Design of X-band 20-MW Klystron

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Abstract: *The market of the high power X-band klystron is expanding these days. CETD (Canon Electron Tubes & Devices co., ltd.) is developing a new X-band 20-MW klystron for industrial and scientific applications. The output power of 20 MW covers the gap between about 10 and 50 MW, which gives klystron users new choice. The klystron was designed based on our experience of the existing X-band 6-MW klystron. The electron gun and the electromagnet were newly designed. To decrease the electric field strength in the output section, the 3-cell output cavity was used. In this report, we show the specifications and design details of the klystron.*

Keywords: klystron; X-band klystron; design; simulation

Introduction

The X-band accelerators are compact and sometimes the total cost of the machine can be reduced. For example, the 12-GHz accelerators for CLIC (Compact Linear Collider) are studied [1]. Klystrons are used as RF sources of such particle accelerators.

Recently the market of the X-band klystron is expanding and the output power ranged between 10 to 50 MW will give the klystron users new choice. CETD newly designed the X-band (11.424 GHz) 20-MW klystron E37116. In this article, design details of the klystron are shown.

Design

The specifications of the klystron E37116 are shown in the table 1. The frequency is 11.424 GHz. The klystron was designed based on our experience of the existing X-band 6-MW klystron [2][3].

The electron gun and the electromagnet were newly designed by using DGUN code [4]. The DC beam simulation result at the beam voltage of 265 kV is shown in the figure 1. The beam ripple was small and the beam smoothly passed the drift tube. The beam perveance was design to be 1.25 μP. The inner shape of the electron gun was carefully designed and the maximum electric field strength on the electrodes was within the design criteria (<25 kV/mm).

The cavity shapes and positions are scaled from the existing klystron and the RF amplification was simulated using FCI code [5]. Totally five cavities were used and the 3-cell pi/2 mode travelling wave cavity was used as the output cavity to reduce the electric field strength of the output section. The simulation target and result are summarized in the table 2. The design target of the output power and the efficiency was set to be a little higher than the standard values of the specifications considering the difference between the simulation and the actual operation in the existing klystrons. After some parameter tunings of the interaction section, the saturated output power of 24.3 MW was achieved in the FCI simulation at the beam voltage of 265 kV and the beam current of 170.3 A. The beam trajectory and the transfer characteristics are shown in the figure 2 and figure 3, respectively. The drive power at the saturation point was 120 W. No back going electrons were observed in the simulation and all the design targets were achieved.

The three-dimensional shape of the 3-cell output cavity was designed by HFSS to meet the cavity parameters determined by FCI. Two RF windows which have the same design as the existing X-band klystron were used.

Table 1. Specifications of klystron E37116.

Parameter	Unit	Min.	Stan.	Max.
Frequency	GHz	11.423	11.424	11.425
Beam voltage	kV	-	265	290
Beam current	A	-	170	195
Output power	MW	-	20	20.2
Efficiency	%	-	44.4	-
Drive power	W	-	120	400
Beam pulse width	μs	-	3.5	3.5
RF pulse width	μs	-	1.5	1.5
Pulse repetition rate	pps	-	400	400
Average output	kW	-	12	12.4

Table 2. Design target and design result.

Parameter	Unit	Design target	Result
Frequency	GHz	11.424	11.424
Beam voltage	kV	265	265
Beam current	A	170.3	170.3
Output power	MW	> 23	24.3
Efficiency	%	> 51	53.8
Drive power	W	~120 (< 400)	120
Max. electric field strength in cavity	kV/mm	< 64.5 (for 1.5 μs RF)	60.4

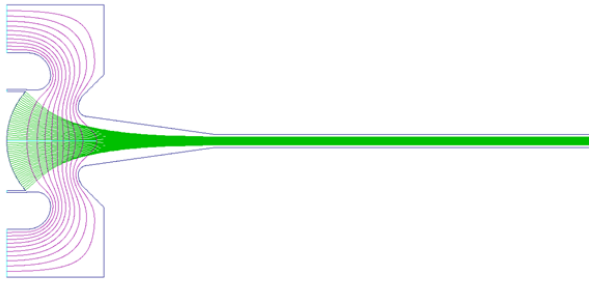

Figure 1. DC beam trajectory in focusing magnetic field simulated by DGUN (beam voltage 265 kV and beam current 170.3 A).

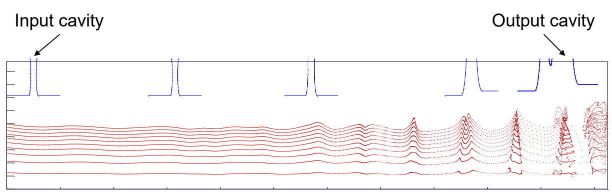

Figure 2. Electron bunching simulated by FCI (drive power 120 W and output power 24.3 MW).

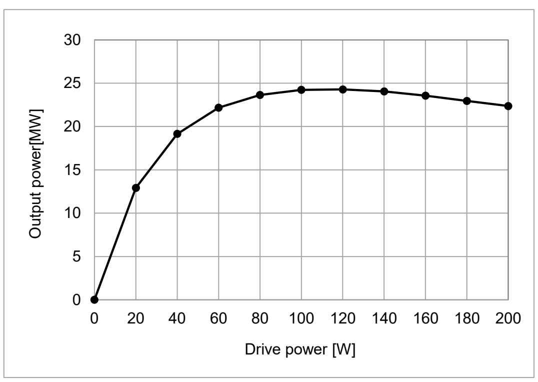

Figure 3. Transfer characteristics simulated by FCI (beam voltage 265 kV and beam current 170.3 A).

After finishing the electrical design works, the overall structure of the klystron was considered and mechanical design has been done. The outline dimension of the klystron and the electromagnet is shown in the figure 4. The collector is surrounded by thick lead shields. The height of the klystron is about 1.3 meters. The weight of the klystron and the electromagnet will be about 300 kg and 800 kg, respectively.

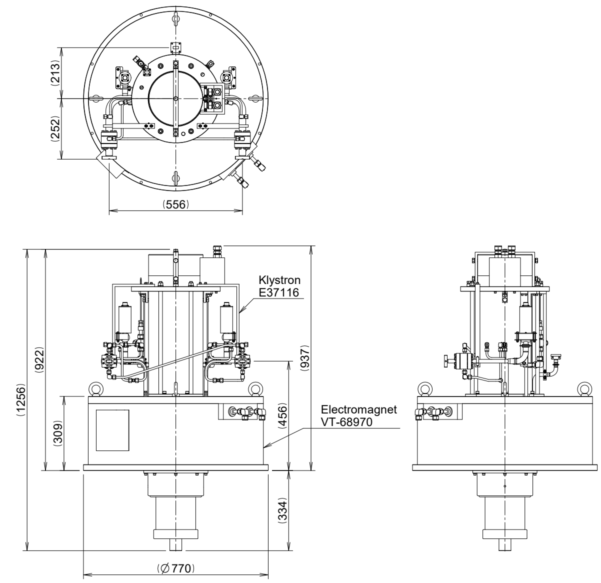

Figure 4. Outline drawing of klystron and electromagnet.

Conclusion

The 11.424-GHz, 20-MW klystron E37116 was designed in CETD. The simulation result showed that the klystron can achieve the output power of 20 MW. The design of the klystron has been completed. The klystron will be prototyped and tested in the near future.

References

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