PROGRESS ON THE CONSTRUCTION OF IHEP 500KV PHOTOCATHODE DC GUN SYSTEM

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Abstract

As one of the most important key technologies for future advanced light source based on the Energy Recovery Linac (ERL), a 500kV photocathode DC gun was supported by IHEP in September of 2011. Up to now, the schematic design of all DC gun subsystems including drive laser, photocathode preparation system, electron gun body and ceramic insulator, high voltage power supply and beam diagnosis system has been finished. The detailed parameters of each subsystem are presented in this paper.

INTRODUCTION

The linac based Free Electron Laser (FEL), and the Energy Recovery Linac (ERL) based light source are the two major types of the 4th generation light source. FEL has higher brightness, shorter pulse length and higher coherent features, but with a minor number of photon beam lines. ERL combines the good beam performance of the linac and good operation efficiency of the storage ring machine, although its brightness and coherent degree not as higher as FEL, but with many photon beam lines. Hence, both FEL and ERL cannot be replaced each other, we really need both of them. Based on this point, IHEP has proposed the suggestion of “one machine two purposes”, both FEL and ERL will share a same super-conducting (SC) linac for having a high efficiency [1].

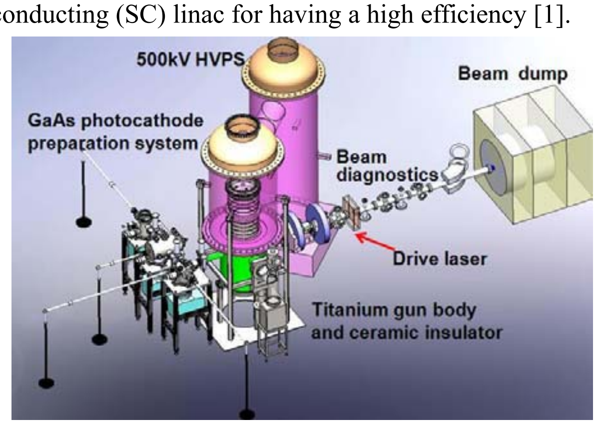

Figure 1: Overall design of the photocathode DC gun.

There are lots of technical challenges on ERL presently, especially on the electron sources which can deliver a high brightness electron beam with a low emittance and high current up to 100 mA are being developed for ERL worldwide [2]. The recent experimental results from JLab and Cornell demonstrated that a photocathode DC gun with a GaAs or multi alkali photocathode is one of the most promising candidate [3][4]. Since September of 2011, a 500kV photocathode DC gun has been supported by IHEP as an innovative project. The overall design of the photocathode DC gun is shown in Figure 1, which consists of the drive laser system, the cathode preparation system, titanium gun body and ceramic insulator, high voltage power supply system and beam diagnosis system. Table 1 shows the main parameters of the DC gun. Up to now, each subsystem has a smooth progress.

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Table 1: Main parameters of the DC gun

Parameter	Design value
High voltage	350 ~ 500 kV
Cathode material	GaAs:Cs/O
Quantum efficiency	5-7% (initial), 1%
Live time	20 h
Drive laser	2.3W，530nm
Repetition rate	100MHz， 1.3GHz*
Nor. emittance	(1~2)mm.mrad@77pC (0.1~0.2)mm.mrad@7.7pC
Bunch length	20ps
Beam current	(5~10) mA

* Two operation modes:
(1) 100MHz-7.7mA-77pC, (2) 1300MHz-10mA-7.7pC

DESIGN AND CONSTRUCTION PROGRESS

Drive Laser System

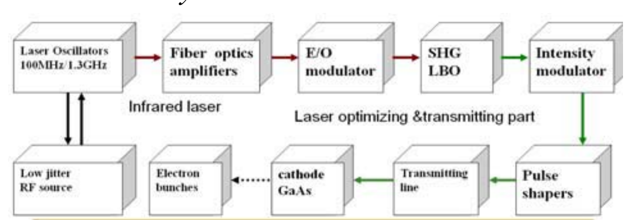

Figure 2: Schematic design of drive laser system.

Drive laser system, as shown in Figure 2, takes a fiber laser technology solution, which is among the most advanced drive laser system so far. Two laser oscillators, one is working at 1.3GHz (PriTel Inc) and the other is 100MHz (Menlosystems Inc) are used in this system,

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corresponding to two operation modes of DC gun. These two laser oscillators have been purchased and some preliminary tests including output power, pulse width and optical bandwidth have been completed. In addition, the independent development work on laser fiber amplifier has also been started.

GaAs Photocathode Preparation System

GaAs semiconductor photocathode which is able to generate a high-current electron beam with ultra small initial emittance due to its high quantum efficiency and low thermal emission from a negative electron affinity surface was used for electron emission in IHEP photocathode DC gun.

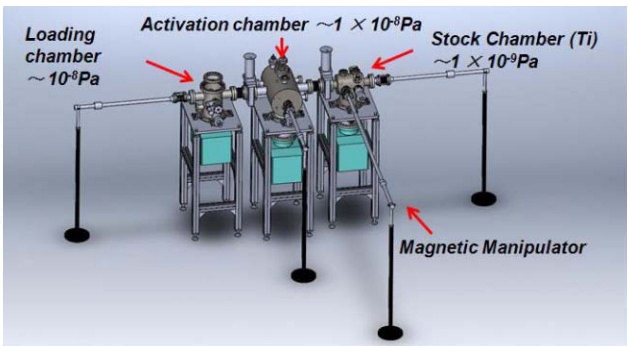

Figure 3: Structure of the photocathode preparation system.

Schematic design of a GaAs photocathode preparation system was shown in Figure 3. There are three load-lock vacuum chambers in the cathode preparation system including loading chamber, activation chamber and stock chamber. These three chambers are required to achieve a very high vacuum environment to preserve QE and lifetime of the GaAs photocathode during its activation process. The cathode puck will be transferred among the three chambers and electron gun body by the movement of magnetic manipulator.

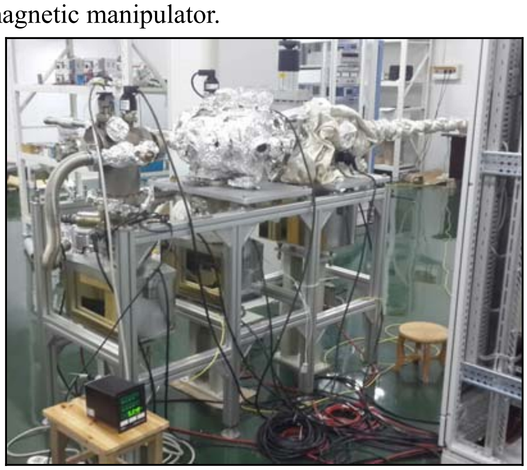

Figure 4: Baking and vacuum test of preparation system.

Up to now, the GaAs photocathode preparation system has finished its machining, assembling, baking and vacuum test. Table 2 shows the vacuum test results of these three chambers.

Table 2: Vacuum test results of these three chambers

	Material	Design vacuum	Measured vacuum
Loading chamber	SS 316L	≤9×10^{-8}Pa	6×10^{-8}Pa
Activation chamber	SS 316L	≤1×10^{-8}Pa	7×10^{-9}Pa
Stock chamber	Body: Ti(TA2) Flange: SS 316L	≤1×10^{-9}Pa	5×10^{-10}Pa

Titanium Gun Body and Ceramic Insulator

The photoemission beam is accelerated by a static electric field applied between cathode and anode electrodes. Generally, the accelerate voltage should be as high as possible to suppress the emittance growth caused by space charge effect, but field emission electrons generated from the stem electrode and cathode will cause damage to the ceramic insulator and the surface of electrodes which is a strict limitation to the increase of accelerate voltage. A simulation about the E-field distribution was done by using CST (EM Studio) [5] to optimize the configuration of the gun body, as shown in Figure 5. And two cases with different gap distances between the cathode and anode (80mm and 100mm) were simulated under a 500kV high voltage direct current condition. From the simulation results, it can be found that the maximum electric field on the stem electrode is 8.17 MV/m and on the cathode electrode it is 10.0MV/m, meanwhile the accelerate field on the cathode surface is 6.8MV/m in case of 80mm. And in the case of 100mm, these three values are 8.17MV/m, 9.26MV/m and 6.0MV/m respectively. Considering the electrical breakdown field between the cathode and anode depends on the gap distance, electrodes material, and surface treatment of the electrodes, in our DC gun system, the stem electrode, cathode electrode and anode electrode are going to be fabricated by using titanium material which shows a higher breakdown field [6].

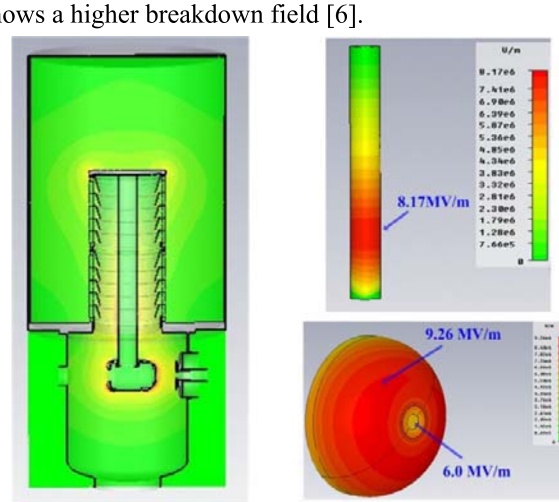

Figure 5: Simulation of E-field distribution by using CST.

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The ceramic insulator is the most critical component in the development of a high-voltage DC gun. It needs to be well insulated and appropriately resistant to avoid any local concentration of the electron charge that can irreversibly damage the ceramic. In our design, the KEK/JAEA option is adopted [7], in which a segmented ceramic insulator structure with guard rings between every two adjacent segments is employed to effectively avoid the field emission electrons generated from the stem electrode toward the ceramic insulator and hence to protect ceramic insulator. Figure 6 shows the structure of one section ceramic insulator of our DC gun, in which two sections ceramics (totally ten segments) are going to be employed. Now, the procurement process of the ceramics is ongoing.

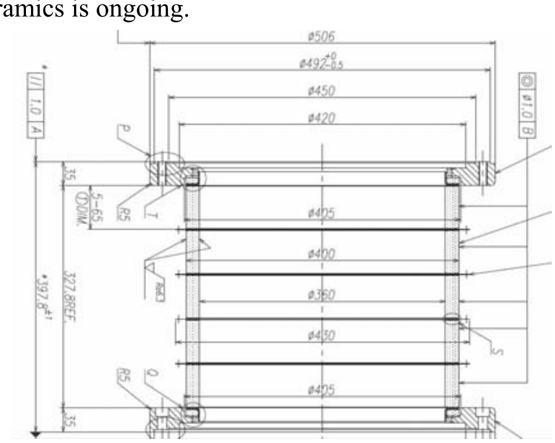

Figure 6: The structure of one section ceramic insulator.

For pumping system, considering the QE and lifetime of GaAs cathode largely depends on the vacuum environment, a kind of low out-gassing rate material titanium was selected for the fabrication of gun body to ensure the inside vacuum environment, which can reach an ultra high level of 5×10^{-10}Pa by employing a 500L/s ion pump and forty-eight 400L/s NEG pumps.

High-Voltage Power Supply System

Figure 7: HiTek HVPS.

Low-emittance is one of the most important parameters in the design of a photocathode DC gun, so the gun voltage must be 500 kV or higher to suppress the emittance growth by space charge effect [8][9]. As a 500 kV photocathode DC gun, the emittance of a 77pC bunch charge would be suppressed to less than 1mm.mrad. Another key parameter of the power supply system is the voltage ripple which is one of the major sources of bunch-to-bunch fluctuation such as jitters in emittance, bunch shape, and energy spread after the full acceleration [10]. According to these requirements of DC gun, a product made by a UK company HiTek [11], as shown in Figure 7, was chosen and its main parameters are listed in Table 3. Now, the construction of this power supply system has been finished and the test on its parameters is ongoing in company. Besides, the design on related HVPS tank and SF6 recycle system has also been completed.

Table 3: Main parameters of the HiTek HVPS

Parameter	Design value
High voltage	500 kV 550kV at HV conditioning
Current	10mA
Type	Cockcroft-Walton generator
Working style	DC
Voltage ripple	$5\text{X}10^{-4}$ (peak to peak)
Isolation medium	SF_6
Output resistor	100MΩ for HV conditioning, 50kΩ at beam operation

Beam Diagnosis System

The preliminary design of the components applied in beam diagnosis system has been completed, as shown in Figure 8. The beam line includes three pairs of solenoid and corrector, a laser box, a deflecting cavity, two YAG screens, a bending magnet and a beam dump. The beam emittance will be measured by solenoid scan and the bunch length will be measured with deflecting cavity.

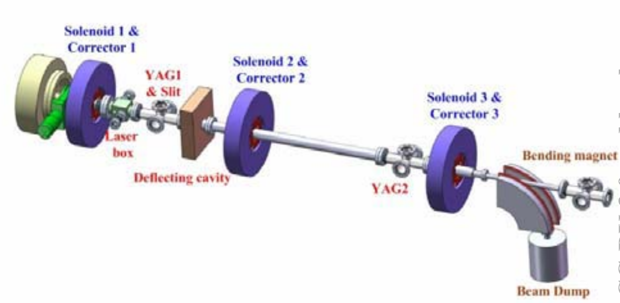

Figure 8: The preliminary design of the beam line.

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SUMMARY

Since September of 2011, a 500kV photocathode DC gun has been supported by IHEP. In this paper we briefly described the major issues of the design studies and construction progress on each subsystem of the photocathode DC gun, including the drive laser system, the photocathode preparation system, the electron gun body and ceramic insulator, the high voltage power supply system and the beam diagnosis system. Up to now, each subsystem has a smooth progress.

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