ISBN: 978-3-95450-231-8 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2023-MOPL080

DESIGN OF A S BAND HIGH POWER KLYSTRON FOR BEPCII*

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Abstract

A S band high power klystron for BEPCII operating at frequency of 2856 MHz has been designed and simulated at Institute of High Energy Physics, Chinese Academy of Sciences. A thermionic electron gun has been designed. The beam current of 379 A is obtained at operating voltage of 325 kV with cathode current density of 6.6 A/cm^2. Then, the full 3-dimensional particle-in-cell simulation of the whole klystron in CST verified that the klystron efficiency was achieved about 40% with output power of 50 MW. In addition, the RF design of cavities for interaction region is described. So far, the mechanical design of this klystron has been completed and the fabrication is in progress.

INTRODUCTION

BEPCII is an electron positron collider running in the tau-charm energy region, which has a 202 m long injector Linac [1]. The power source system of Linac consists of twenty S band high-power pulse klystrons with peak output power of 50 MW. Currently, there are 8 Canon E3730A klystrons, 5 Mitsubishi PV3050I klystrons and 7 Hubei Hanguang K418A klystrons running online. Based on the successful development of the 65 MW klystron for BEPCII in 2011, a more compact 50 MW klystron with 5 resonant cavities and single output window has been designed. The basic design parameters are listed in Table 1. In this paper, the detailed design and simulation results are presented. Up to now, the manufacturing of the 1st prototype klystron is in progress. The high-power test will be carried out in the second half of 2023.

Table 1: 2856 MHz/50 MW klystron design parameters

Parameters	Value
Operating Frequency	2856 MHz
Beam Voltage	325 kV
Beam Perveance	2.05 μA/V$^{3/2}$
Efficiency	≥40%
Saturation Gain	≥50 dB
Output Power	50 MW
RF Pulse Width	4 us
Repetition Rate	50 Hz
Number of Cavities	5
Drift Tube Radius	15.9 mm
Beam Filling Factor	0.6

ELECTRON GUN DESIGN

A diode thermionic electron gun has been designed following Pierce's theory [2]. In order to increase the lifetime of the cathode, a scandate type dispenser cathode is used with emission current density of 6.6 A/cm^2. The cathode diameter is 85 mm. At operating voltage of 325 kV, a beam current of 379 A is obtained. Figure 1 shows the electron beam trajectory. The shape of electrodes is optimized to reduce the maximum electric field on the surface, which can reduce the risk of breakdown of electron gun. The maximum electric field is 24.2 MV/m on the focusing electrode, as shown in Fig. 2.

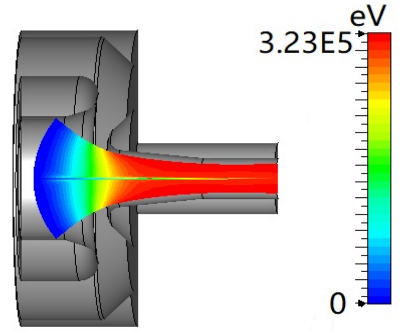

Figure 1: Electron beam trajectory.

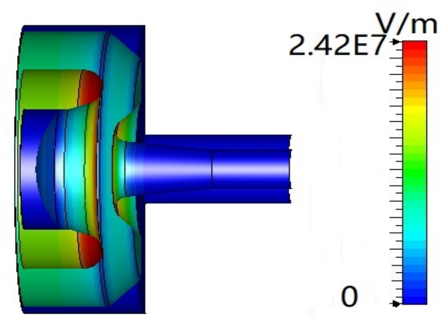

Figure 2: Static electric field distribution.

WINDOW DESIGN

The RF design of the pillbox window has been completed, which consists of a thin ceramic disk mounted at the centre of a circular waveguide and two standard WR-284 rectangular waveguides [3]. The high purity alumina ceramic AL300 from Morgan Company is selected for its good properties of dielectric loss, dielectric strength and mechanical strength. The dielectric constant is 9 and the loss tangent is 4E-4. The diameter of the ceramic disk is 84.5 mm based on the impedance matching criteria between the dominant TE_{11} mode of the circular waveguide and TE_{10} mode on the rectangular waveguide and is given by the relation D = 1.1723a. The TiN coating is applied to the window surfaces for multipactor suppression. The pillbox window should be cooled by water to prevent ceramic

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overheating. Figure 3 shows the electric field distribution of the window.

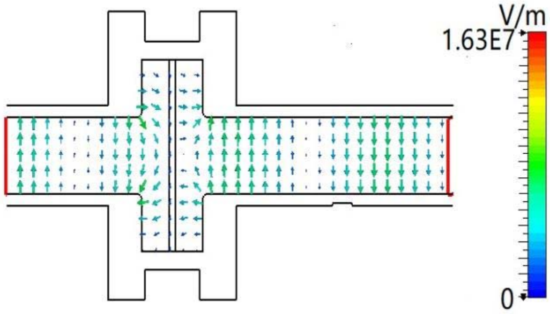

Figure 3: Pillbox window electric field distribution.

BEAM DYNAMICS SIMULATION

The RF section plays an important role in efficiency, gain and bandwidth, which includes five cavities and drift tubes between cavities. The drift tube diameter is 15.9 mm. The beam filling factor is chosen to be 0.6 to compromise between optimum coupling and minimum interception. The drift length and the cavity characteristic parameters such as frequencies, characteristic impedance, coupling coefficients and external quality factor Q_e of input and output cavity are optimized to obtain maximal efficiency. AJDISK is used for parameters optimization due to its fast calculation speed, as shown in Fig. 4 [4]. The full 3D particle-in-cell simulation in CST indicates that the klystron efficiency reaches about 40% without instability and returning electrons, as shown in Fig. 5 [5].

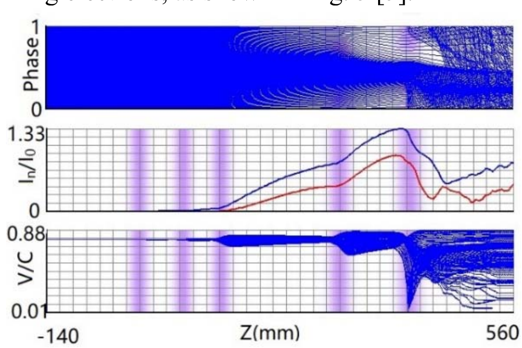

Figure 4: Simulation results in AJDISK

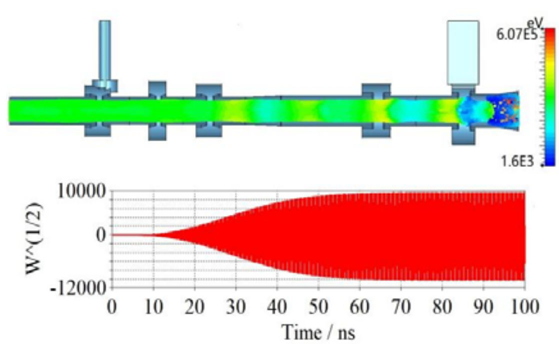

Figure 5: Simulation results in CST.

CAVITY DESIGN

The klystron includes five cylindrical re-entrant cavities operating in the TM_{010} mode. The oxygen free high conductivity copper (OFHC) is used for cavity fabrication material. All cavities are cooled by water to take away the ohmic heat loss on the copper surface and maintain the cavity frequency stable. The main characteristic parameters are listed in Table 2. The electric field distribution of the output cavity is shown in Fig. 6.

Table 2: Cavity design parameters

Cavity NO.	Frequency (MHz)	R/Q	Q_e
1	2856	62.7	230
2	2862	57.9	-
3	2871	69	-
4	2935	69.7	-
5	2847	75	21

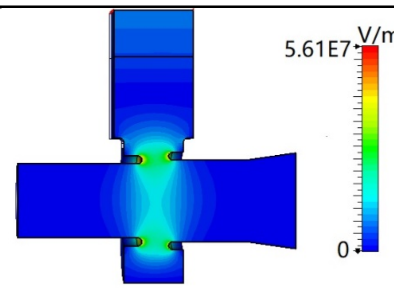

Figure 6: Electric field distribution of the output cavity

CONCLUSION

The S band 50 MW pulse klystron is the key component of Linac injector in BEPCII. Since the first domestical 65 MW klystron was successfully developed in early 2011, seven klystrons of this type have been put into operation online. In order to reduce production costs, a more compact klystron with 5 resonant cavities and single window has been designed.

ACKNOWLEDGEMENT

We would like to acknowledge the Hubei Hanguang Company for their great cooperation.

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