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RECENT IMPROVEMENT OF Cs_2Te PHOTOCATHODES AT HZDR

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Abstract

The ELBE SRF gun has been successfully operated for the radiation source at HZDR. To achieve higher current and lower beam emittance, a new niobium cavity with superconducting solenoid and a new 13MHz laser have been recently developed. Meanwhile, better photocathodes with high quantum efficiency are urgently in demand. In this work we improve the present Cs_2Te preparation system for cleaner environment and more precise stoichiometric control than before. A new mask is designed to prevent cesium pollution of the cathode body. Instead of Kapton only alumina ceramics are used for isolation, and the cathode plugs are degassed at higher temperature. New evaporators are produced for an accurate deposition rate. Furthermore, the cathode transfer system is improved for a better vacuum condition.

INTRODUCTION

The development of photocathode electron guns has become a significant technology for large accelerator facilities and modern light sources. There are several successful photo-guns around the world [1], like Cornell DC gun, DESY rf gun, ELBE SRF gun, and so on. For the photo-guns producing high average current and high bunch charge, searching for suitable photo cathodes is a sustained effort, while there is still space to improve the photocathode both in the quantum efficiency (QE) and the life time.

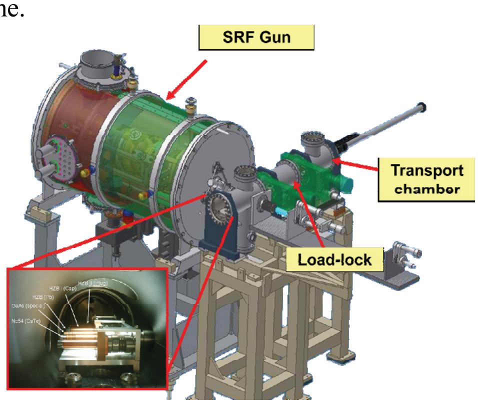

Figure 1: ELBE SRF gun, photocathode transport chamber, and vacuum load-lock system.

The ELBE SRF gun developed within a collaboration of the institutes HZB, DESY, MBI and HZDR has been operated for the supercondctung linac since 2007 [2] (Fig.1). With the Cs_2Te photocathode driven by a 13 MHz UV laser, the SRF gun produced beams up to 400 µA. The maximum energy of the electron beam reaches 3.3 MeV, bunch charge 400 pC and transverse emittance is 3±1 mm mrad with 80 pC bunch charge. In April 2013 the first IR-FEL laser succeeded from SRF gun beam [3]. In our experiments the photocathode has long lifetime and relatively stable QE, at least in the case of illuminated by the laser with low and medium energy intensity. On the other hand, there is no obvious degradation found in the cavity quality, since the RF measurement result shows that the cavity with cathode inside has the quality factor Q_0 as same as the virgin cavity [2].

In order to improve the beam quality, in May 2014 the new SRF gun with improved parameters was installed for the ELBE SC Linac. A new superconducting cavity with fein gain niobium and a superconducting solenoid are the key points of the new SRF gun. Meanwhile, to realize the two modes operation task, eg., high average current (1mA) mode and high bunch charge (1nC) mode, photocathodes with stably high quantum efficiency (QE) are urgently in demand.

The HZDR photocathode laboratory is responsible to prepare Cs_2Te photocathodes for the SRF gun operation [4]. The SRF gun requires photocathodes with QE higher than 1% in months. The present Cs_2Te preparation system has several weak points, which limit the life time and the uniformity of the photocathodes, and possibly cause the undesired multipacting. Recently the preparation system was updated for a better vacuum condition and to prevent cesium pollution on the cathode body. Furthermore, the cathode transfer system is also in the phase of improving.

STATUS OF Cs_2Te CATHODE

In order to combine the normal conducting Cs_2Te semiconductor and the SC niobium cavity, and at the same time to get the highest electric field on the cathode surface, a special cathode support is installed in the centre of the half-cell cavity [2]. This makes the cathode isolated from the SC cavity by a vacuum gap and cooled down to 77 K with liquid nitrogen.

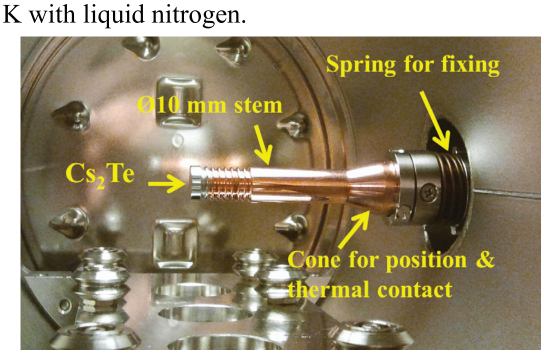

Figure 2: photocathode plug in transfer system waiting for insertion. The spring is used to fix the plug firmly in the cathode holder. The concave rings on the stem are designed to suppress multipacting.

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Figure 2 is the photocathode structure. In order to provide a good thermal contact the cathode body is made of copper. Cs_2Te is deposited on the tip of Molybdenum plug, which is screwed on the cathode body.

Up to now more than 30 Cs_2Te photocathodes have been produced at HZDR photocathode laboratory. The typical QE of the fresh cathodes are from 8% to 15%. Among them 8 cathodes ever worked in the 1st SRF gun. The QEs in the gun are normally about 1%, and the life time can be months. For example, cathode #17.04.2012 Cs_2Te has fresh QE of 8.5%, but the QE dropped down to 0.6% after it was transferred to gun. Nevertheless, it provided beam time more than 2100 hours, totally extracted charge more than 264 C.

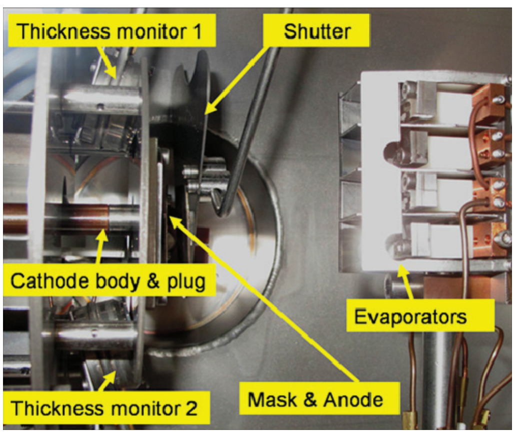

Figure 3: The inside view of the preparation chamber.

The background vacuum in the preparation chamber is normally good 10^{-9} mbar. As in Fig. 3, the cathode plug in preparation chamber is degassed at 200 °C for 3 hours in the vacuum of $1*10^{-8}$ mbar. The deposition is done with co-evaporation in the vacuum of 10^{-8} mbar (Fig. 4). The photocurrent was used to diagnostic the preparation process. The cathode is stored in the transport chamber, where the vacuum is in the order of 1×10^{-9} mbar.

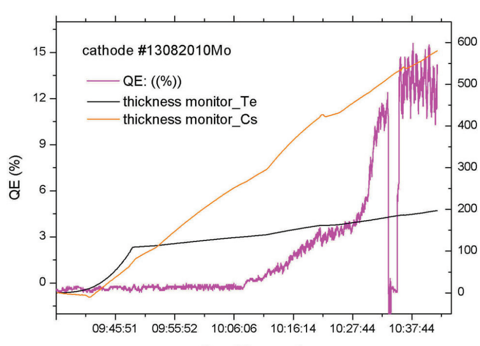

Figure 4: Co-evaporation process of Cs_2Te photocathode.

However, several problems limit the cathode quality: QE dropping down, inhomogeneous and multipacting due to cesium contamination.

QE and Lifetime

The QE of the fresh photocathodes is between 8% to 15%. But the QEs drop down quickly to 1% - 2% because of the photoemission layer degradation and also the vacuum variation during transportation (Fig. 5). Once the cathode is installed in the gun cavity, no obvious QE degradation has been found during the beam production.

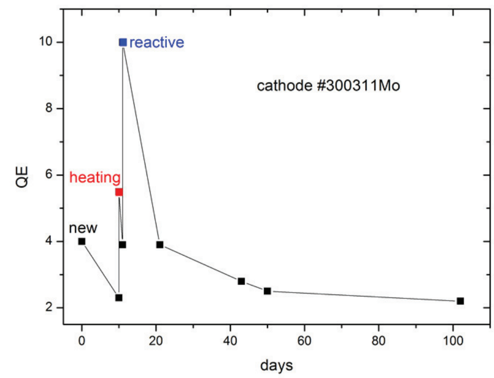

Figure 5: The QE history of one Cs_2Te photocathode.

Uniformity

The photocathodes are scanned soon after the fabrication and again in the gun. For several cathodes, the colour on surface was not uniform, later they were found inhomogeneous in QE distribution. This distribution may change during the operation in SRF gun.

Energy dispersive x-ray analysis (EDX) was then done to detect the content of Cs/Te for one cathode after it was taken out from preparation chamber. The centre of film had the rate of 2.3, and in the rim it was 2.0. So the cesium might be too rich in the fresh cathode, which could be the reason of short life time as well.

Dark Current and Multipacting

The main problem for the high gradient operation of SRF gun is that the dark current increases rapidly along with gradient. The Mo-plugs with Cs_2Te layer induced 30% of the total dark emission [5]. Meanwhile, cesium contamination is considered as the reason of undesired multipacting at low gradient, which leads a lot of trouble for the rf system.

PREPARATION CHAMBER UPDATE

In order to produce better Cs_2Te photocathode for the new SRF gun, the preparation chamber and the transfer system are on the way of updating. Firstly effort is paid to solve the problem of QE quick degradation, mainly by improving the vacuum in all cathode system.

We add a thermal shield around the photocathode plug and the halogen light, which will bring benefit to the

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higher degasing temperature and the better vacuum condition during the heating process than before. At the same time, the shield will prevent the cathode body from cesium flow during the evaporation so that the multipacting due to cesium contamination can be reduced. In order to improve the vacuum, Kapton is now replaced with alumina ceramic as isolation material. The mask is modified to minimize the cesium deposition on the undesired area. At last the whole preparation chamber is cleaning to reduce the rest cesium in chamber.

On the other hand, Ar^+ ion beam will be used again for cleaning the Mo surface. Lower evaporation rate will be used to improve the homogenous distribution.

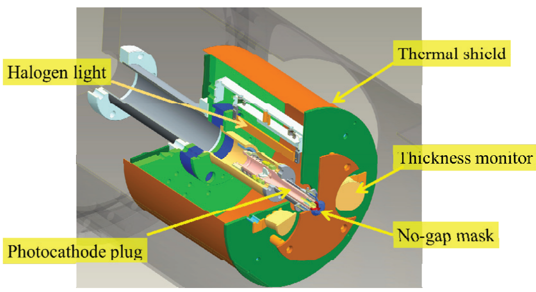

Figure 6: The new design of preparation system.

PHOTOCATHODE TRANSFER SYSTEM

The Cs_2Te photocathodes are prepared separately in the cathode lab and then transported to the SRF gun. A UHV transport system with low particle generation is used to realize this function. Up to 5 cathodes can be transported at the same time. It takes only half an hour to exchange photocathodes in the accelerator hall without warm-up the gun cavity. In this way the time-consuming cathode preparation process doesn't disturb the gun running.

The vacuum condition was a problem for the transport system. The typical vacuum was only 1×10^{-9} mbar. And during the manipulator movement and the valve operation, there was also pressure increasing.

Recently the transfer system is under updating as well. For the load lock system, an ion getter pump is used to maintain the best vacuum condition and the molecular turbo pump is only for the pre-vacuum pumping. SAES NEG pumps [6] are used together with ion getter pump in the transport chamber. Moreover, all of the parts will be cleaned thoroughly, and later will be baked in vacuum. The task of the transport system updating is to enhance the static vacuum up to 10^{-11} mbar, especially in the cathode storage transport chamber.

CONCLUSION

To achieve higher current and better beam quality, the new ELBE SRF gun with a new niobium cavity with superconducting solenoid has been installed. Meanwhile, better photocathodes are urgently in demand to provide higher QE, longer life time and cleaner surface for the new gun.

From our experience of the cathode production and operation, a good vacuum better than 10^{-10} mbar and the clean cathode surface are important for the stability of Cs_2Te photocathode in SRF gun. We update the Cs_2Te preparation system for better vacuum and less cesium contamination than before. The cathode transfer system is also modified for a better vacuum condition.

The updating work will be finished in the summer of 2014. After commissioning phase, the first Cs_2Te photocathode will be inserted into SRF gun during the autumn shutdown of ELBE radiation source.

ACKNOWLEDGE

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