

DESIGN OF MULTI-ALKALI PHOTOCATHODE PREPARATION SYSTEM FOR CTFEL FACILITY*

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Abstract

The first saturated lasing of the China Academy of Engineering Physics tera-hertz free electron laser (CTFEL) facility has been realized. In order to improve the performance of the facility, the multi-alkali photocathode with much longer life-time has been proposed to replace the GaAs photocathode currently used. This paper presents the design of the multi-alkali photocathode preparation system, which consists of three chambers: the suitcase chamber, the preparation chamber, and the loading chamber. The function of each chamber is also discussed.

INTRODUCTION

Next generation light sources like energy recovery linacs and free electron lasers need electron sources for the generation of high brightness electron beams [1]. Semiconductor photocathodes such as gallium arsenide and alkali antimonides have been widely studied in many laboratories because of its high quantum efficiency and low emittance. GaAs and alkali antimonides cathodes were studied in detail by Bruce Dunham, comparing with GaAs cathode, the alkali antimonides cathodes have better stability [2].

CAEP THz FEL (CTFEL) facility is the first high average THz source based on FEL in China [3, 4], which is driven by a DC gun with a GaAs photocathode [5, 6], its working parameters are shown in Table 1. The facility has achieved saturated light emission last year [7, 8], but due to the short operational life-time of the GaAs photocathode, it can only work for about one week after each preparation. In order to improve the performance of the device, a multi-alkali photocathode preparation system was designed to carry out the research of alkali antimonides cathodes, which can effectively improve the working time and the using efficiency of the facility.

PREPARATION SYSTEM DESIGN

Overview

Figure 1 shows the cathodes preparation system consists of three chambers: the suitcase chamber, the preparation chamber, and the loading chamber. The loading chamber can complete the cathode substrate installation without destroying the vacuum of system. The multi-alkali cathode

Table 1: GaAs Photocathode Parameters

Parameters	Value	Unit
Initial QE	12%(@532nm)	
Dark life-time	1000	hour
Micro-pulse repetition	54.167	MHz
Macro-pulse repetition	1~20	Hz
Duty cycle	0.01	
Bunch charge	100	pC
Duty life-time	~80	hour
Charge	~16	C

are prepared in the preparation chamber. The suitcase chamber can transport the prepared cathodes into the gun. The chambers are isolated with VAT all metal gate valves. It is kept under vacuum by ion pump and NEG pump, with the vacuum pressure 1×10^{-9} Pa. The precision magnetic manipulators are used to accomplish the movement of the cathodes between the three chambers.

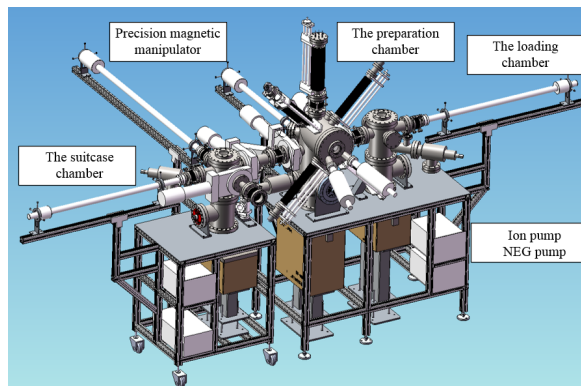


Figure 1: 3D model of the multi-alkali photocathode preparation system.

Cathode Loading and Transport

The cathode substrate is cleaned by ultrasonic of deionized water, ethanol and acetone. After drying with nitrogen, the cathode is fed on the storage structure into the top flange of the loading chamber. The chamber exposed the atmosphere for as quickly as possible, and the NEG pumps need to be filled with nitrogen to protection. After loading the cathode substrate, the flange was sealed and the vacuum of the chamber will pumping to 5×10^{-4} Pa within 1 hour, then baking the chamber. The baking temperature of the chamber is 200 °C, and the baking temperature of the precision magnetic

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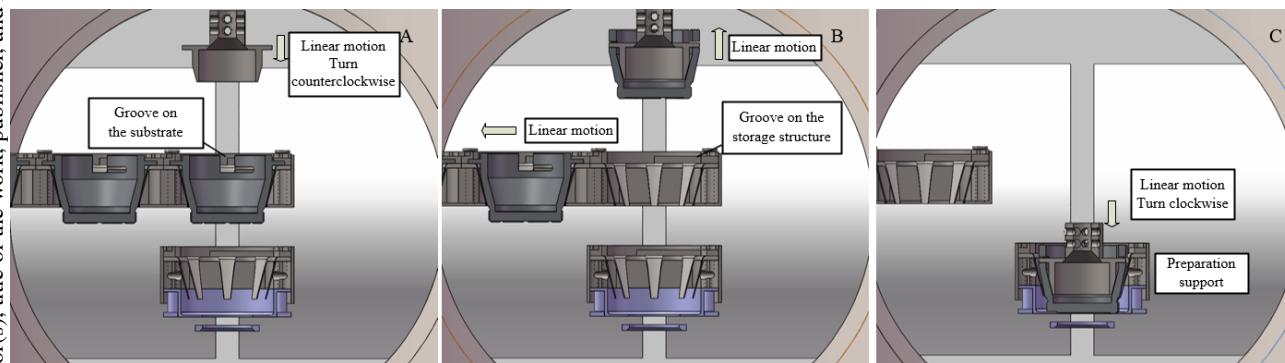


Figure 2: The cathode transmission diagram.

manipulators are limited to 180 °C. At the end of baking, the NEG pumps were activated and the ion pump were turned on. Turning off the baking power, the system temperature decreased slowly to room temperature, and the vacuum can reach 10^{-9} Pa. Finally, the cathode loading was completed.

As shown in Fig. 2, the cathode is transmitted using a linear/rotary precision magnetic manipulator. First, the gripping structure extends into the groove of the base and rotates counterclockwise (a). The cathode is detached from the storage structure and magnetically transmitted on the precision magnetic manipulator, exiting the precision magnetic manipulator, and removing the cathode storage structure (b). Move the precision magnetic manipulator forward to the cathode preparation rack, rotate clockwise, mount the base on the holder (c), and transfer the substrate.

Preparation Chamber

As shown in Fig. 3, 7 plurality of linear movement sections are mounted on the cathode preparation chamber for mounting alkali metal sources, a heater, a quartz crystal microbalance, and a liftable cathode preparation support. Several reserved flanges are used to install Sb source, RGA, vacuum-maintained ion pumps and NEG pumps, vacuum gauges for vacuum measurement, and observation windows, etc. By combining the ion pump and the NEG pump, the vacuum in the preparation chamber can reach 10^{-9} Pa.

The evaporation source is the most critical component in the preparation of the cathode. The alkali metal source is a 12mm long product from SAES, and the contents of caesium, potassium and sodium are 5.2mg, 2.9mg and 1.7mg, respectively. In order to increase the amount of evaporation source, a group consists of 6 sources, and 6 groups can be installed for each source. The Sb source uses pure Sb with a purity of 99.999% for evaporation. Select the appropriate source by adjusting the length of the bellows. The mounting surface of the source is directly opposite to the center of the cathode substrate, which ensures uniform vapor deposition and uniform distribution of the quantum efficiency of the prepared cathode. The heater extends from the rear end of the substrate, which can heat the substrate up to 600°C for degassing the cathode substrate and ensuring its cleanness. The temperature at which the cathode was prepared was

measured with a thermocouple attached to the substrate, and the temperature of the substrate at the evaporation of the different sources was precisely controlled by the temperature controller.

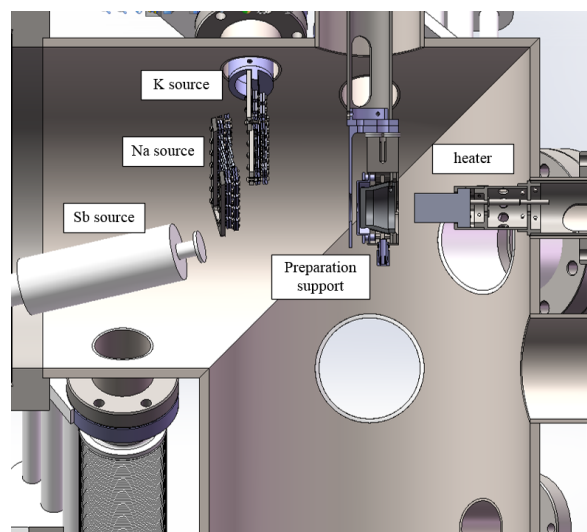


Figure 3: The preparation chamber.

THE CATHODE PREPARATION

The cathode substrate is heated inside preparation chamber with a base vacuum level of 10^{-7} Pa up to 600°C in order to degas the substrate support and remove contaminants from the substrate surface. During the heating the residual gas analyzer (RGA) continuously measures the partial pressures of the most abundant chemical species. The substrate is kept hot until the measured partial pressures of both water vapor and oxygen are better than 10^{-9} Pa.

According to Cultrera's sodium potassium antimonide photocathodes growth method [9], when the heated degassed cathode substrate was naturally cooled to 180°C, 20 nm thick Sb was evaporated on the cathode substrate. The thickness of the Sb film was measured by a quartz crystal microbalance (QCM). When the cathode substrate temperature was reduced to 160°C, the K source was vaporized until the photocurrent reached a maximum (532nm laser irradiation) and

eventually starts to decrease. The quantum efficiency of the photocathode at this time can usually reach 0.5%. In the process of steaming K, when the photocurrent is close to the maximum value, the heater is turned on so that the cathode substrate temperature rises to 220°C. At this time, the Na source current is turned on, and the photocurrent begins to rapidly increase, the heater is turned off to cool the cathode substrate. The sudden drop in photocurrent after reaching its peak is most likely due to the instability of Na vapor on the NaKSb surface at this temperature. The quantum efficiency is due to excess Na on the surface of the cathode. By alternately evaporating very thin (less than 1 nm) Sb and K to compensate for excess Na, the quantum efficiency of the photocathode can be restored or even increased. The photocathode quantum efficiency synthesized by this method reaches a few percent under the irradiation of a 532 nm laser.

SUMMARY

This article describes the design of the multi-alkali photocathode preparation system for CTFEL facility in details. The vacuum of the preparation system is 10^{-9} Pa, and preparation and testing of alkali antimonide cathodes such as K_2CsSb and Na_2KSb can be completed. At the same time, the Na_2KSb photocathode preparation process was described. In the future, the multi-alkali cathode preparation system will be installed on the CTFEL facility to carry out research on the multi-alkali photocathode and create conditions for improving the performance of the CTFEL facility.

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