power supply is developed for the RF performance test at KAPRA. The power rating is 1.8 MW and the pulse length is up to 2 ms. Two self-healing energy storage capacitors (100 kV, 3 μF each), two high power spark gaps, current limiting resistances and trigger circuits are incorporated. Figure 11 shows the cathode heating and the pulse power switching circuits. 1 MW RF dummy load and related waveguide circuits are equipped and ready for test (Figure 12).

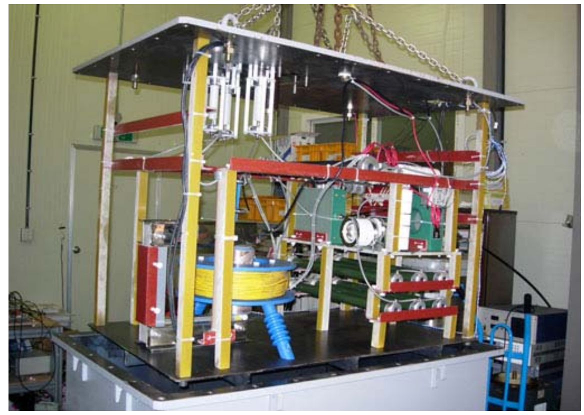

Figure 11: Cathode heating and pulse power system.

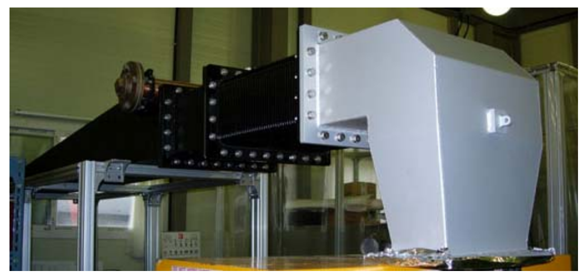

Figure 12: Waveguide and 1 MW CW RF dummy load.

SUMMARY

The first phase of R&D for the development of 700 MHz, 1MW, CW klystron is in progress. As parts of this R&D effort, a prototype klystron is designed to meet the specifications and infra-structures from designs to tests are equipped along with training of domestic industries for the component fabrications and processing. Machining and assembling of parts are done. The soft baking process is ongoing, after which a series of long pulse tests is planned in the very near future at a reduced duty.

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