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PHYSICAL DESIGN OF THE 500 MeV ELECTRON LINAC FOR THE HIGH ENERGY PHOTON SOURCE *

S. Pei†, D. He, X. He, J. Li, J. Liu, X. Ma, C. Meng, G. Shu, X. Wang, O. Xiao, J. Zhang, Z. Zhou,
Key Laboratory of Particle Acceleration Physics and Technology, Institute of High Energy Physics,
100049 Beijing, China

Abstract

The High Energy Photon Source (HEPS) is a 6 GeV light source with ultra-low emittance, it is proposed to be built at Huairou district, northeast suburb of Beijing, China. A 500 MeV electron linac will be used to generate the electron beam for injection into the booster. Here the preliminary physical design of the electron linac is presented.

INTRODUCTION

To fulfil the booster acceptance requirement, the HEPS linac should be able to provide an electron beam with small energy spread and low emittance. In the meantime, the beam energy and orbit should be stable to get high transportation efficiency and injection rate. Moreover, the linac operation should be steady and reliable for top-up injection and high operation efficiency. Through synthetical consideration, the linac will be constructed based on the traditional and mature technologies.

Figure 1 shows the schematic layout of the electron linac. The gun is a thermionic gun for its long lifetime and ultra-stability. A conventional standard bunching system based on the split prebuncher/buncher/accelerating structure system is adopted. The accelerating structure is S-band normal conducting travelling wave (TW) constant gradient (CG) one powered by the radio frequency (RF) power source based on the klystron and the solid-state type modulator. The RF power distribution system is based on the S-band standard RF components. Low Level RF (LLRF) system based on the Micro-TCA technology and the energy feedback system will be applied. Table 1 lists the parameters of the electron linac.

Table 1: Parameters of the HEPS Linac

Parameters	Values
RF frequency	2998.8 MHz
Pulse repetition rate	50 Hz
Beam energy	≥500 MeV
Charge per pulse	≥2.5 nC
FWHM pulse length	1.1 ns
Bunch number per pulse	4~5
Bunch length	5 ps
RMS energy spread	≤0.5%
RMS energy stability	≤0.5%
Unnormalized RMS emittance	≤41 nm.rad
Normalized RMS emittance	≤40 μm.rad
Beam timing jitter @ linac exit	≤100 ps

GUN AND BUNCHING SYSTEM

The gun is optimized to operate at 150 kV with 4 A peak beam current. At the electron gun exit, the normalized RMS emittance is demanded to be less than 26 μm.rad, the TWISS parameters α, β and γ are calculated to be 1.75, 0.42 m and 9.7 m^{-1}, respectively. Figure 2 shows the beam optics in the electron gun calculated with the EGUN code [1]. Based on the BEPCII electron gun development and operation experience [2], the supposed longitudinal pulse structure of the beam emitted by the electron gun is shown in Fig. 3, this will be used as the input of the PAREMLA program [3] to study the beam dynamics downstream the gun. The beam pulse duration at the half maximum and the bottom are 1.1 ns and 1.6 ns.

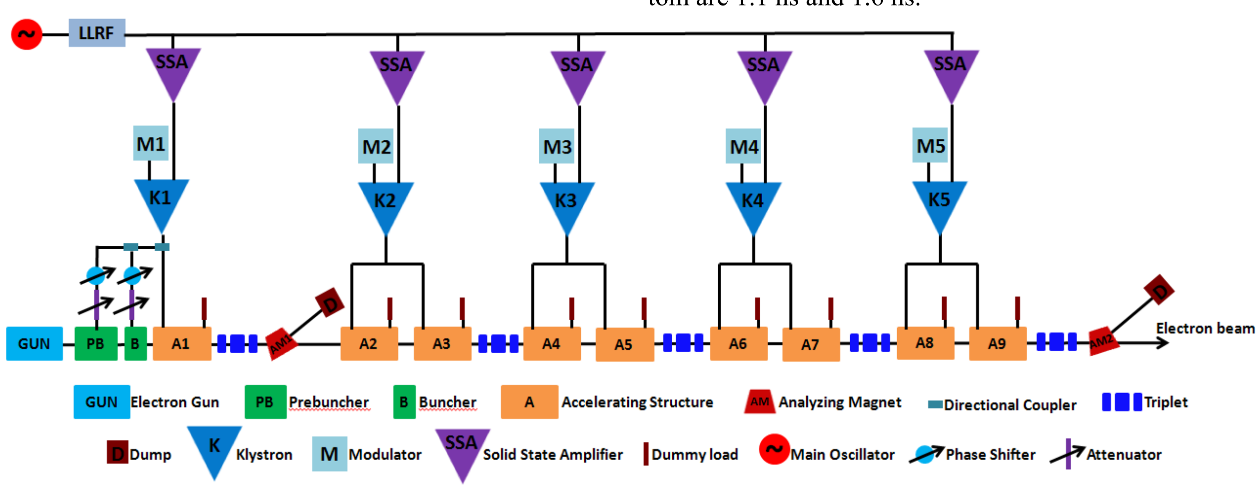

Figure 1: The schematic layout of the electron linac.

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† peisl@ihep.ac.cn

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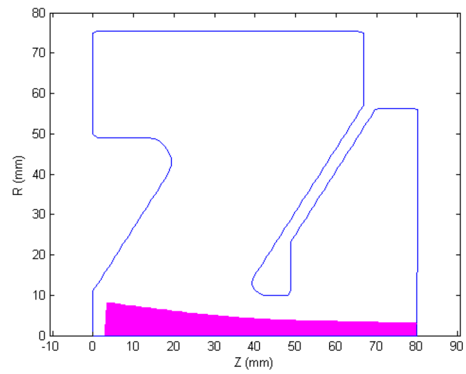

Figure 2: The gun beam optics at 150 kV and 4 A.

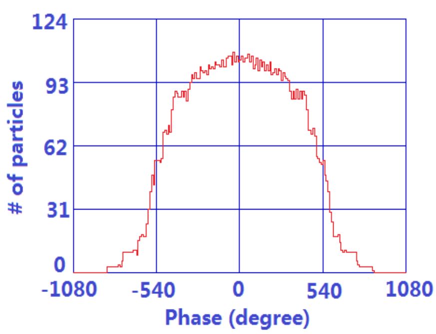

Figure 3: The longitudinal pulse structure of the electron beam emitted by the electron gun.

Figure 4 shows the schematic layout of the bunching system, which consists of a standing wave (SW) prebuncher, a 6-cell TW buncher and a 3 m long accelerating structure.

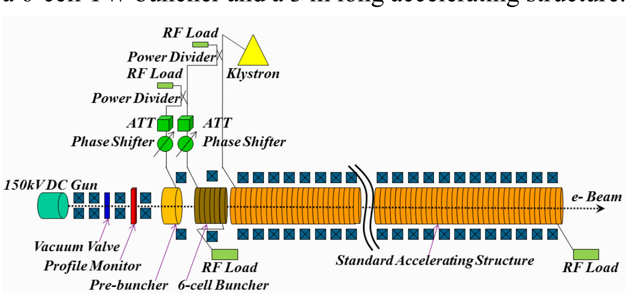

Figure 4: The layout of the bunching system.

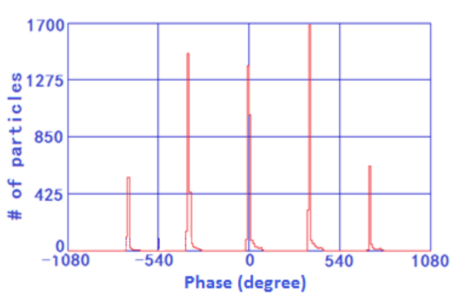

Figure 5: The electron beam pulse structure at the bunching system exit.

Figure 5 shows the electron beam pulse structure at the bunching system exit. There are 5 micro bunches in one macro pulse. For each micro bunch, ~75% electrons are located within ±5 ps, the normalized RMS emittance for these electrons is ~29 µm.rad. The PARMELA simulated beam transportation efficiency from the electron gun to the bunching system exit is ~89%. The beam can be accelerated to ~55 MeV by the bunching system. Figure 6 shows the beam spectrums for the micro bunch located at the longitudinal centre of the beam pulse.

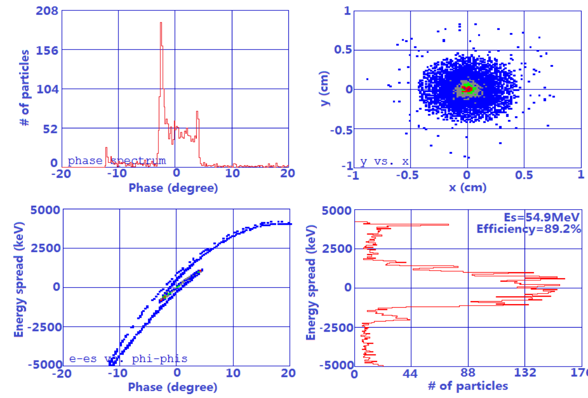

Figure 6: The beam spectrums for the micro bunch located at the longitudinal centre of the beam pulse.

Figure 7 shows the solenoid magnetic field distribution along the bunching system. 4 solenoid focusing lens are used for the beam matching from the gun to the prebuncher. To control the beam envelope during the bunching process, the prebuncher, the buncher and the accelerating structure are immersed in the magnetic field of the 22 solenoids.

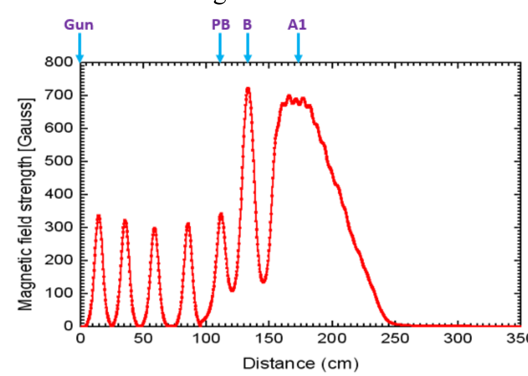

Figure 7: The solenoid magnetic field distribution along the bunching system.

MAIN LINAC

In the main linac, 8 accelerating structures are employed to boost the electron beam energy from ~55 MeV to ~500 MeV at the linac exit, there are total 4 sets of RF power sources. Each RF power source feed power to 2 accelerating structures. To enhance the RF peak power fed into the accelerating structure, SLEDs will be used. To control the beam envelop along the main linac, 5 triplets are applied for the whole linac.

Figure 8 shows the energy boosting curve along the main linac. The energy contribution for each accelerating strucure is ~56 MeV, the required input RF power is ~30 MW. Figure 9 shows the beam spectrums at the mail linac exit for the micro bunch located at the longitudinal centre of the beam pulse. The beam transportation efficiency from the electron gun to the main linac exit is ~87%. For the electrons located within ±5 ps of each micro bunch, the

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RMS and peak-to-peak (p-to-p) energy spread is ~0.13% and ±0.39% at the linac end. Taking into account of the ±0.5° phasing jitter, the ±0.1% modulator voltage jitter, the ±0.25% gun high voltage jitter and the multi-bunch wakefield effect, the RMS energy spread at the main linac exit can be successfully controlled to be lower than ±0.5%.

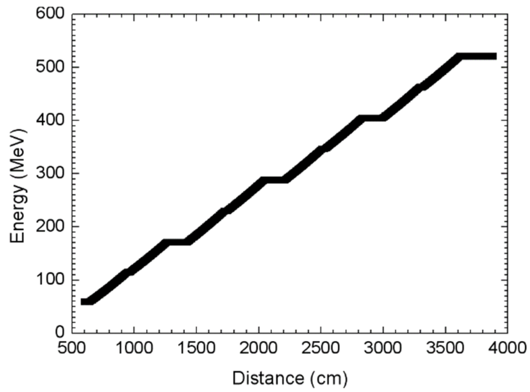

Figure 8: The energy boosting curve along the main linac.

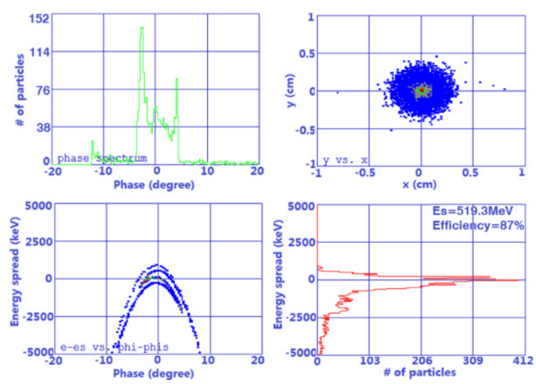

Figure 9: The beam spectrums at the main linac exit for the micro bunch located at the longitudinal centre of the pulse.

TRANSVERSE BEAM DYNAMICS

By compromising the beam transportation efficiency and the emittance growth, the solenoid field distribution along the bunching system and the magnetic field strength of the triplets in the main linac were optimized.

Figures 10 to 12 show the distributions of the beam trajectories, the beam emittance and the transportation efficiency from the electron gun to the linac end.

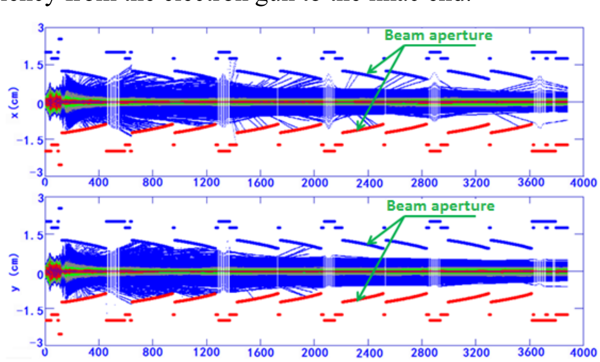

Figure 10: The beam trajectories distribution from the electron gun exit to the linac end.

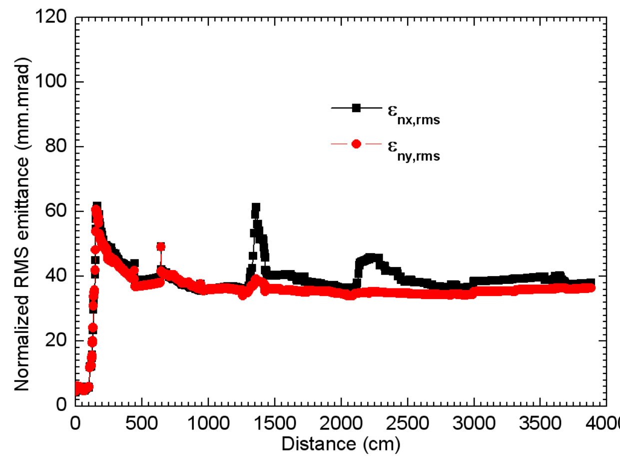

Figure 11: The beam emittance distribution from the electron gun exit to the linac end.

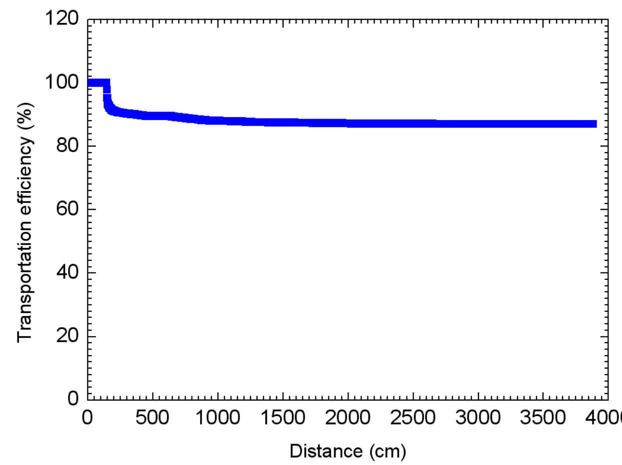

Figure 12: The beam transportation efficiency distribution from the electron gun exit to the linac end.

By strictly controlling both the initial beam offset and the alignment error to be less than ±0.2 mm and applying the 1-to-1 beam orbit correction combined with the global method, the normalized RMS emittance at the linac exit can be successfully controlled to be less than 40 μm.rad.

CONCLUSION

The HEPS linac is a 500 MeV electron linac. To satisfy the booster requirements, the conventional and traditional mature technologies will be adopted. Here the preliminary beam dynamics design are described, further studies is still going on.

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