

DEVELOPMENT OF 972MHZ KLYSTRON FOR HIGH-INTENSITY PROTON ACCELERATOR FACILITY

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Abstract

In the lilac of the High-Intensity Proton Accelerator Facility, 972MHz klystrons are adopted as the RF source for the acceleration from 190MeV to 400MeV. The klystron is required the RF power of 2.5 MW to drive the ACS accelerator. A prototype klystron was produced, and was evaluated the RF characteristics at the test stand in the JAERI. At the first test, a saturation power of 2.1 MW was obtain on the cathode voltage of 104kV, and an unstable output power causing by a gun oscillation was observed.

gun was adopted to form the long pulse width (700 μ s, 50pps). To compensate a beam loading in the ACS cavity, the output power will be slightly modulated at frequency of 1.3MHz. The klystron has six cavities for the required wide bandwidth (972MHz \pm 5MHz). A pillbox window was chosen for the klystron output structure. The ceramic was 30cm in diameter and was coated with a TiN thin layer. The ceramic is indirectly cooled with water from the outside. The collector was also chosen to be the same as the 324MHz klystron to minimize the backstreaming electrons which caused the oscillation at the prototype 324MHz klystron test [4].

1 INTRODUCTION

High Intensity Proton Accelerator Facility utilized a proton accelerator complex is provided a high power proton beam for nuclear physics, materials science, life science and nuclear technology [1]. The accelerator complex consists of a 400MeV linac, a 3GeV synchrotron and a 50GeV synchrotron. In the linac, 20 units of 324MHz klystron are arranged for acceleration of less than 190MeV, and 25 units of 972MHz klystrons are arranged for acceleration from 190MeV to 400MeV[2].

The prototype tube of 972MHz klystron (E3766 #01) was produced in 2001 and was installed in the JAERI site [3]. Since the required output power for the 972MHz klystron was the same as the 324MHz klystron, the gun structure was chosen to be basically the same one as the 324MHz klystron. In the klystron, a modulating anode

2 FIRST TEST AND RESULTS

Figure 1 shows the block diagram of the test stand. The test stand is consists of a high voltage dc power supply, an anode modulator, drive units, wave guide system and low level control units. The system can be operated on the maximum cathode voltage of 110kV, beam current of 45A, pulse width of 700 μ s and repetition rate of 50pps. The klystron output power was checked by both a measurement using crystal detectors and a calorimetric measurement using a dummy load. The difference of those results was less than 1.5%.

In the prototype tube test, it was observed oscillations that occur without the RF input power. Those frequency components were measured by a spectrum analyzer and the three oscillation modes were identified. The

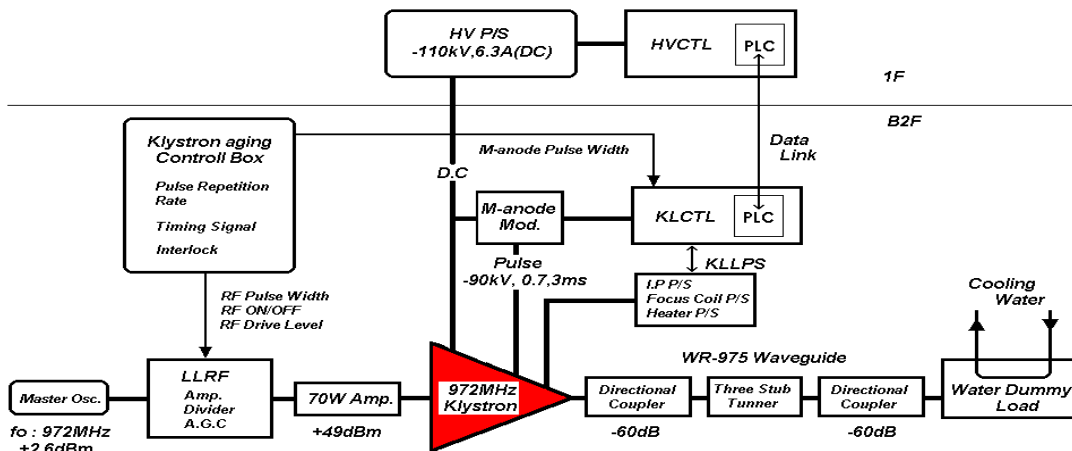


Fig. 1: Block diagram of klystron test stand.

Table 1: Oscillation frequency and its occurrence voltage.

Mode	Frequency	Cathode voltage
A	1300MHz	100 kV
B	3210MHz	90 kV
C	1460MHz	70 kV

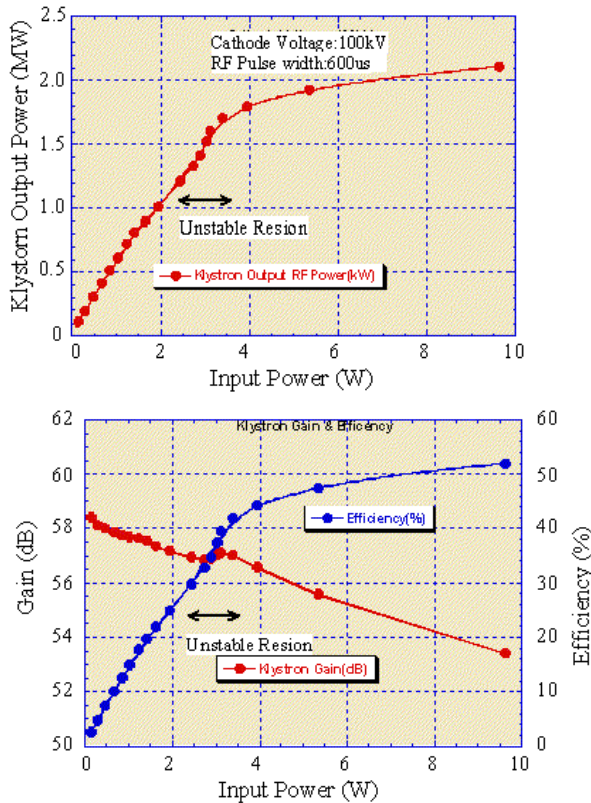


Fig. 2: Characteristics of prototype 972MHz klystron. (Cathode voltage: 100kV, pulse length: 600μs, repetition rate: 50pps)

occurrence of the modes was dependent on the applied cathode voltage. Table 1 shows the oscillation frequency and its occurrence voltage.

The evaluation of the klystron was carried out on the condition that cannot occur the oscillation. It was seemed to be significance to conform the validity of the klystron design parameters. Figure 2 shows the characteristics with the cathode voltage of 100kV. In the characteristics, an unstable output region that the output power varies irregularly was observed. Since the power level to be unstable is changed with applied cathode voltage, we surmise that it is not simple multipactoring phenomenon. We consider that the oscillation affect the instability because the occurrence cathode voltage of the oscillation and the instability is almost same. In this measurement, a saturation power of 2.1MW, a gain of 53db and an efficiency of 52% were obtained. Since the influence of the oscillation became large, the test at designed voltage of 110kV was not performed.

One of features of this klystron is a wide bandwidth. The dependence of the output power on the drive

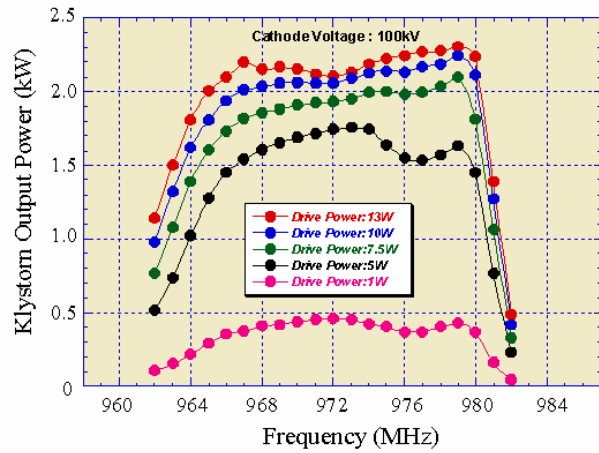


Fig. 3: Bandwidth characteristic.

frequency is shown in Fig.3. The instantaneous bandwidth (-3dB bandwidth) of 17MHz is observed. So the cavities that are input-, 2nd- and 3rd-cavity was tuned at suitable frequency.

The surface temperature on the output window was measured by an infrared thermal imager. The viewpoint was the central part of the ceramic window. For the output power of 2MW with pulse width of 600μs, repetition rate of 50pps, the temperature rose to 60 °C at cooling water temperature of 27 °C ($\Delta T=33$ K). It was smaller than a permissible design value.

3 GUN OSCILLATION

Figure 4 shows the waveforms when the oscillation occurred. A pick up loop was set above the view port of the klystron oil tank. The output power was decreased and was disappeared when signal of the pick up loop was detected, though the drive signal inputted. The spectrum of the pickup signal was composed of the one the oscillation mode A and C. We inferred that the gun oscillation occurred for the following reasons: the pickup signal was detected strongly around the view port; the

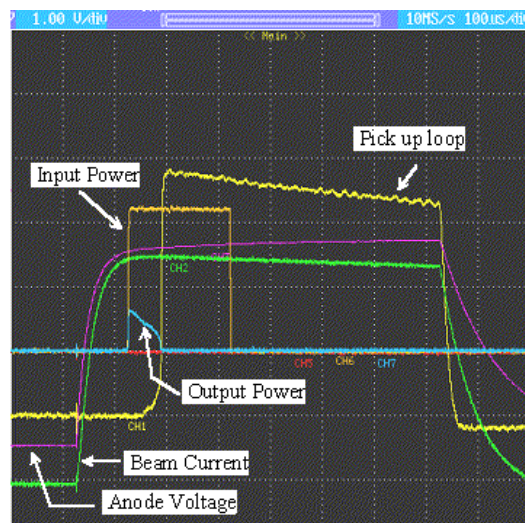


Fig. 4: Typical waveforms at oscillation occurring.

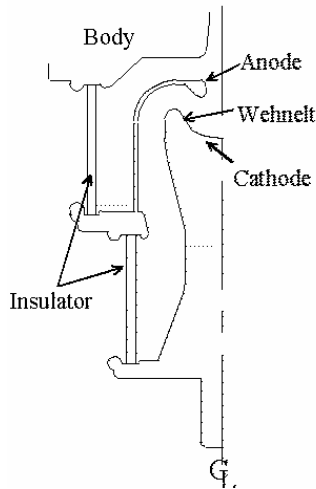


Fig. 5: Gun geometry used in simulation.

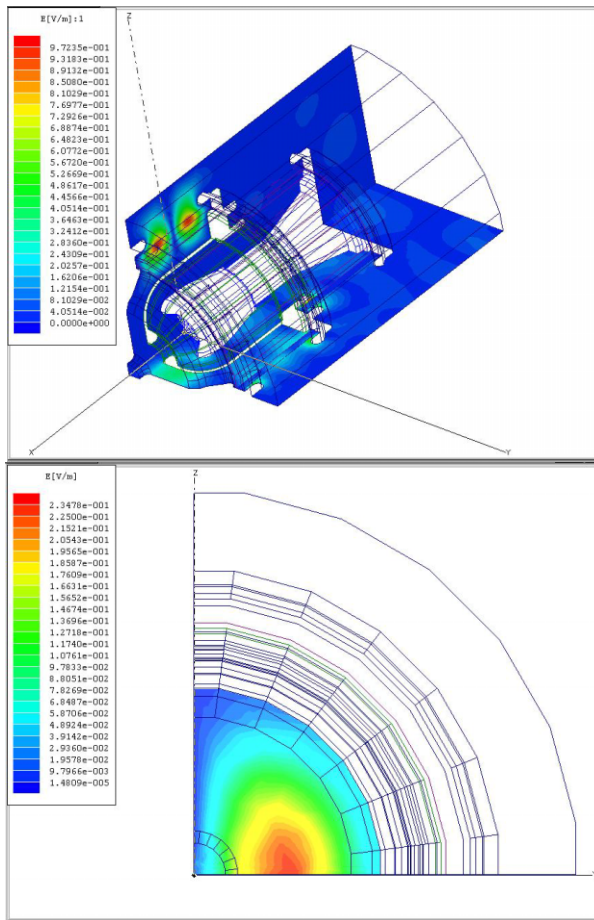


Figure 6: Electric field profile of resonance mode TE_{11N} . (frequency:1490 MHz, Q:1450)

occurrence voltage was raised by decreasing the heater current.

Analyzing these gun oscillations are performed by the Toshiba Corporation side. Though the theoretical gun impedance was calculated based on the Llewellyn diode equation [5], it is difficult to solve them in this practical case. As a first step, the resonance modes with high-Q value in the gun housing are searched by the HFSS code

Table 2: Resonance mode in gun housing.

Resonant Frequency (MHz)	Q_0	Mode	Correspondence with oscillation
1357	2500	TE_{21N}	Mode A
3256	5700	TE_{21N}	Mode B
1490	1450	TE_{11N}	Mode C

[6]. The geometry for the simulation model is shown in fig. 5. As results of the simulation, we distinguish three kinds of resonance modes with high Q-value as compared with other modes. Figure 6 shows the electric field profile of a mode (TE_{11N}) with the resonant frequency of 1490MHz, which is almost same frequency we called the oscillation mode C. Table 2 is listed in resonance modes. We find that the resonance modes with high-Q value correspond to each oscillation mode.

4 SUMMARY

The prototype 972MHz klystron was produced and was evaluated at the test stand in the JAREI. In this test, it was observed gun oscillations and an output power of 2.1MW at the cathode voltage of 100kV was obtained. As the first-test result, the design parameters without the gun were considered to be reasonable. From the simulation results, the oscillation frequencies are in good agreement with the resonant frequencies in the gun housing. However we will perform the more detailed analysis, in order to suppress the oscillation, we will attempt to make the lower Q-value of the resonance mode using high-resistivity electrode-materials in the next tube producing

5 REFERENCES

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