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HIGH QUANTUM EFFICIENCY PHOTOCATHODE PREPARATION SYSTEM FOR TTF INJECTOR II

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Abstract

The TESLA Test Facility (TTF) Injector II photocathode preparation system is in opera-tion since spring 1998. High quantum efficiency tellurium and alkali metals based pho-toemissive films are routinely produced at Milano with typical 10% quantum efficiency (QE). Photocathodes are then successfully transported with no QE degradation, using a handy ultra high vacuum (UHV) system, to DESY and here transferred to the RF gun. The main characteristics of the system and the future developments are here discussed.

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1 Introduction

During winter 1998/99 the Injector II was commissioned at the TESLA Test Facility LINAC (TTF) [1] that, first in the world, in February 2000 has produced SASE (Self Amplified Spontaneous Emission) radiation at 109 nm [2] reaching few months later 80 nm. The electron source is a laser driven RF gun, based on cesium telluride photocathodes, in place of the thermionic source used with Injector I.
The photocathodes are produced at Milano and used at DESY, hence a fully UHV split system was developed. These materials are always stored, from the production to the operation into the gun, in UHV condition due to their high sensitivity to gas exposition [3]. For these reasons, thanks to the experience on cathode production and vacuum technology of our group, we have designed and built an handy transport system whose main peculiarity is to preserve cathodes in UHV condition during their travel from Milano to DESY.
A significant effort has been dedicated to the movements of the cathode in the UHV environment. The final design consisted of an evolution of the system we realized for the A0 experiment at Fermi National Laboratory [4]. The new cathode preparation system is equipped with the diagnostics necessary for cathode characterization, before their delivery to DESY. Here the installed system is used to transfer the cathode from the transportation system to the gun.
The preparation chamber is discussed in the following section together with the material choice for the moving parts in vacuum (needed for cathode manipulation). The transportation system is presented in the third section. The DESY transfer system is the subject of the fourth section; a final discussion of the performances and future improvements of the whole system concludes the present paper.

2 The preparation chamber

The preparation chamber was designed to allow different tasks: cathode preparation, photoemissive property characterization and finally cathode manipulation. A sketch of the preparation chamber is presented in fig.1. An UHV chamber is pumped by a 400 l s^{-1} ion pump. In fig. 1, the region "A" shows the cathode preparation and characterization area. In this area a photoemissive layer is deposited on a molybdenum substrate. The cathode deposition process has been already extensively discussed elsewhere [5]. The tellurium and the alkali metals sources are installed on a frame in front of the masking area which is used to shape the cathode area. The current flowing through the sources controls the evaporation process. A LTM (Linear Transfer Mechanism) moves the molybdenum sub-

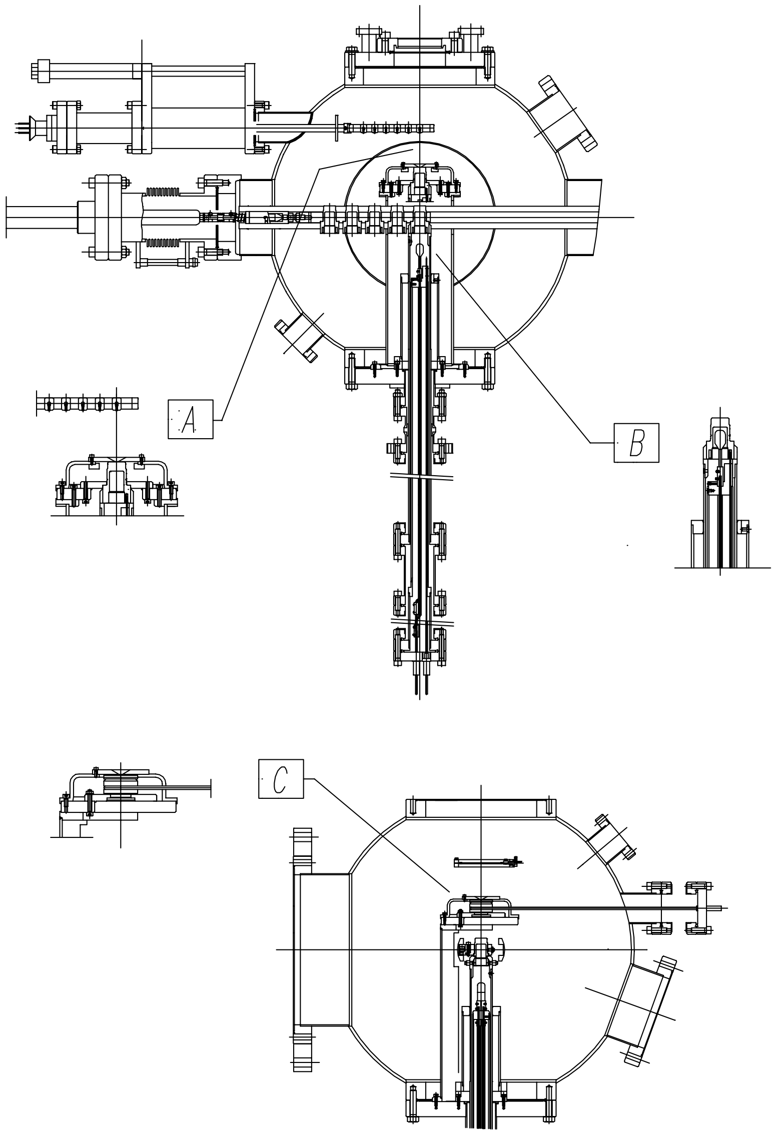

Figure 1: Preparation system sketch. The cathodes are produced and characterized in the area with the label ”A”. The area label ”B” shows the LTMs used for moving and heating the cathode. Finally area ”C” shows the microbalance and its position when inserted in place of the cathode.

strate in the deposition area. A second LTM translator (fig. 1 ”B”) moves the cathode heater, a halogen lamp, together with a thermocouple into the back of the substrate. A feedback loop, between the thermocouple and the halogen lamp power supply, allows a substrate temperature stabilization within 1 °C. Another LTM moves the thickness monitor (a microbalance) from the top of the chamber into the evaporation area, exactly in the cathode position, for source calibration (fig. 1 ”C”).

A remarkable feature of this system is the possibility to change the shape of the photoe-

missive area over the molybdenum substrate. This possibility can be used to explore the dependence of the electron beam emittance on the source geometric parameter. As an example, a photoemissive area smaller than the laser spot size avoids the diffraction effects otherwise coming from the laser beam shaping.
In the area between the sources and the masking, a polarized anode measures the photocurrent. It allows the monitoring of the QE also during the deposition. The light source is a Hg lamp with interference filter (λ= 254 nm). After the cathode production, the spectral response and the QE distribution over the cathode area are measured using a beam steering system. In this way, a map of the QE is performed and non-uniformity in the photoemissive film can be detected.
For the cathode movement inside the system, a proper carrier has been designed that holds up to five cathodes. Magnetic coupled translators move the carrier; upper and lower rails guide it along the entire path from the preparation system to the transportation system. Ball bearings are located on the upper and lower part of the carrier in order to reduce the friction during the movement. CuBe and Stainless Steel (SS) bearings have been used, both without lubricant: SS ball bearings have shown longer lifetime and reliability. Additionally, CuBe spacers are mounted on the lower part of the carrier and allow centering of the in respect to the guiding sections. The cathode is locked on the carrier by three stainless steel plungers, positioned at 120° one respect to the other. To remove the cathode from the carrier and move it in the different areas of the chamber, proper pincers have been designed. Two sapphire balls are centers the cathode on the pincer. The balls are loaded with Tungsten springs and mounted on opposite sides of the pincer in positions corresponding to two groves machined on the cathode. Fig. 2 shows a sketch of the cathode machining.

The preparation chamber and all its components have been assembled at Milano during winter 1997/98 and since then they are operative. Cathodes are routinely produced and transported to DESY.

3 The transportation system

The transportation system has been developed to move the photocathodes from Milano to DESY in UHV condition. To accomplish this task, a CF 63 six ways cross was modified in order to contain the cathode carrier. A 60 l s^{-1} ion pump maintains the system in UHV. Fig. 3 shows a sketch of the transportation system.
To disconnect the carrier from the magnetic manipulator, a bayonet coupling device has been designed. This device allows a fast and reliable connection and detachment of the carrier from the manipulator. A small translator takes in position the carrier during the

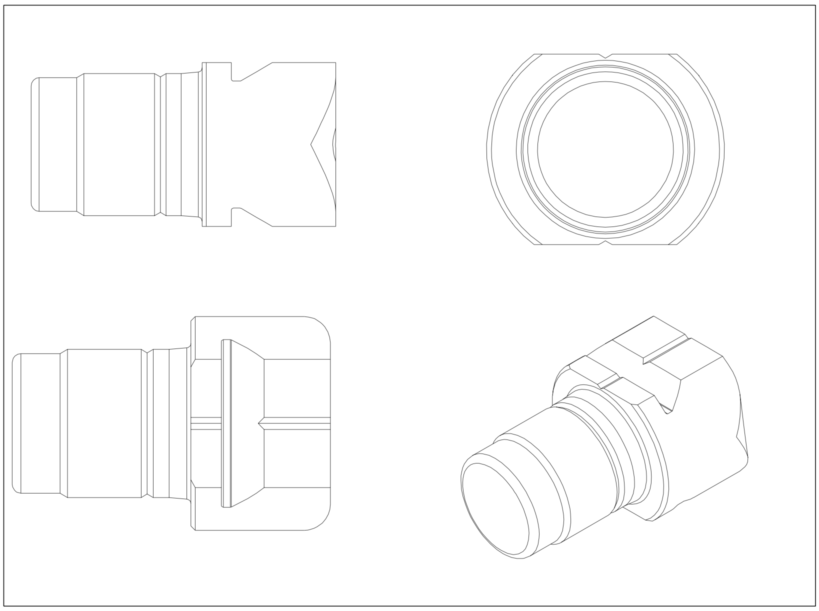

Figure 2: Details of the cathode machining. From the left down clockwise, a top view with the groves for the plungers, a detailed view of the machining for the coupling with the pincer, and the insertion hole for the heating lamp on the back of the cathode. The last insert is a 3D view where the complex machining of the cathode is visible.

transportation, inserting a catch in the back of the last cathode. In front of the cathode, an anode and a Fused Silica viewport allow photocurrent measurement. This is particularly important because no photocathode diagnostic device is available in the transfer system at DESY. In order to connect the transportation system to the other systems without breaking the vacuum, a CF 63 all metal valve is installed. Another all metal valve is mounted on the other system and a small transition piece allows the connection. This transition piece is the only one, in all the apparatus, that is exposed to air when the transportation system has to be connected or disconnected. To speed up the pumping time a LN_2 (Liquid Nitrogen) trap is foreseen. The typical time necessary to connect the transportation system is about half an hour while the pump down time for the connection piece is of the order of couple of days before UHV conditions are established (without the LN_2 trap). As mentioned in the introduction, one noticeable feature of the transportation system is its compactness. During the transportation, a small DC/DC converter supplies the ion pump. We are currently using a modified Penning power supply powered by a battery. Since the current drained by the ion pump is very low, the battery is sufficient for the time needed to transport the cathode. The first cathode transportation was done on July 1998 without any degradation of the QE properties of the cathode [6].

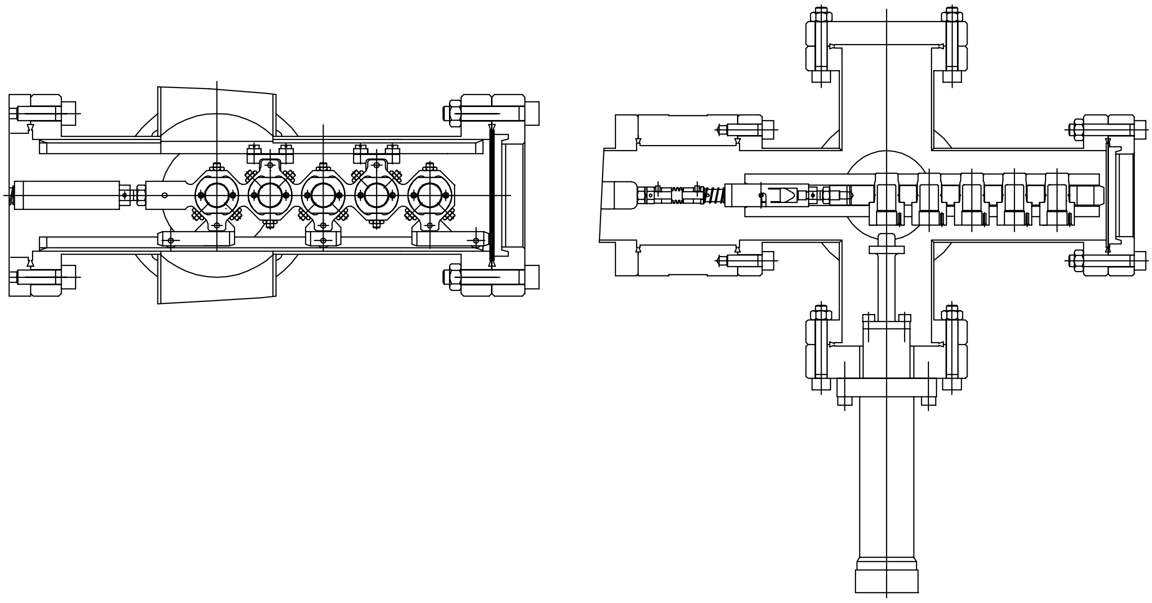

Figure 3: Sketch of the transportation system. On the left, the carrier is visible while, on the rigth, the small manipulator is drawn. A small viewport for QE measurement is mounted in front of the last cathode.

4 The transfer system

The transfer system is installed at DESY and is directly connected to the RF gun: it allows cathodes being transferred from the transportation system to the gun (fig. 4). It mainly consists of an UHV chamber pumped by a 60 l s^{-1} ion pump and a Titanium Sublimation Pump (TSP). A long arm magnetic coupled translator moves the carrier from the transportation chamber to the main chamber. Here a pincer, similar to the one used in the preparation system and mounted on a second translator, removes the cathode from the carrier. Non magnetic materials have been used for all the pincer components to avoid any influence on the gun performances. Once the second manipulator held the cathode, it is moved into the gun. The vacuum piping from the transfer system to the gun has been designed to guide and center the cathode in respect to the gun while the cathode itself is moving toward it. To avoid any damage to the photoemissive surface, all the guiding is done in respect to the outer dimensions of the pincer. The final centering of the cathode into the gun is achieved using a spring installed into the gun itself. Up to now two types of spring are used: a watch-bend type copper beryllium silvered spring is installed in the DESY gun while a standard copper beryllium round spring is mounted on the FNAL gun. The alignment of the cathode front surface with respect to the gun inner wall is ensured

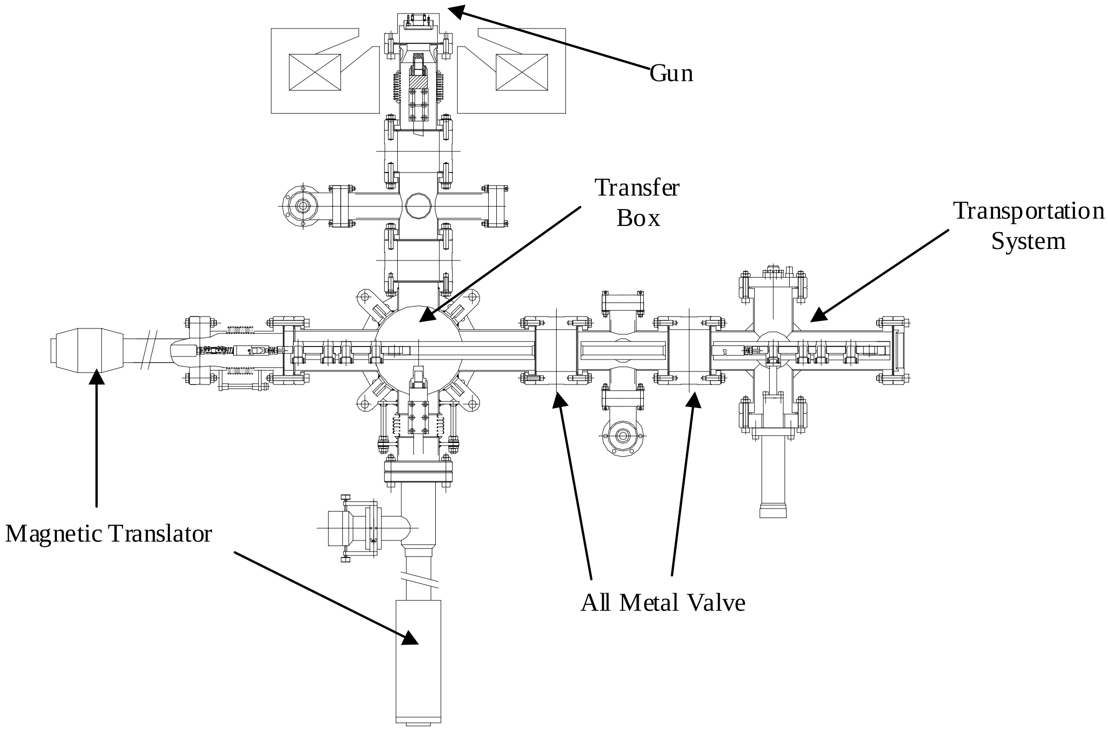

Figure 4: Top view of the transfer system. The transportation system is connected on the right and a long magnetic coupled translator moved the carrier in the main chamber where a second manipulator moves the selected cathode into the gun.

by a precision machining both of the cathodes and of the back plain of the insertion piece. In this way, only a final fine adjustment of the cathode position is needed in order to tune the frequency of the RF gun. The transfer system is operative at DESY since July 1998 and has been used, at first, on the DESY RF gun and then assembled on the beam line and connected to the FNAL RF gun where it is operative since November 1998.

5 Conclusion

The system is fully operative since almost two years and no major problems have been detected. Cathodes are routinely produced and characterized at Milano. The cathode transportation has been successfully accomplished without any QE degradation and the transfer system is fully operative at TTF. New developments are foreseen in the carrier designed and in the transportation system. The critical point of the system is the carrier transfer from the transportation system to the other ones (preparation chamber and transfer system). Furthermore, the removing of the cathode from the carrier itself would be improved. In order to have an easier cathode handling, a new carrier has been designed

with a different positioning of the cathode holders. The new design has been based also on the results of calculation done on the carrier balancing providing a safer movement of the carrier itself in the systems.
Moreover, a new cathode transfer system has been delivered to DESY in winter 1999. This system is designed for the gun test stand that is being installed at DESY-Zeuthen.

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