Photocathode Preparation System for the ALICE (Accelerators and Lasers in Combined Experiments) Photoinjector

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Abstract. ALICE is a relatively new accelerator built at Daresbury Laboratory that will demonstrate the process of energy recovery by the end of 2008. The project is a research facility to develop the technology required to build a New Light Source (NLS) in the UK. This paper details the current ALICE photoinjector design and highlights the limitations before focusing on a photoinjector upgrade. The key component of the upgrade is a three-stage extreme high vacuum load-lock system that will be incorporated in to the ALICE photoinjector in 2010.

The load-lock system has *de facto* become a standard component of a type III-V semiconductor photocathode injector and comprises:

1) Loading chamber to allow new photocathodes to be introduced
2) Cleaning chamber for atomic hydrogen cleaning of the photocathodes
3) Preparation and Activation chamber where the photocathodes will be activated to the NEA state ready for use on the ALICE accelerator

Once commissioned the load-lock system will allow rapid transfer of photocathodes between the load-lock system and the ALICE photoinjector whilst maintaining the integrity of the vacuum system and providing many other benefits. The new load-lock system will not only remove the problems with the existing set-up, it will also permit a new vacuum chamber to be designed for the gun itself. This new design will also aim to improve vacuum performance by addressing some of the major vacuum associated problems ALICE has encountered in the past 2 years
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Introduction

The current ALICE photoinjector is based on the Jefferson Laboratory IR-FEL injector design [1] which is a 350 kV DC injector with a single vacuum chamber design as shown in figure 1. The semiconductor GaAs is used as the electron source, although it requires activating to the Negative Electron Affinity (NEA) state to maximise the electron emission (Quantum Efficiency). The activation of the GaAs photocathode is done by depositing alternate layers of Cs/O_2 or NF_3 all of which has to be done inside the photoinjector. For successful operation the integrity of the vacuum system is critical to cathode performance [2], the vacuum requirements for the ALICE photoinjector were to achieve 5 x 10^{-11} mbar whilst ensuring the residual gas species are not detrimental to the GaAs photocathode.

The single-chamber design has a number of limitations some of which have been problematic during ALICE operations. The main limitation is the fact it is a single vacuum chamber design so only has the ability to accommodate one GaAs photocathode. This limitation means that whenever a new GaAs photocathode is required the photoinjector must be vented to atmospheric pressure with dry nitrogen. Given that the vacuum integrity is critical then a minimum period of one month is required to condition the vacuum system back to its original state prior to venting. This conditioning requires an extensive bakeout to 250ºC and this itself can create further vacuum problems. The activation of the GaAs photocathode also impacts on vacuum performance and high voltage, operating Cs dispensers at high temperature whilst injecting O_2 or NF_3 through a fine leak valve meaning the vacuum recovery time can be a number of hours.

Given these basic design problems it was decided that a new multi-chamber design was required that would allow the introduction of photocathodes without compromising the ALICE photoinjector vacuum system. This new design would also allow the activation of the photocathode to be performed external to the ALICE photoinjector.

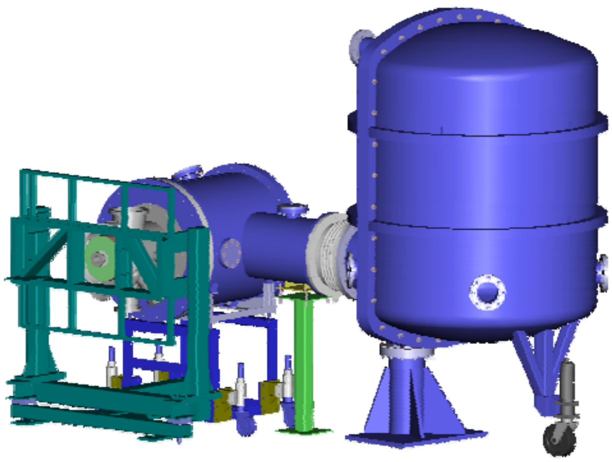

FIGURE 1. Current ALICE Photoinjector Based On JLab IR-FEL Design

New Multi Chamber Load-Lock Design

Figure 2(a) shows the new load-lock design with figure 2(b) showing a plan view of how it will be incorporated on to the ALICE photoinjector. It is a 3-stage load-lock design with each chamber having a purpose-designed function. There is a loading chamber where photocathodes will be introduced to the system, a hydrogen cleaning chamber to remove contaminants from the photocathode surface and a preparation chamber where photocathodes will be activated to the NEA state before being transferred into the ALICE photoinjector. The system is primarily pumped using Sputter Ion Pumps (SIP) and Non Evaporable Getter (NEG) strips, and the vacuum specification was to achieve a minimum of $5e^{-12}$ mbar in the preparation chamber. To help achieve this, the system was vacuum fired at a temperature of 950ºC for 5 hours to deplete the 316LN Stainless Steel of hydrogen.

(a) (b)

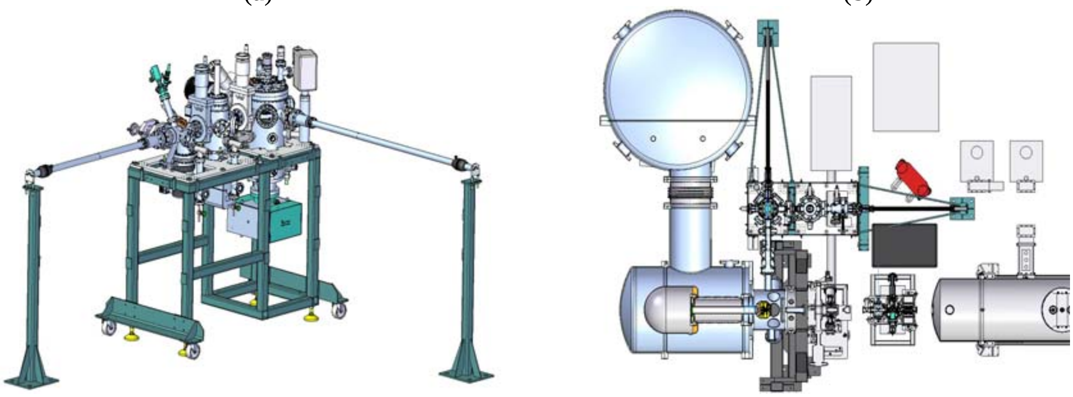

FIGURE 2. (a) New Load-lock System, (b) Plan View Of ALICE Photoinjector With New System

Loading Chamber Overview

Figure 3(a) shows a section through of the loading chamber, whilst 3(b) shows the z-translation stage with a magazine holder that can accommodate up to four photocathodes at any one time. To load new photocathodes the z-stage is removed from the loading chamber and transported under dry nitrogen to a nitrogen-purged glove box. The newly prepared photocathodes are inserted into the magazine holder, and the z-stage is closed such that the ‘O’ ring seals (fig. 3(b)). The photocathodes are thus stored in a leak tight nitrogen environment. The z-stage is then re-inserted in to the loading chamber, the ‘O’ ring seal opened and the chamber evacuated to ensure the photocathodes are not exposed to any contaminants from the atmosphere.

(a) (b)

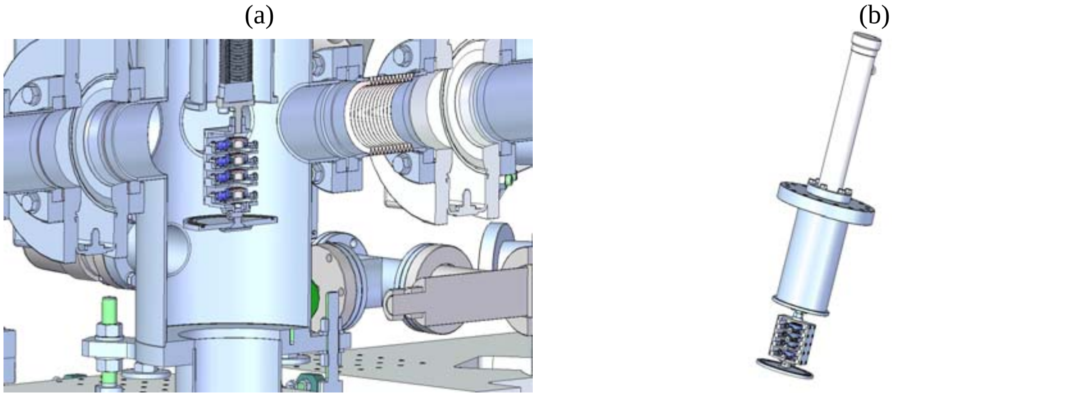

FIGURE 3. (a) Section-Through of Loading Chamber, (b) Z-Translation Stage With Magazine Holder

Hydrogen Chamber Overview

Figure 4(a) shows the hydrogen cleaning chamber, whilst 4(b) shows a section through the chamber. Here the cathode is heated to an appropriate temperature ready for hydrogen cleaning (~300ºC). This heating process is done via the use of a 250W halogen bulb, shielded by tantalum to avoid any radiative heating of other components whilst focusing the heat onto the photocathode, thus minimising the power requirements. The hydrogen cleaning process makes use of a thermal gas cracker that uses electron bombardment of a tungsten capillary to thermally dissociate the gas passing through it. Given the right conditions the thermal cracking efficiency of hydrogen is very high and this is important in order to minimise the number of H^+/H^- ions in the cleaning process. Once hydrogen cleaned the photocathode is then transferred through to the preparation chamber ready for activation.

(a) (b)

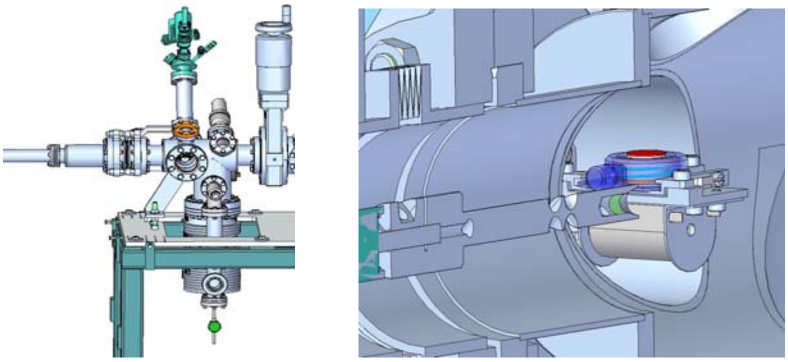

FIGURE 4. (a) Hydrogen Cleaning Chamber, (b) Section-Through Hydrogen Chamber

Preparation Chamber Overview

Figures 5 (a) and (b) show the preparation chamber, 5(a) showing the complete preparation chamber, with 5(b) showing a section through of the preparation chamber.

(a) (b)

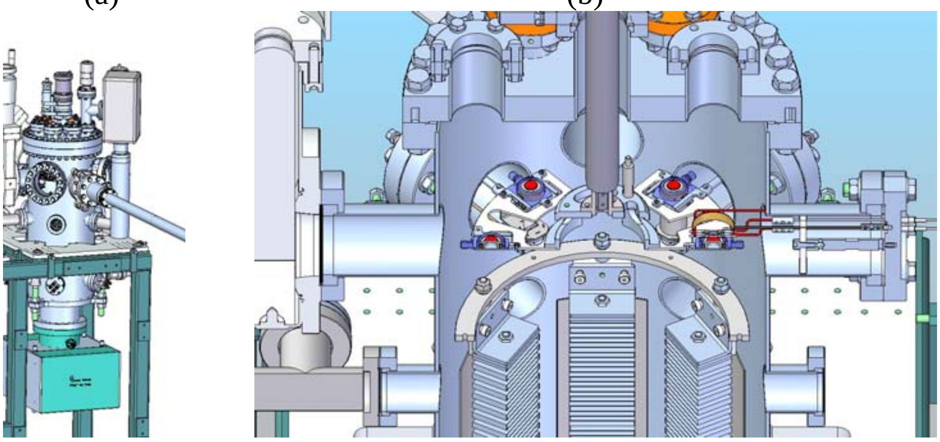

FIGURE 5. (a) Preparation Chamber, (b)Section-Through View Of Preparation Chamber

Once a photocathode has been loaded into the system and hydrogen cleaned, it is ready for a full activation in the preparation chamber using the standard 'yo-yo' method. As shown in fig.5 the preparation chamber has a carousel with the capability to hold six photocathodes. There are two possible heating positions again using halogen bulb heaters, they are in the 10 and 2 'o'clock positions in fig.5. After heating to ~560-580ºC for upto 3 hours [3] and cooling to RT the carousel is rotated such that the photocathode to be activated is in the 3 'o'clock position in fig.5. The Cs dispensers are positioned within 10mm of the photocathode surface, as is the charge collector used to measure the photocurrent. The O_2/NF_3 is injected into the system via a piezo-electric fine leak valve which is positioned on the 2.75 inch conflat flange that sits directly above the 3 'o'clock position in fig.5. Once activated to the NEA state the photocathode is ready for transport in to the ALICE photoinjector and is ready for use.

Insertion Of Photocathode Into ALICE Photoinjector

The activated photocathode will be transferred into the ALICE photoinjector via a side loading mechanism into the cathode ball, see figure 6(a). Figure 6(a) shows the slot in the cathode ball were the photocathode will be inserted [4] whilst figure 6(b) shows the mechanism inside the cathode ball from the opposite side to fig.6(a). A separate transfer arm will locate onto the small joystick shown in fig.6(b) and through rotation of the joystick in a clockwise/anti-clockwise direction the photocathode can be moved forward or backward until it is located in its correct position. Once in position the activated photocathode is ready for use as an electron source.

(a) (b)

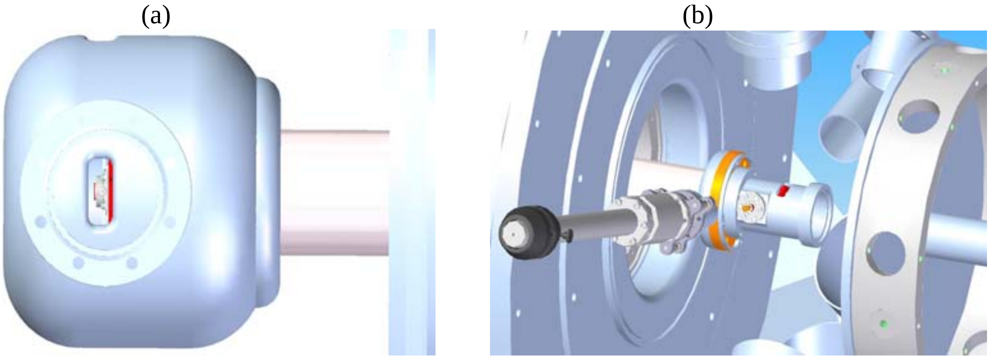

FIGURE 6. (a) Slot In Cathode Ball For Insertion Of Photocathode, (b) Internal Mechanism For Movement Of Photocathode

REFERENCES

1. T. Siggins, C.K. Sinclair, C. Bohn, D. Bullard, D. Douglas, A. Grippo, J. Gubeli, G.A. Krafft & B. Yunn, Performance of a DC GaAs photocathode gun for the Jefferson lab FEL, Nuclear Instruments & Methods A; 475 (2001), pages 549–553.
2. T. Reichelt *et al*, Applied Surface Science. 143 (1999) P319–322
3. N. Chanlek, Study of Activated GaAs Surface for Application as an Electron Source in Particle Accelerators, these proceedings.
4. J. McKenzie, 3D Modeling of the ALICE Photoinjector Upgrade, these proceedings.