DESIGN STUDY ON THE HIGH POWER KLYSTRON FOR KOMAC

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Abstract

The design study of the 700 MHz, 1 MW CW klystron for driving the CCDTL (Coupled Cavity Drift Tube Linac) of KOMAC (KOrea Multipurpose Accelerator Complex) proton accelerator has been carried out by KAPRA (Korea Accelerator and Plasma Research Association).

A triode type electron gun including a modulating anode, six cavities including one second harmonic cavity and the electromagnets for electron beam focusing were designed to meet the requirements of the KOMAC RF source using various computer codes. Thermal analysis at the RF structure and the collector was performed to effectively remove the heat generated by the wall loss of the RF power and the kinetic energy loss of the electron beam. The effects of the configuration of the output coupler on the coupling coefficient were analyzed by numerical method. The preliminary design study and expected performance evaluation of the RF window were carried out. In this paper, the components design and the expected performance of the klystron are presented.

1 INTRODUCTION

The purpose of design study of the 700 MHz, 1 MW CW klystron amplifier is to acquire various experiences in the domestic design and parts fabrication of the MW grade klystron amplifier, which are essential in proper and efficient operation of high power RF system. 700 MHz, 1 MW CW klystron tube is considered as a coupled cavity drift tube linac (CCDTL) RF source of the KOMAC proton accelerator. Several computer codes were used to design the tube and predict the performance of the tube.

After the electrical design including electron gun, cavity, electromagnet were accomplished, the mechanical analysis including the cavity and collector cooling, electron gun dimensional change caused by the cathode heating should be performed on the basis of the results of the electrical design. If necessary, several iterations between electrical and mechanical design should be carried out.

2 DESIGN

The design parameters for the 700 MHz 1 MW CW klystron for the KOMAC CCDTL and the conceptual drawing are shown in Table 1 [1] and Figure 1, respectively.

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Table 1: Design Parameters for the KOMAC klystron

Parameter	Value
Operating frequency (MHz)	700
Output RF power (kW)	1,000
Maximum beam Voltage (kV)	100
Maximum beam current (A)	20
Efficiency (%)	> 60 %
Power gain (dB)	~ 40
Number of cavities (Incl. 2nd Harm.)	6
Drift tube radius (mm)	30
Beam radius (mm)	~ 20
Focusing magnetic field (G)	250 ~ 300
Collector dissipation (kW)	1,000

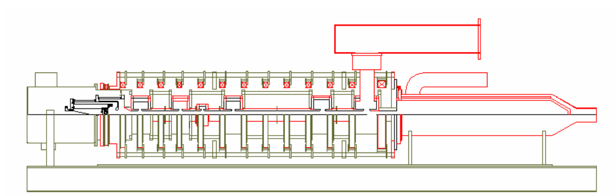

Figure 1 : Conceptual Drawing of the MW CW Klystron

2.1 Electron Gun and Focusing Magnets

The electron gun was designed using electron trajectory program E-gun code. The electron gun was a triode type with a modulating anode. With the modulating anode, it is possible to switch the beam, and vary the perveance or the beam current without varying the beam voltage. The electron gun, which was a Pierce type, generated a laminar beam with a low ripple ($\Delta r/r_0 < 0.2$). In addition, for a long lifetime and conservative design, cathode peak loading was limited below 0.6 A/cm^2 and peak operating electric field below 7 kV/mm. When the beam voltage was 95 kV and the modulating anode voltage 51 kV, beam current of 16.6 A was achieved through the code running. Both Th-W and M-type dispenser cathode are considered as a cathode material. The M-type dispenser cathode is generally used as a cathode of high power klystron because of its lower operating temperature (~1000 °C) but needs ultrahigh vacuum condition (< 10^{-8} torr) [2]. The Th-W cathode needs less stringent vacuum condition but higher operating temperature (1500 ~1800 °C) [3].

In high power multicavity klystrons, axial magnetic field was used in order to keep the electron beam focused during its propagation through the drift region. The important parameters were the linkage of magnetic flux with the cathode, the field increase slope at the gun region and the ratio of the magnetic field in the drift region to the Brillouin value. The magnetic flux density at the beam drift region was 2.3 times of the Brillouin value, which was 110 gauss. In the vicinity of the output cavity, the magnetic flux density was raised to about three times of the Brillouin value in order to counteract the increased space charge forces in the heavily bunched beam. The total number of coils was fourteen including one bucking coil which was used for the fine tuning of the field values near the gun region [4].

The solenoid magnet was designed by the POISSON code, and the output results of this code were used as the input data of E-gun code. Figure 2 shows electron beam trajectory with the magnetic flux density plot at the axis of the beam.

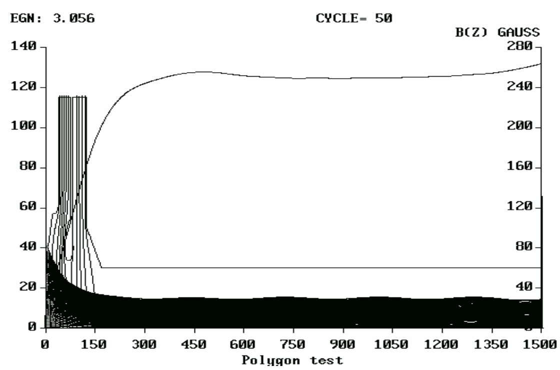

Figure 2 : Electron Beam Trajectory

With the modulating anode, it is possible to switch the electron beam. According to the E-gun calculation, applying the negative 2.5kV to the modulating anode with respect to the cathode made the beam cut off. Electric field distributions near the electron gun region on the normal operation state and the cut off state are shown in Figure 3 and Figure 4, respectively.

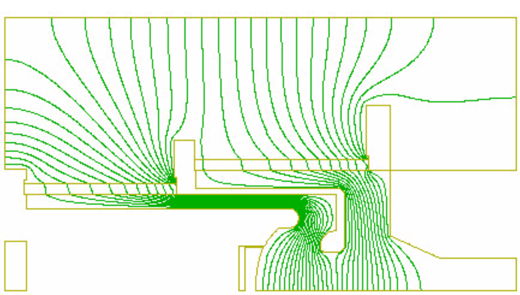

Figure 3 : Field distribution at normal operation

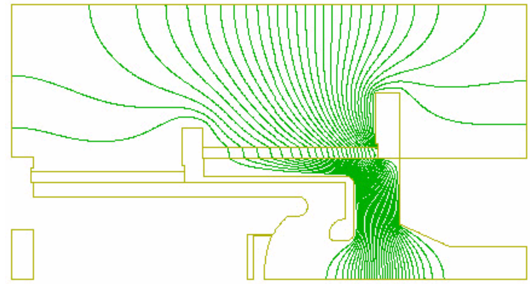

Figure 4 : Field distribution at cut off state

2.2 RF Structures

The geometries of the resonant cavities were determined to maximize the r/Q of the cavity using the SUPERFISH code. The klystron had six cavities including one 2nd harmonic cavity for higher efficiency. The second cavity was tuned to lower frequency and penultimate cavity to higher frequency than the center frequency for a better efficiency also. Simulation results showed that the efficiency of 63 % and the gain of 40 dB could be achieved. The characteristic curve (output rf power depending on the input power) of the designed klystron is shown in Figure 6. As can be seen in the Figure 5, 1MW output rf power can be obtained with the input power of about 80W.

In addition, the power dissipation on each cavity was also calculated through the code simulation and the results are shown in Table 2. The power dissipation on the output cavity is over 4kW, which shows that output cavity needs water-cooling.

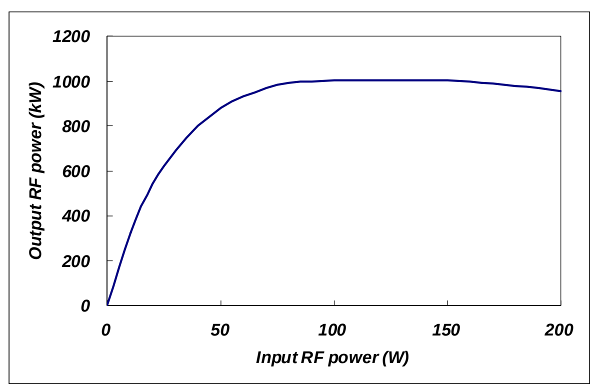

Figure 5 : Output rf power depending on driving power

Table 2 : The power dissipation on each cavity

Cavity	Shunt impedance [MΩ]	Power dissipation [W]
1st	2.2	6
2nd	2.3	39
3rd	1.1	98
4th	2.5	70
5th	3.3	587
6th	3.6	4445

2.3 The Collector

To design the collector, we calculated the beam power dissipation on the collector. The initial beam power is about 1.6MW(95kV, 16.6A) and considering the efficiency as 60%, the total power to be dissipated in the collector is about 640kW. The inner radius of the collector was determined to be 10cm to make the peak power dissipation per unit area below 200W/cm^2. The beam power dissipation on the collector inner surface and the temperature distribution of the collector are shown in Figure 6 and Figure 7, respectively and the designed collector parameters are summarized in Table 3.

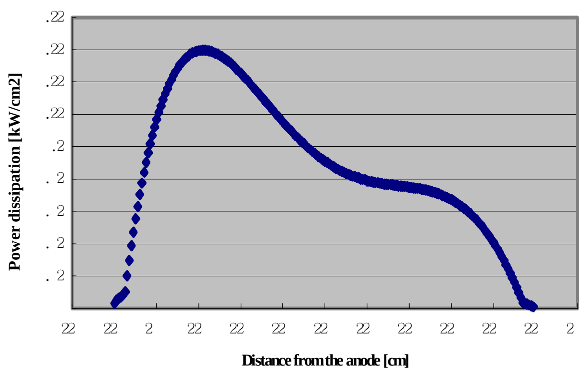

Figure 6 : Power dissipation on the collector

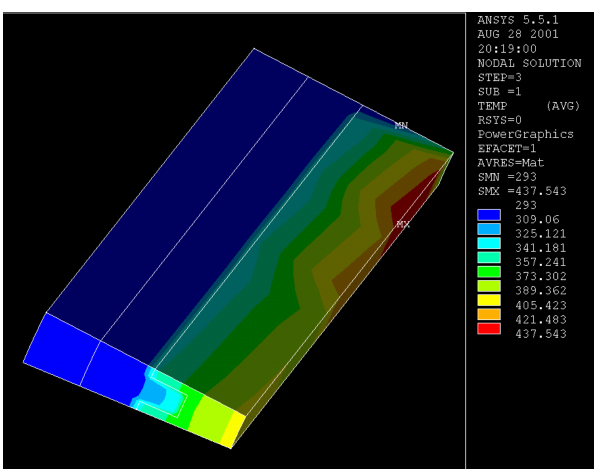

Figure 7 : Temperature distribution on the collector

Table 3 : Design parameters of the collector

Parameter	Value
Peak power dissipation	<200 W/cm^2
Temperature increase on collector	<150 °C
Temperature increase in coolant	<20 °C
Flow rate of the coolant	~1500 L/s
Average inlet coolant velocity	~1.5 m/s
Coolant flow condition	Turbulent
Radius of the inner jacket	10 cm
Length of the inner jacket	~1 m
Number of the cooling fins	72 ea

3 SUMMARY

The 700 MHz 1MW CW klystron was designed to meet the requirements of the KOMAC rf source. Each part of the klystron was designed and expected performance was calculated by using various computer simulation codes.

4 ACKNOWLEDGEMENTS

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