CEPC LINAC HIGH EFFICIENCY KLYSTRON*

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The injector linear accelerator (LINAC) for the High Energy Circular Electron Positron Collider (CEPC) requires a higher efficiency klystron with 80MW output power to reduce energy consumption and cost. The efficiency is expected to improve from the currently observed 42% to more than 55% and output power will be improved from 65 MW to more than 80 MW with same operational gun parameters. In this paper, BAC bunching method is applied for klystron efficiency improvement and beam dynamic optimization. The design of the gun and solenoid parameters has been completed with 2-D code DGUN and is also checked by 3-D code CST. The preliminary design of the cavity parameters has also been completed with 1-D disk model based AJDISK code while the verification of 2-D code EMSYS and 3-D code CST are in progress. Finally, new klystron prototype will be fabricated in Chinese company after design parameters are determined.

INTRODUCTION

The RF power source system of CEPC LINAC includes 33 sets of pulsed klystron operating at a frequency of 2860 MHz. The output power of klystrons are excepted to be 80 MW so that the gradient of the accelerating structure will be up to 22 MV/m. The RF distribution system is shown in Figure 1. Based on the existing S band 65 MW klystron currently applied in the Beijing Electron Positron Collider II (BEPCII) LINAC injector, the BAC method will be adopted to increase the klystron efficiency from 42% to 55% to meet the CEPC LINAC requirement. Table 1 shows parameters of the klystron operating in BEPCII and the proposed BAC-based klystron.

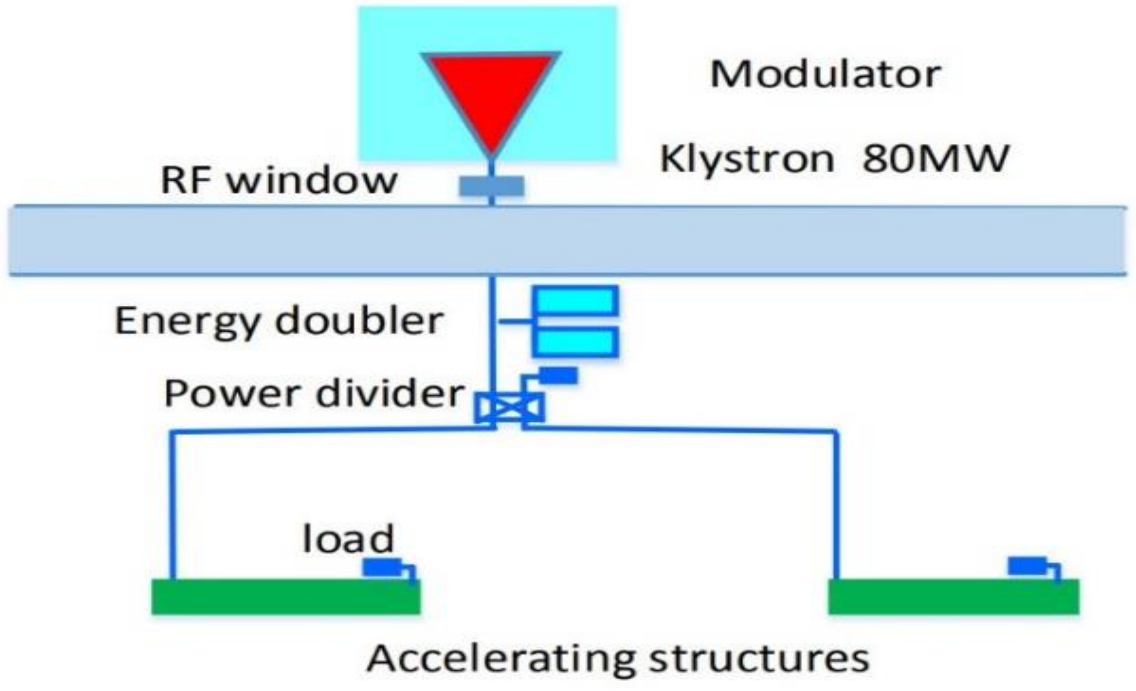

Figure 1: Accelerating structure of CEPC LINAC

Table 1: Klystron parameters

Parameters	BEPCII	BAC-based
Operating frequency	2856 MHz	2860 MHz
Output power	65 MW	80 MW
RF pulsed width	4 μs	4 μs
Beam voltage	350 kV	350 kV
Beam current	414 A	414 A
Beam perveance	2.0 μP	2.0 μP
Efficiency	42%	55%

BAC METHOD

The BAC method consists of 3 stages: traditional bunching, alignment velocity spread of electrons and collecting outside electrons. Compared with COM bunching mechanism, BAC method can shorten the length of klystron besides improving efficiency. The present BEPCII S band 65 MW klystron has 6 cavities in its interaction section. In order to apply BAC method, The 4 additional cavities including 2 second harmonic cavities are added between the 4th and 5th cavity of the original klystron. The 1-D code AJDISK is suitable for the preliminary optimization of the interaction section parameters. Based on AJDISK, a 1-D automatic optimization code via NSGA-II is developed at IHEP. With this code, the length of the drift tube between the cavities and the cavity characteristic parameters such as frequency, R/Q and coupling coefficient are optimized to obtain a maximal efficiency. Figure 2 shows the AJDISK simulation result of the original klystron and the proposed BAC-based klystron. With the four new cavities, the process of the electron core oscillation and the process of collecting 'particle-outsiders' is accelerated. Therefore, compared with the original klystron, more outside particles are collected by the interaction section of the BAC klystron at the output cavity. The 1-D efficiency is improved from the original 49% to 64.47%.

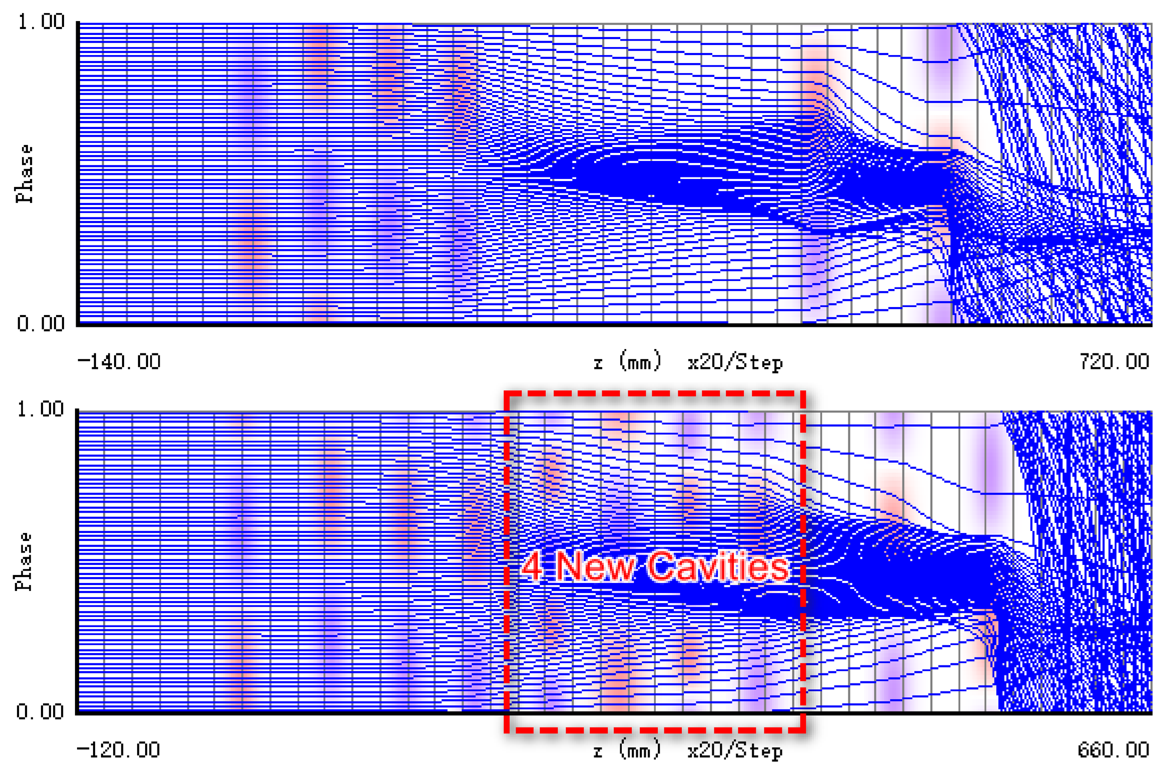

Figure 2: 1-D simulation results in AJDISK

GUN AND SOLENOID

The prototype of the electron gun for the new BAC-based klystron is optimized from that of the original one. Table 2 shows the parameters of the previous gun and the new one. The radius of the drift tube is decreased to cut off the second harmonic wave.

Table 2: Comparison of gun parameters

Parameters	BEPCII	BAC-based
Beam voltage	350 kV	350 kV
Beam current	414 A	414 A
Beam perveance	2.0 μP	2.0 μP
Drift tube radius	15.986 mm	12.3 mm
Beam radius	9.45 mm	8.65 mm

The solenoid of BAC-based klystron is also re-designed based on the original one. Because we have extended the length of the interaction section to achieve a higher efficiency, it is necessary to have a longer magnet that also has a stronger field at the output cavity to suppress the higher space-charge effect. The value of the magnetic field is firstly simulated by 2-D code POISSON SUPERFISH and then input to 2-D code DGUN for beam optics simulation. The result is also checked by 3-D code CST. Figure 3 and Table 3 shows the comparison of beam optics simulation result in DGUN and CST.

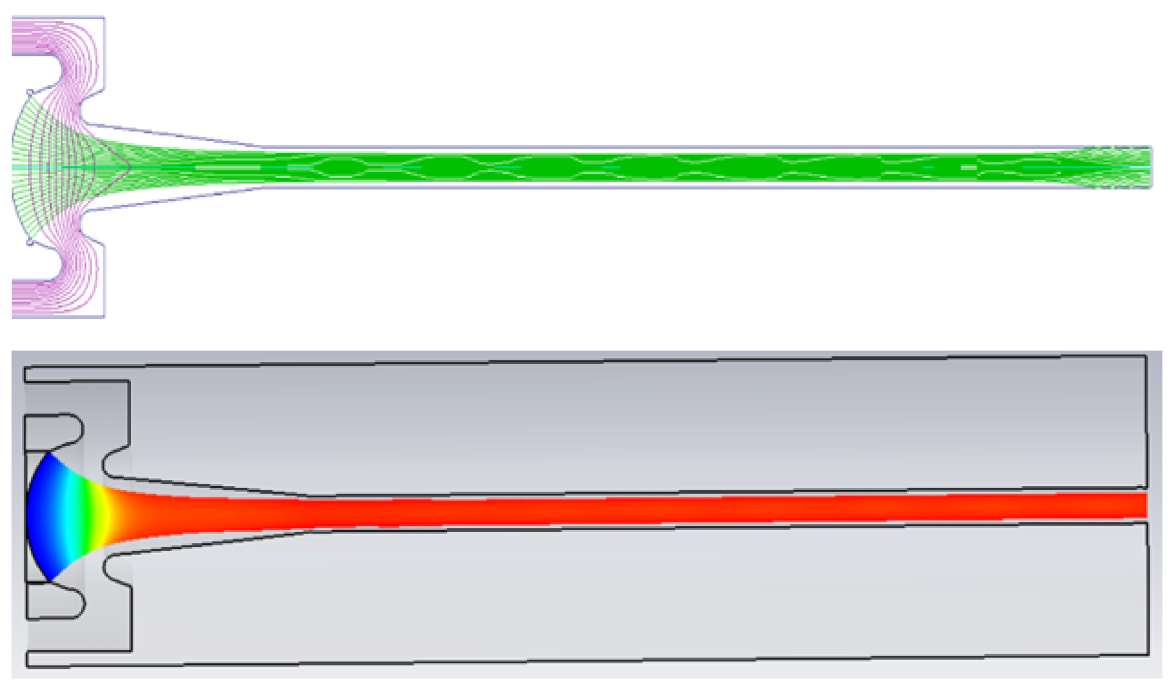

Figure 3: Beam optic simulation results in DGUN and CST

Table 3: Beam optic parameter in DGUN and CST

Parameters	DGUN	CST
Beam perveance	1.978 μP	1.997 μP
Beam maximum radius	8.54 mm	8.64 mm
Beam minimum radius	7.93 mm	8.02 mm
Beam ripple	3.7%	3.6%

2-D DYNAMIC SIMULATION

With beam optic parameter from DGUN, the dynamic simulation of interaction section is firstly done in the 2-D code EMSYS. Figure 4 shows the comparison of the simulation result of the original klystron and the new BAC-based klystron. As is shown in these two situations, more electrons are bunched at the output cavity of BAC-based klystron than that of the original one. The 2-D efficiency simulation result increases from original 45% to 56%. The optimization work is still ongoing now.

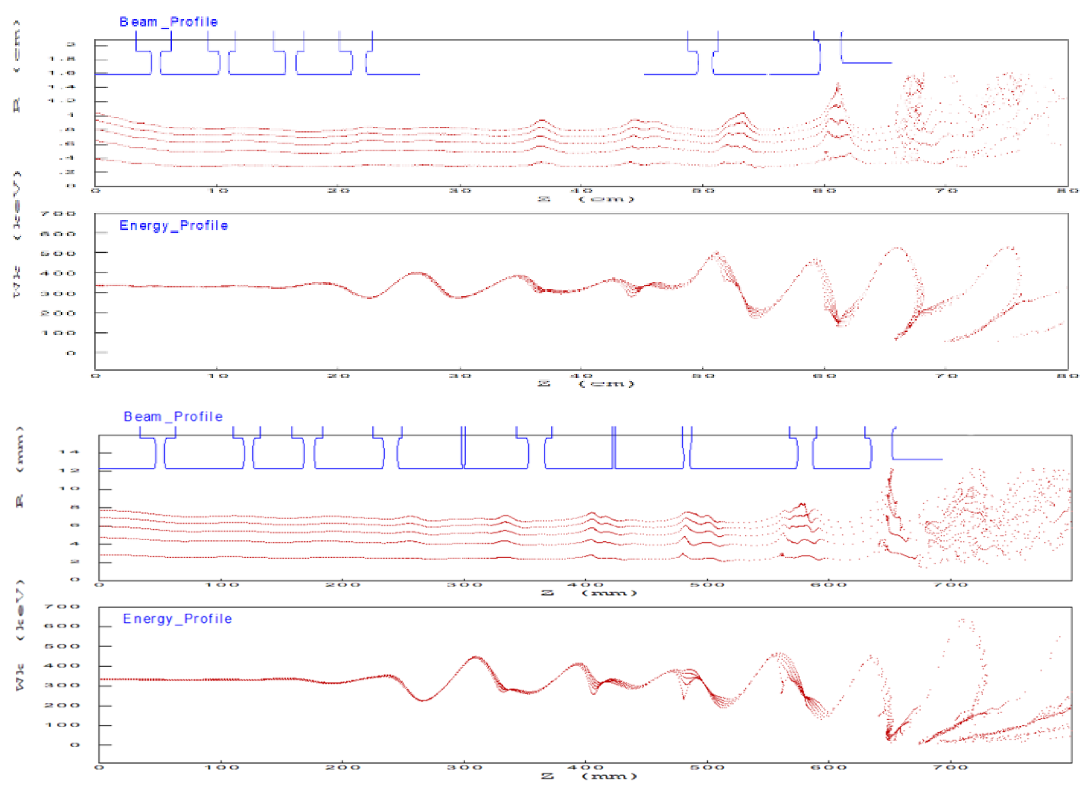

Figure 4: Beam and energy profile simulated by EMSYS

SUMMARY AND OUTLOOK

For the design of the CEPC LINAC klystron, we try to apply the novel bunching mechanism known as BAC method to the current BEPCII LINAC klystron. Now, the gun and the solenoid are well optimized according to the new requirement. The efficiency result simulated by 1-D code AJDISK is shown 64% while the 2-D simulation result in 2-D code EMSYS is 56% which is 4% lower than our expectation.The optimization work will be continued in the future. And then we will check the dynamic simulation result in 3-D code CST. Besides, the cooling system and the output window should also be re-designed due to the increase of the magnetic field and the output power. We hope the fabrication of the first prototype of CEPC LINAC klystron will start in Chinese company as soon as possible.

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