Development of a High Power 1.2MW CW L-band Klystron

K. Hirano, Y. L. Wang, T. Emoto, A. Enomoto†, I. Sato†
Power Reactor and Nuclear Fuel Development Corporation (PNC)
4002 Narita, Oarai-machi, Ibaraki, 311-13 Japan

ABSTRACT

The high power CW L-band klystron has been developed as the RF source of the PNC high power CW electron linac (10MeV, 100mA). CW power of 1.2 MW at 1.249135GHz and efficiencies over 65% were the design goals. RF analysis of the windows using high-frequency simulation codes provided information about power loss distribution in the ceramic and optimizing properties of the RF structure. The prototype klystron window was replaced with a long pill-box type beryllia window as a result of the simulation and hardware tests. The klystron has reached CW power of 885kW with efficiency above 45%. This paper describes key points of the designs and results of the high power RF tests.

I. INTRODUCTION

The development of a high power CW electron linac was started in 1989 to study the feasibility of nuclear waste transmutation [1]. Figure 1(a) shows the prototype klystron with the original pill-box type beryllia window (standard window). The maximum power of the prototype klystron was limited to 330 kW with CW operation because the temperature of the window increased by 53 degrees, reaching near the critical point of destruction by thermal stress. The results of high power tests of the prototype klystron indicated that the maximum RF output power was limited by the heating of the klystron RF window. A long pill-box type beryllia window (long window) was designed and measured using an L-band resonant ring in KEK (National Laboratory for High Energy Physics) [2]. The transmission RF power through the test window in the resonant ring is thirty-six times the RF input power. Surface temperature changes were observed in the beryllia disk with the RF window. The temperature of the window increased by 51 degrees at 1.7 MW CW RF power.

The standard window of the prototype klystron was replaced with the long window. High power tests were carried out for the klystron with the long window (shown in Figure 1(b)) in a factory of the klystron's manufacturer.

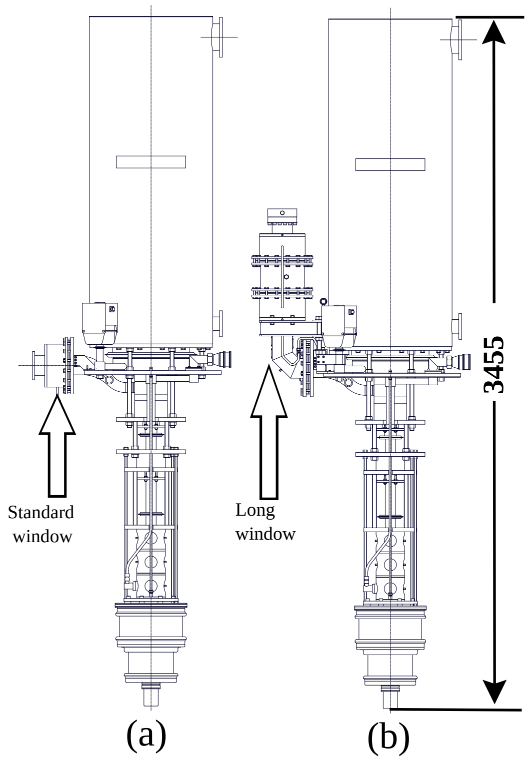

Figure 1. (a) Prototype klystron with the standard window.
(b) Klystron with the long window

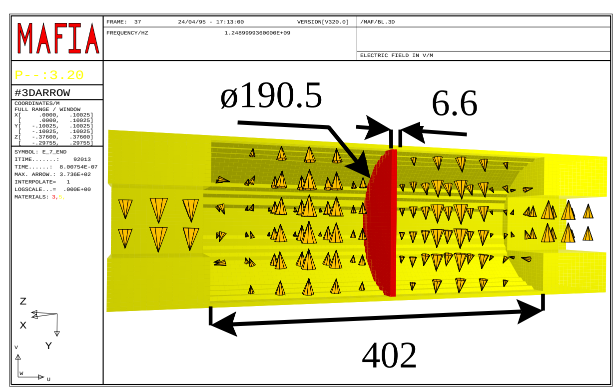

Figure 2. Dimension and electric field of the long window.

† Guest Scientist from National Laboratory for High Energy Physics (KEK)

II. DEVELOPMENT OF AN RF WINDOW

The long window was designed for decreasing the electric field along the ceramic disk. Figure 2 shows a dimension of the long window and electric field calculated by MAFIA. The maximum electric field in the standard and long window is shown in Figure 3. The dielectric loss of long window is approximately half of standard one from the result of the maximum electric field on the ceramic surface.

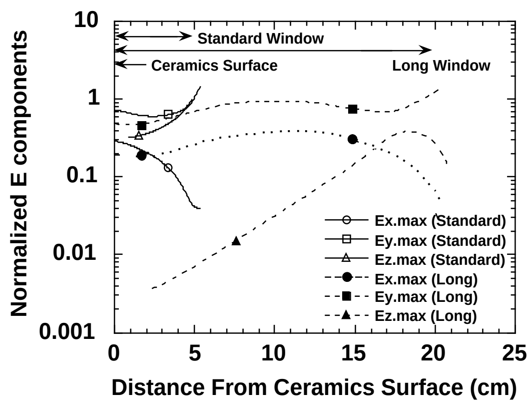

Figure 3. Maximum electric field in the long and standard window.

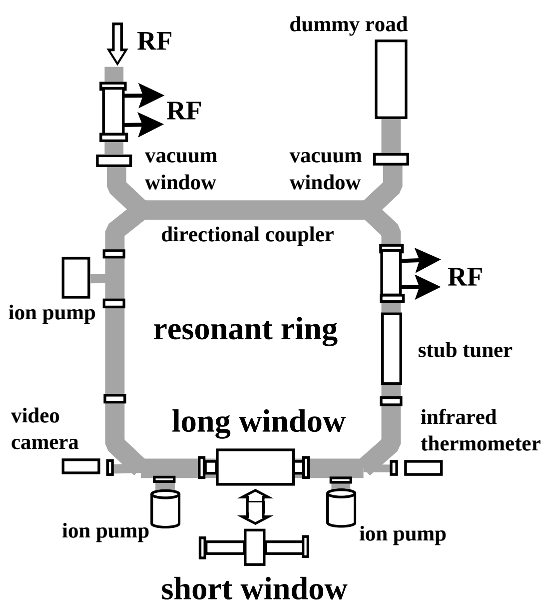

Figure 4. Resonant ring experiment of the long window and the standard window.

The electric field perpendicular to the surface of the disk is lower in the long window, which prevents multipactor more than the standard one.

The standard and long window were evaluated in the resonant ring (shown in Figure 4). Figure 5 shows the dimension of the tested pill-box windows. The light emission from the ceramic surface was observed by a video camera and the surface temperature measured by a infrared-thermometer. Figure 6 shows the window temperature vs. RF power of the two type windows tested in the resonant ring and of the standard window of the prototype klystron and the long window of the klystron tested in a factory of the klystron's manufacturer.

Test window		Standard Window	Long Window
Ceramics		beryllia	
Total length of pill-box L[mm]		293.0	595.0
Length of the cylinder A[mm]		106	402
Inside diameter of the cylinder ø[mm]		190.5	
Thickness of the RF window disk D[mm]		6.6	
VSWR	MAFIA calculation	1.039	1.001
	Measurement	1.04	1.03
Phase length	MAFIA calculation	2π+8.8	2π+297.3
	Measurement	2π+9.7	2π+298.9

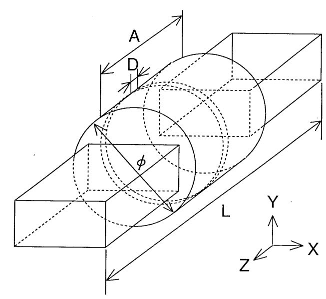

Figure 5. Dimension of the tested pill-box windows.

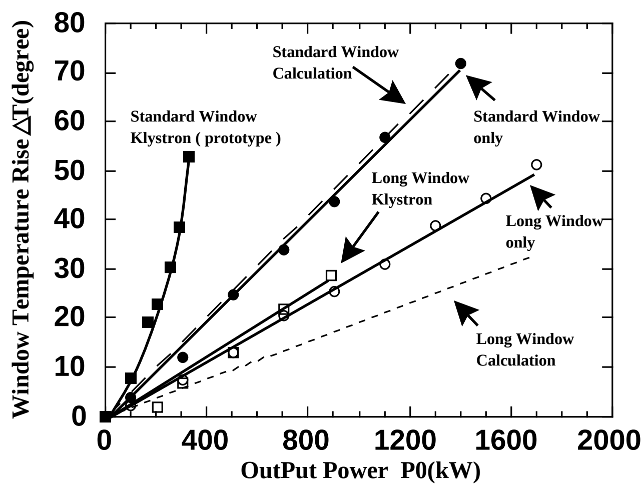

Figure 6. Window temperature rise vs. RF power.

The standard window endured 1.4 MW CW RF power. The long window endured the 1.7 MW CW RF power. Both sides of the window were coated with 60 Å thick Titanium Nitride (TiN) to prevent multipactor. No multipactor was observed on the window during the RF test. MAFIA was used to calculate the power dissipation of the ceramic window (shown in Figure 6) and model RF fields.

The perimeter of the ceramic is brazed into the thin copper cylinder cooled by water. The finite element nonlinear structural analysis system (FINAS) was used for thermal and stress analysis of the window. The variance of dielectric loss (tanδ) of ceramic disks showed that measurement in the long type window is 1.5 times larger than calculation and showed good agreement in the standard one.

The window of the prototype klystron was replaced with the long pill-box type window. A change in the color from white to yellow of the ceramic surface on the vacuum side was found when the standard pill-box was removed from the prototype klystron. The prototype klystron window faced to the output cavity. The impact of drifting electrons from output cavity caused to make color change.

III. KLYSTRON WITH THE LONG WINDOW

The long window was attached to the klystron with E-corner, by which electrons could not travel directly from output cavity to the ceramic. The observed temperature increase in the window of the klystron with the long window agreed approximately with the results of the resonant ring measurement. The klystron with the long window was tested with the CW operation and the pulse operation of 50msec long at a repetition of 1 pps. Figure 7 shows RF peak power vs. beam voltage.

The window temperature increase was 29 degrees when the klystron with the long window had achieved CW RF output power of 885kW, efficiency of 45%, and beam voltage of 85kV in the present measurement. The pulse operation at 85kV produced 1MW with this measurement. 1.2MW will be expected of the nominal beam voltage of 90kV for the pulse operation and 1MW for CW. RF power diffrence above beam voltage 75kV is the dimension changes of cavities due to thermal expansion. High power RF tests up to 1MW will be conducted upon the completion of the PNC linac power facility in mid-1995.

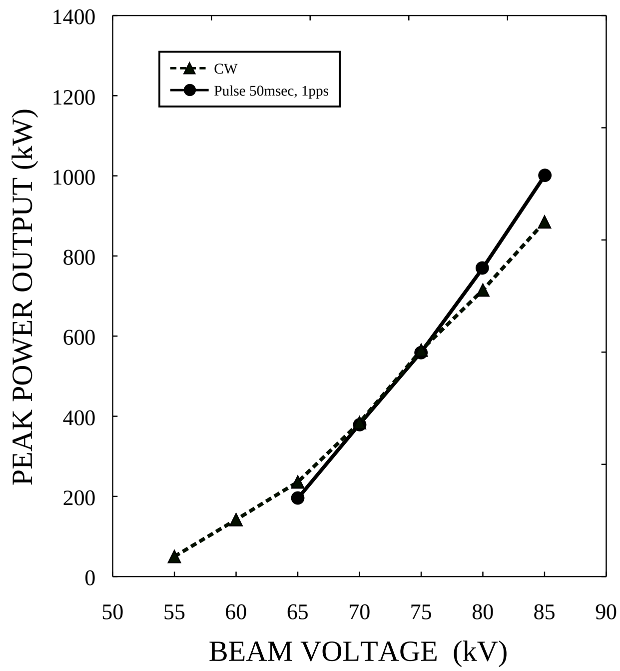

Figure 7. RF peak power vs. beam voltage of the klystron with the long window, provides that the beam perveance is constant at 9×10^{-7}.

IV. SUMMARY

Considerable progress has been made towards the realization of a high power 1.2MW L-band CW klystron. Simple approach using a pill-box type RF window has been shown to handle 1.7 MW CW, which is optimized by simulation codes. The klystron with the long window has achieved output power of 885kW CW and efficiency of 45% in the present measurement. High power RF tests up to 1MW will be carried out at the PNC linac facility in mid-1995.

V. ACKNOWLEDGEMENT

The authors wish to thank the KEK colleagues, especially Dr. S. Fukuda for his invaluable guidance in designing the klystron window.

VI. REFERENCES

[1] S. Toyama et al , "High Power CW Linac in PNC", **Proc. PAC 93** 546 (1993)

[2] M.Nomura et. al , "Status of High Power CW Linac at PNC", **Proc. EPAC 94** 745 (1994)