

# FABRICATION AND TEST OF PULSED 200-MW ELECTRON GUN FOR HIGH-POWER KLYSTRONS\*

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## Abstract

A 200-MW pulsed electron gun has been developed for 80-MW klystrons. It is a Pierce type with the areal convergence ratio of 16:1. The cathode is scandate with 90-mm diameter. The electrode geometry was optimized utilizing EGUN code. Structures around the cathode were vacuum-brazed with pure copper fillers. In order to test the gun, we have also fabricated a beam collector and an insulated drift tube. The electron beam from the electron gun is focused by the magnetic field by an electromagnet, transported through the drift tube, and finally dumped into the beam collector. The insulated drift tube enables measuring lost beam current during the transportation.

## 1 INTRODUCTION

An S-band 100-MW pulsed klystron is under development at the Pohang Accelerator Laboratory. Special fabrication facilities were established including the vacuum baking station and the vacuum induction furnace. Using these facilities, one out of two failed klystrons (Toshiba E3712's) had been successfully repaired [1][2]. As the next step, an electron gun, that was designed to reliably provide 200 MW (400 kV, 500 A) pulsed electron beams, has been developed. Using the Hermannfeldt's EGUN code, we found the optimum electrode geometry which can provide laminar electron flows with a uniform current density. For reliable operations without high-voltage breakdowns, the surface electric field strength is kept below 250 kV/cm. In order to determine the "cold" dimensions of electrodes and supporting structures, a thermal-structural analysis is carried out by the ANSYS code. And also, an optimum focusing magnetic field profile was determined by the POISSON code in combination with the EGUN code.

## 2 DESIGN WORK

Fig. 1 is the result of EGUN code simulation. The simulation was done separately in gun and drift tube regions. For 400-kV, 500-A beam, Brillouin field level was 750 G. Providing enough safe margin to this, the peak focusing field in the drift tube (interaction) region was set to about 1.2 kG. Cathode field was about 30 G. Although perfect matching between gun exit and drift tube entrance was not achieved, and there was some scalloping in the drift tube region, no rays were found to hit the wall of drift tube.

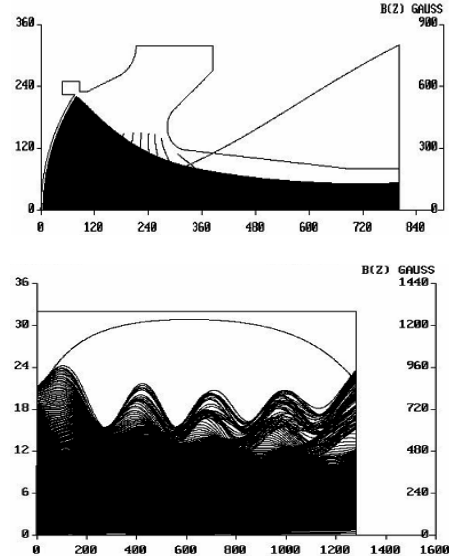


Figure 1: EGUN simulation of electron gun region (top) and drift tube region (bottom).

In order to determine so called "cold dimension" of the electron gun, which is important for fabrication, we have performed ANSYS simulation. We have calculated thermal expansion of cathode and surrounding structures when the cathode is heated up to 1000 °C. Full 3D modelling of the cathode structure had been done for the purpose of including the radiation heat transfer. Later we have also tried simple 2D modelling that only include the conduction heat transfer. The two results were not different significantly, which implies that the radiation heat transfer should be mainly downstream direction (in the direction of beam propagation) and does not affect thermal expansion of the cathode structure. Fig. 2 is the result of the ANSYS calculation that shows thermally deformed shape overlaid with the original one.

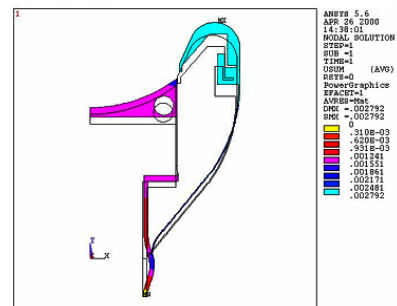


Figure 2: Calculation of thermal expansion using ANSYS.

### 3 MEASUREMENT OF THERMAL EXPANSION

In order to remove any possible contaminants, cathode structure is processed before integrating into the electron gun. The processing is done in an UHV induction furnace that is capable of heating the cathode structure up to 800 °C. During this process, we have tried to measure the real thermal expansion of the cathode structure. Experimental setup is shown in Fig. 3.

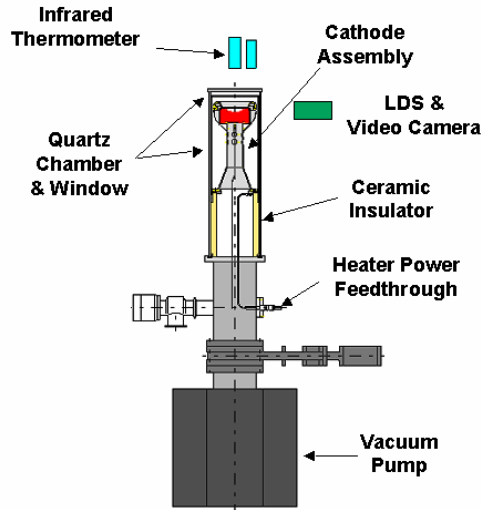


Figure 3: Experimental setup for measuring thermal expansion of cathode structure.

Cathode structure is located inside of a quartz vacuum chamber. Heater power is supplied through a vacuum feedthrough. Cathode temperature is measured by an infrared thermometer. Radial expansion of the focus electrode was measured by a LDS (Laser Displacement Sensor). Axial expansion was measured by video-recording the position of the laser spot, formed on the surface of the focus electrode, which was provided by a solid-state laser that is located outside the vacuum chamber. See Fig. 4.

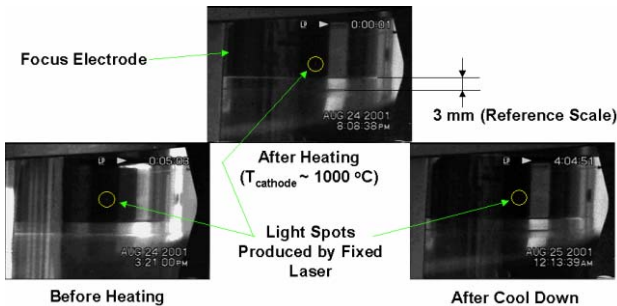


Figure 4: Method of measuring axial expansion of cathode structure.

Tracking the position of the laser spot, and scaling to a reference feature on the focus electrode, we estimated the magnitude of the axial expansion.

Results of the measurements are summarized in Fig. 5. It was found that the cathode structure expand by ~2.4 mm axially and ~0.7 mm radially. These are quite large amount that would cause perveance error more than 10 %. It is also seen that there is considerable time delay (~1 hour) of full equalization of electrode temperatures after the cathode temperature saturates.

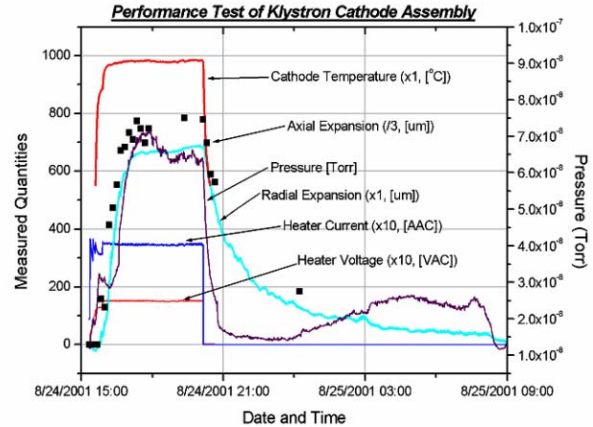


Figure 5: Results of thermal expansion measurement of cathode structure.

### 4 FULL-POWER TEST

After bake-out, water pipes and lead shieldings were attached. Finished electron gun was delivered to the test-lab that is equipped with 150-MW modulator system. Since we have attached drift tube and collector with the same axial dimensions as the PLS linac klystrons, we could utilize existing pulse tank and focusing electromagnet. Fig. 6 is the schematic of test set-up.

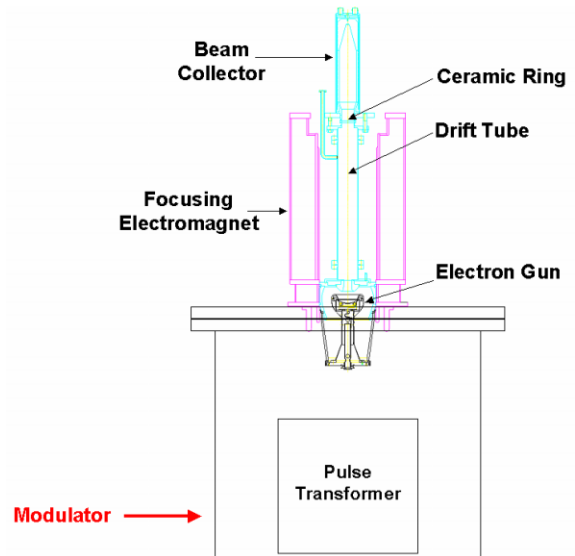


Figure 6: Schematic of test set-up for electron gun.

Starting from low beam voltage (~10 kV) with lots of initial outgassing, we could raise the voltage smoothly up

to 250 kV. After this, several arcing were observed but the voltage reached up to 300 kV. Unfortunately, we could not go further beyond this point. Due to some problems of the test system, there were incidents that abrupt high voltage was applied to the electron gun before it is well processed.

As the next step, we have tried to measure the amount of beam loss during the beam propagation through the drift tube. This was possible owing to a ceramic ring that was installed between the drift tube and the collector during fabricating the electron gun. The contact resistance between the electron gun and the corona ring (at the bottom of the focusing electromagnet) was about 100 k $\Omega$ . Fig. 7 is an example of the beam-loss measurement. Note varying beam-loss current waveforms as the excitation current of electromagnet changes.

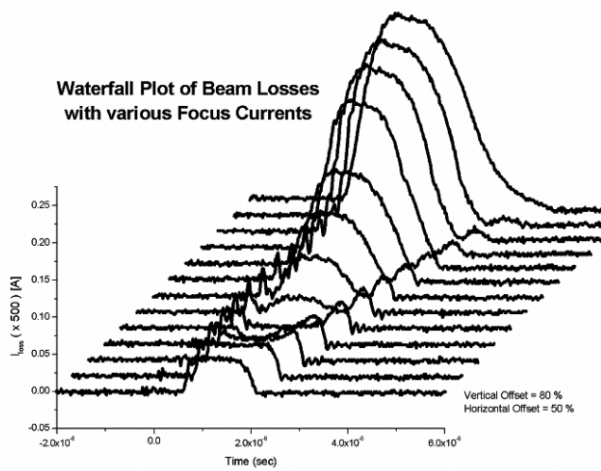


Figure 7. Measurement of beam loss. Waterfall plot of beam-loss waveforms for focus coil currents, 3.7 to 0.8 A (front to rear direction).

It was done at low voltage. (170 kV) A current probe, installed between the drift tube and the ground, did current measurement.

## 5 SUMMARY

- Electron gun for high-power klystrons was successfully fabricated.
- Calculation and measurement of electrode thermal expansion were performed.
- HV processing was not so successful partly due to troubles in test systems. Possible sites of electrode damages will be identified after tube autopsy.

## 6 REFERENCES

- [1] S. J. Park et al., "R&D Status of High-Power Klystrons at Pohang Accelerator Laboratory," *Journal of Accelerator and Plasma Research*, Vol. 6, No. 1, p. 44, December (2001)
- [2] S. J. Park et. al., "Developmental Status of S-band 100-MW Klystron," *Proc. 2000 KAPRA KPS/DPP Joint Workshop*