DESIGN STUDY OF ELECTRON GUN FOR CEPC 650 MHz KLYSTRON*

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Abstract

This paper presents the design and simulation of an electron gun for 800 kW CW klystron of which frequency is 650 MHz for CEPC project. An electron gun with a modulating anode is designed using DGUN software. The uniform beam trajectories, with a beam perveance of 0.64 $\mu A/V^{3/2}$ are simulated. We employed a Ba-dispenser cathode of radius 35 mm with Φ10 hole at the centre and obtained a current density on cathode less than 0.45 A/cm^2. The beam trajectories were also simulated over whole tube length with a magnetic field of 207 Gauss. Expecting functions using the modulating anode gun are also described. Proposed beam tester and whole CEPC klystron layout are also shown in this paper.

INTRODUCTION

IHEP has been successfully operating electron-positron collider (BEPC-II) and lots of pulsed klystrons are used in the linac section. Recently the future plan of Circular Electron-Positron Collider (CEPC) is proposed. For this project, many high-power klystrons, of a frequency of 650 MHz and an output power of CW 800 kW are required [1]. In this project, a high efficiency of the klystron is desired. At the same time, it is desired that the IHEP designs the klystron and manufactured it domestically. As it is first time to manufacture such a high-power klystron in IHEP, we have a strategic plan to proceed it step by step. First we are going to manufacture a beam tester to evaluate the gun design and collector, and then add the interaction region to evaluate the RF design and the output window. Our first goal is to achieve the efficiency more than 70%. General plan is presented in this conference [2]. As perveance greatly determine the klystron efficiency, in order to have a high efficiency, the most likely perveance is tentatively chosen to be a micro perveance of 0.64 $\mu A/V^{3/2}$ from the empirical formula [3]. We are planning to start from a single beam klystron. This klystron development is performed by the several members of IHEP. The electron gun, the focusing magnet and the relating structure of the klystron are described in this paper. The collector design is described in Ref. [4], since a collector is very important for CW operation. In this paper, the collector has assumed to be durable to full beam load, but in Ref. [4], another choice is also mentioned due to the current manufacturing limitation. The RF interaction and cavity design based on the classical approach of cavity layout is described in Ref. [5].

For designing of a reliable klystron, electron gun is one of a critical part. Since the requirement of electron gun for both CW and pulsed operated klystron is different, so we need to consider this difference on designing [6]. Because of these reasons, though a diode gun is a final goal, a modulated anode (MA) gun is chosen at first as described in next section. This choice enables us to study many problems of the CW klystron relates to thermal heat problem involving in collector and RF window. For gun design, an exact setting of distance between cathode and anode is not so easy for building new tube due to the cathode envelop expansion. This is also expected to study using MA gun.

DESIGN OF THE GUN ASSEMBLY

Cathode and Electrode Design

In CW operations, many parameters should be lower than the pulsed case, such as applied voltage, and cathode emission as known empirically [6]. We proposed to use an MA gun structure for CEPC klystron at first. The MA gun with the Pierce gun design [7] is achieved using the simulation code of DGUN [8], EGUN [9], and CST [10]. Main work was done by DGUN and then reliability of the results was checked with other codes.

Table 1: Calculated Parameters of CEPC Gun

Applied Voltage on Cathode	kV	−81.5
Applied Voltage on MA	kV	−47.5
Beam Waste Diameter	mm	34.4
Beam/Gun Perveance	$\mu I/V^{3/2}$	0.64/1.45
Max. Field on BFE/MA	kV/mm	3.90/3.56
Av. Cathode Density(given)	A/cm^2	0.45
Cathode Uniformity		1.24

The parameters of the electron gun with spherical cathode are summarized in Table 1. Beam current of 15.09 A at operating voltage of 81.5 kV is required by RF design. For cathode loading we chose the conservative value; a cathode radius of 35 mm having a current density less than 0.45 A/cm^2. A Ba-dispenser cathode having a Φ10 hole at the centre is used to avoid the damage by the ion bombardment [11]. Focusing magnetic field and electric field simulations are done by using POISSON code [12].

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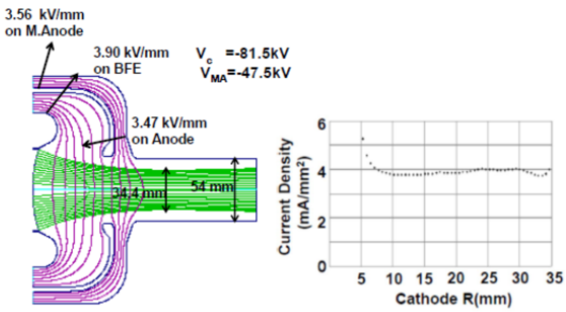


(a) (b)

Figure 1: Results of the simulation for MA gun of 800 kW CEPC klystron are shown. Figure (a) shows beam trajectory and maximum electric field on electrode. (b) shows the current density on cathode.

By using the modulated anode, we have a simulation for CEPC klystron. Simulation results using DGUN code is shown in Figure 1: including the maximum field on the electrode and the current density on the cathode. The ratio of a beam radius to a drift tube radius is 0.64 and is a usual accepted value. These gun design parameters are required from the RF simulation of ref. [5], and we have achieved this goal by simulation. From this design, a cathode uniformity of 1.24 was obtained. As we know that gun is subjected to high levels of electrical stress where the breakdown and arcing phenomenon occurs. By considering these phenomenon's, a simulation and a design of HV gun envelop of CEPC klystron has been done using POISSON code as shown in Figures 1 and 2. The electric field strength is less than 3.80 kV/mm to avoid the breakdown phenomenon.

HV Ceramic Design

Layout of ceramics relates to an outside layout of a socket tank and a magnet design (configuration of extra coil), a consistent design is required. Average field on the ceramic was 0.32 kV/mm (C-MA) and 0.25 kV/mm (MA-A) along the length (150 mm) of ceramic. Electric fields

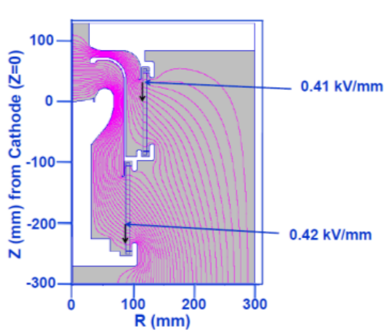


Figure 2: HV gun envelope design for CEPC klystron is shown. Electric field is calculated by POISSON Code. Applied electrode voltages are same as Figure 1. Equipotential line step shown above is 0.4 kV.

calculated by POISSON and maximum field on the each of ceramic insulation are shown in Figure 2.

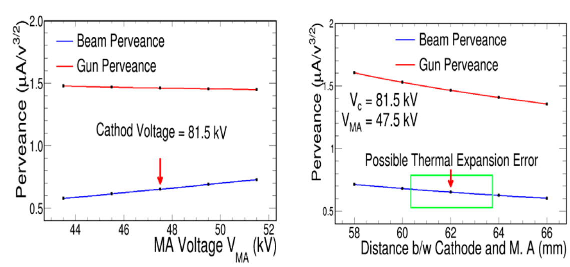
EVALUATION ITEMS EXPECTED FROM MODULATED ANODE GUN OPERATION

We employ MA gun to investigate the design ambiguity of the CEPC klystron. In MA klystron, a current is determined by the voltage of an MA and a cathode (gun perveance) and a tube perveance is derived by the voltage between an anode and a cathode (a beam perveance).

Using MA klystron, we investigate the following items.

1. Perveance simulated by the various gun codes has some errors and MA gun can correct this ambiguity. In fact empirically EGUN and DGUN predict perveance by about 5% lower values. Furthermore the gun assembly expands thermally when it operates and if we do not know this variation, an operating perveance deviates from design value. We may make clear about this point by using MA gun.
2. Feasibility for a maximum electric field and a current density in CW operation should be cleared by comparing a pulse voltage with a CW voltage on the modulated anode.
3. Concerning about the heating capability for collector and RF window, it is useful to evaluate them by changing the pulse duty.

Figure 3 (a) shows the perveance with a function of an MA voltage and if the manufactured gun has different performance, it is possible to get design value by slight change of MA voltage because gun perveance is more sensitive to MA voltage. Figure 3 (b) shows the relation between perveance and MA distance from the cathode. This situation indicates the possibility of adjusting the perveance change if it deviates from expected value between the manufactured dimensions (cold dimension) and operating dimension (hot dimension).



(a) (b)

Figure 3: (a) shows the perveance with a function of an MA voltage and if the manufactured gun has different performance, it is possible to get design value by slight change of MA voltage. (b) Shows the relation between perveance and MA distance from the cathode.

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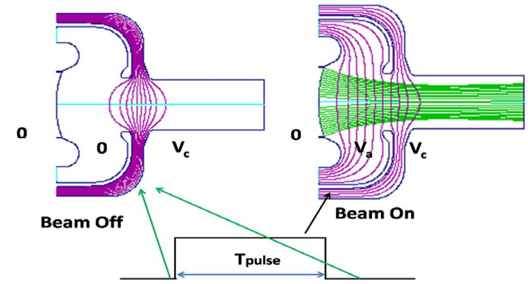


Figure 4: Concept for pulse operation of modulating anode gun is shown. Using this method, it is possible for klystron to be performed from small duty of pulse to CW operation.

We aim to build the CW klystron, while in order to start the tube evaluation from the low duty, pulse operation is also useful and MA klystron is possibly operated in this mode as shown in Figure 4.

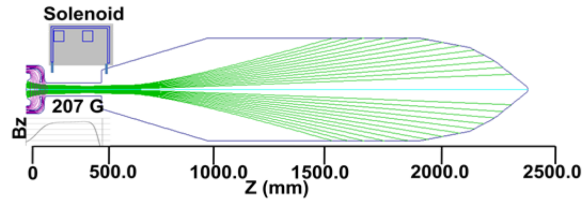
SIMULATION RESULTS OF WHOLE STRUCURE IN CURRENT DESIGN

Beam optics over the structure is simulated including the magnetic field using EGUN and DGUN. Magnetic field of Br and Bz calculated by using POISSON code. We assume the semi-confined flow allowing the 26 Gauss on the cathode and 207 Gauss for the drift tube region (Brillouin field of 111 Gauss). As we cannot get perfect matching between the gun and magnetic field due to the limited space for beam forming magnetic field, there is scalloping in the interaction region but as 100% beam transmission is established and we thought it is not a serious problem. After simulation of gun using different codes including the magnetic field, all results shows 100% beam transmission but concerning about the ripple rate there are discrepancies of 10 to 20%.

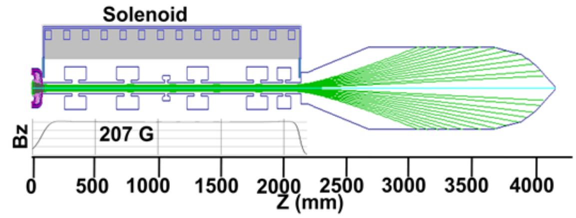
Considering the manufacturing restriction and empirical training, we have a plan to start from beam tester and then add the interaction region between gun and collector [2], Figure 5 shows simulation results of beam tester using DGUN code. In this case the cathode has a Φ10 hole at the centre. Short magnetic coil is added for quick divergence of the beam for beam tester (Figure 5 (a)). The whole layout of the CEPC klystron; from gun, cavity section and collector are shown with the beam trajectories in Figure 5 (b). The whole length of CEPC klystron layout is reached up to about 4.5m and current limitation for the baking furnace, different size of the collector is also considered in Ref. [5].

SUMMARY

The electron gun for the CEPC 800 kW CW klystron of which frequency is 650 MHz has been designed. Computer simulation tools DGUN, EGUN and CST are used to design the electron gun. We employed the modulated anode gun having the perveance of 0.64 $\mu A/V^{3/2}$. It is shown that the Perveance adjustment is possible by changing the modulating anode voltage. This enables us to check the perveance ambiguity and dimension difference of gun electrodes. It is also shown that pulse operation helps us to evaluate the thermal rating of collector and windows. We will start to manufacture a beam tester within this year to evaluate the basic parameters.



(a)



(b)

Figure 5: (a) Beam Tester (b) Whole CEPC Klystron Layout.

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