High Quantum Efficiency Photocathode Preparation System for TTF Injector II

P. Michelato, C. Gesmundo, D. Sertore

INFN Milano-LASA, Via F.lli Cervi 201, 20090 Segrate (Milano), Italy
a) DESY, Notkestrasse 85, 22607 Hamburg, Germany

Abstract

The TESLA Test Facility (TTF) Injector II photocathode preparation system is in operation since spring 1998. High quantum efficiency tellurium and alkali metals based photoemissive 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.

1. Introduction

During winter 1998/99 the Injector II was commissioned at the TESLA Test Facility LINAC (TTF) [1]. The new 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.

Due to the high sensitivity of these materials to gas exposition [2], they are always stored, from their production to their operation into the gun, in UHV condition. Moreover, thanks to the experience on cathode production and vacuum technology of our group, we have designed and built a 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 [3].

The new cathode preparation system is equipped with all the diagnostics that are necessary for characterizing the cathodes produced, before their delivery to DESY. Here the installed system is mainly 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 pumped by a 400 l s⁻¹ ion pump mainly composes it. 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 [4]. The tellurium and the alkali metals sources are installed on a frame in front of the masking area. The adjustment of the current, flowing through the sources, controls the evaporation process. An LTM (Linear Transfer Mechanism) moves the Molybdenum substrate 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 photoemissive area over the Molybdenum substrate. This possibility can be used to explore the dependence of the injector emittance on the source 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, an anode, placed in front of the cathode, gives the possibility to measure the photocurrent. During the deposition, it
allows the monitoring of the QE. For this purpose a Hg lamp with interference filter (\(\lambda = 254\) nm) is used. After the cathode production, the spectral response and the QE distribution over the cathode area are measured. Moreover a beam steering system scans the cathode area by moving over it the light beam. In this way, a map of the QE is performed and non-uniformity in the photoemissive film can be detected.

For the movement of the cathode inside the system, a proper carrier has been designed: it holds up to five cathodes. Magnetic coupled translators are used for moving 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 decrease the friction during the movement. CuBe and Stainless Steel (SS) bearings has been used, both with no lubricants: SS ball bearings have shown longer lifetime and reliability. Additionally, spacers in CuBe, mounted on the lower part of the carrier, allow its centering 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 move the cathode in the different areas of the chamber, proper pincers, able to be coupled with the cathode, have been designed. Two sapphire balls are used for centering the cathode on the pincer. They are loaded with Tungsten springs and mounted on opposite sides in correspondence to two groves machined on the cathode. Fig. 2 shows a detail 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. Until now, ten cathode have been produced and four of them were successfully 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 transportation, inserting a catch in the back of the last cathode. In front of the cathode, an anode and a Fused Silica viewport allow the 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 one day 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, as reported at this conference [6]. A second cathode transportation followed in December 1998 with the same good results.

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 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 in respect to the gun inner wall is ensured 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. It is operative since November 1998.

5. Conclusions

The system is fully operative since one year 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. The new cathode transfer system has been designed and will be delivered to DESY in fall 1999. This system is designed for the gun test stand. All the components are now at Milano and the assembling will take place after summertime.

6. Reference