DESIGN STUDY ON THE RF SOURCE FOR KOMAC

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Abstract

A study on the design of 700 MHz, 1 MW CW klystron amplifier for 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 electromagnet for electron beam focusing were designed to produce desired output rf power. Thermal analysis at the collector according to the magnetic field profile near the collector side pole face was performed to efficiently cool the heat generated through the kinetic energy loss of the electron beam. In addition to the design study, operation experiment of the klystron for broadcasting whose output power was 15 kW and frequency range 574 - 698 MHz was performed at 700 MHz. In this paper, the results of the design study and the operation experiment of the klystron for broadcasting at 700 MHz are presented.

1 INTRODUCTION

The purpose of the design study of 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 required for the 700 MHz 1 MW CW klystron for the KOMAC CCDTL are shown in Table 1 [1].

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

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, an axial magnetic field was used in order to keep the electron beam focused during it propagated through the drift region. The important parameters were the linkage of magnetic flux with the cathode, field increase slope at the gun region and 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

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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 POISSON code, and the output results of this code were used as the input data of E-gun code. Fig. 1 shows electron beam trajectory with magnetic flux density plot at the axis of the beam.

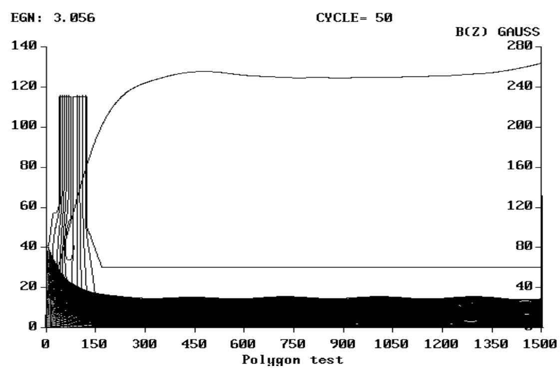

Fig. 1. Electron Beam Trajectory

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 Fig. 2 and Fig. 3 respectively.

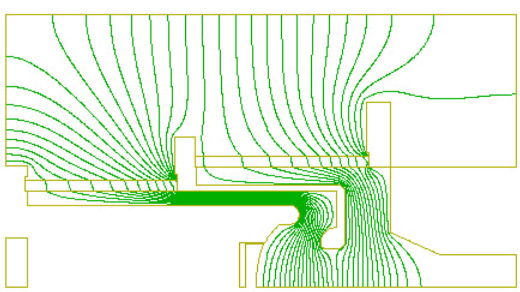

Fig. 2. Field distribution at normal operation

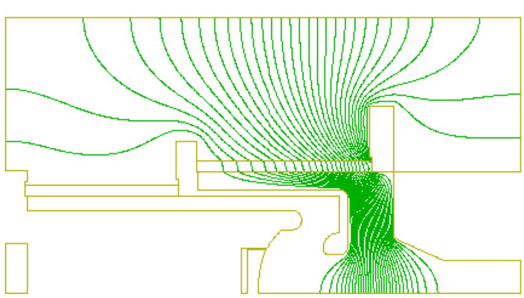

Fig. 3. Field distribution at cut off state

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. The efficiency of 63 %, and the gain of 40 dB were achieved. The characteristic curve (output rf power depending on input power) of the designed klystron is shown in Fig. 4.

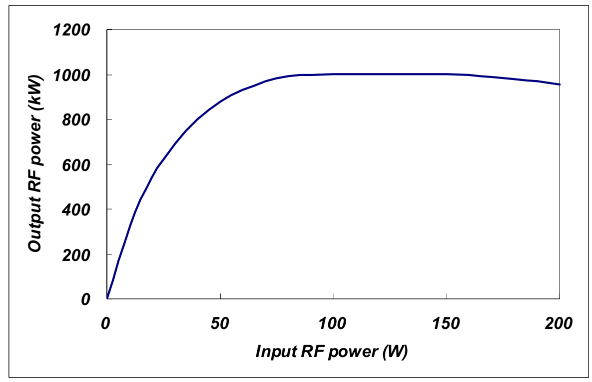

Fig. 4. Expected output rf power depending on driving power

3 OPERATION EXPERIMENT

3.1 Experimental Set-up

To acquire the operation experience prior to the running of 1 MW rf system and to use as a rf source for the test of KOMAC CCDTL, a 10 kW CW rf system was integrated and tested. The rf system consists of the oscillator, solid state amplifier, klystron, dummy load, and coaxial transmission line. The klystron used for the system was for the broadcasting, made by NEC (Model: 1AV58). The main parameters of the klystron are shown in Table 2.

Table 2. Main Parameters for the 1AV58 klystron

Parameter	Value
Operating frequency (MHz)	599.25
Output RF power (kW)	15
Beam Voltage (kV)	18
Mod. Anode voltage (kV)	13.7
Cathode Current (A)	1.93
RF drive power (W)	10
Power gain (dB)	32.3
Heater voltage (V)	6
Heater current (A)	16
Ion pump (l/s)	1
Collector dissipation (kW)	38

As can be seen in Table 2, typical operating frequency of the klystron was not matched to that of the KOMAC CCDTL, which was 700 MHz. In addition, the focusing magnet was not available, therefore some modifications were required such as,

1) cavity tuning for the 700 MHz operation
2) design and fabrication of the electromagnet.

The cavity tuning data were obtained by the 3D analysis of the klystron cavity and the electromagnet for focusing was designed with POISSON code. The measured magnetic flux density profile of the fabricated electromagnet was agreed with that of calculated one within 4 %. The integrated 10 kW rf system are shown in Fig. 5.

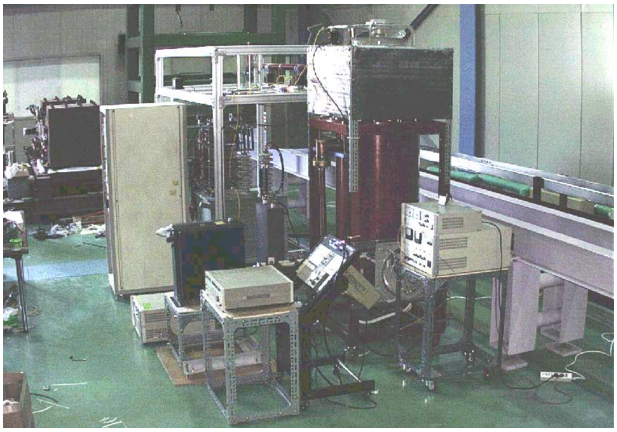

Fig. 5. 10 kW rf System

3.2 Operation Results

Fig. 6 shows the result of the DC beam extraction test. Measured perveance was about 0.85μperv, whereas the calculated value from the cold dimension data of the electron gun was 0.79μperv. It seemed that the discrepancy resulted from two factors. One was that the cold dimension of the electron gun was used to simulate the electron gun and the other was the measurement error of the electron gun dimension. As can be seen in Fig. 7, 9.1 kW rf output power was achieved at 700 MHz, which was above the typical operating frequency of the klystron. Because the power capacity of the dummy load used in the system was 10 kW with forced air cooling, maximum output power was limited below 10 kW. It is considered that it is possible to obtain above 10 kW rf power with increasing the beam voltage to its typical operation value. The measured values was agreed with the calculated one within 10 %

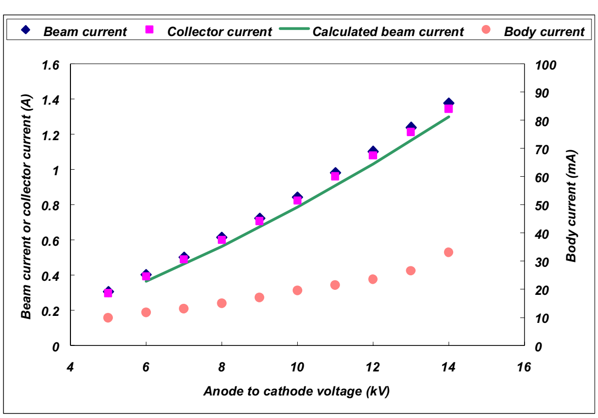

Fig. 6. DC Beam Extraction Result

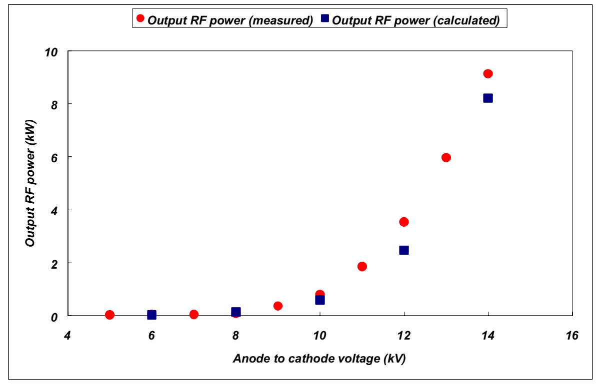

Fig. 7. Output Power vs. Beam Voltage

4 SUMMARY

700 MHz 1MW CW klystron was designed to meet the requirements of the KOMAC rf source and the operation experiment with the frequency-modified klystron was performed. The operation test results showed a good agreement within 10 % between the measured data and calculated one.

5 ACKNOWLEDGEMENTS

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6 REFERENCES

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