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Reliability studies of the photo cathodes

Introduction

The operation of a short wavelength free electron laser in the self-amplified spontaneous emission regime requires a high-quality electron beam. For continuous operation, photo cathodes with high quantum efficiency and long life times are necessary. For a further understanding of the cathode behaviour during RF-operation, quantum efficiency (QE) measurements are performed before and after the cathode usage as well as during operation at different conditions.

In this report, reliability studies of photo cathodes used at the Photo-Injector Test facility in Zeuthen (PITZ) and at FLASH are presented. In the first part of this report, statistics for the usage of each Cs_2Te cathode are presented.

A necessary step toward achieving required emittance for the European XFEL project is to raise the accelerating gradient in the gun cavity from 42-45 MV/m up to 60 MV/m [1]. Therefore we present in the second part of this report more detailed studies of photo cathodes used with accelerating gradients at the cathode of about 60 MV/m.

Photo cathode statistics for FLASH and PITZ

At both facilities Cesium Telluride (Cs_2Te) photocathodes are used as sources for electron beams because of their high quantum efficiency and their ability to release high peak current electron bunches in a high gradient RF-gun. Starting from a high QE level of about 10 % the quantum efficiency of these cathodes decreases during operation in a photo-injector to below 0.5 %, which is lower QE limit for operation at FLASH. The cathodes used at FLASH and PITZ are prepared at LASA (INFN-Milano, Italy) [2].

All data related to the main steps of the production process have been organized in a web-accessible database [3]. Besides information concerning the production, the database includes in addition QE measurements after preparation and after usage performed at LASA as well as the same type of investigations during operation and dark current measurements in the photo-injector.

In figure 1 the usage in days for each photo cathode is shown for PITZ and for FLASH [2]. Up to now 30 Cs_2Te cathodes (Fig. 1, left) have

been used in different RF-guns at PITZ. On average a cathode was 30 days in the photo-injector. Figure 1 (right) presents the same data for FLASH, where 27 photo cathodes were used in average 56.5 days [3]. Details on QE of different cathodes presented in figure 1 can be found in [3, 4, 5].

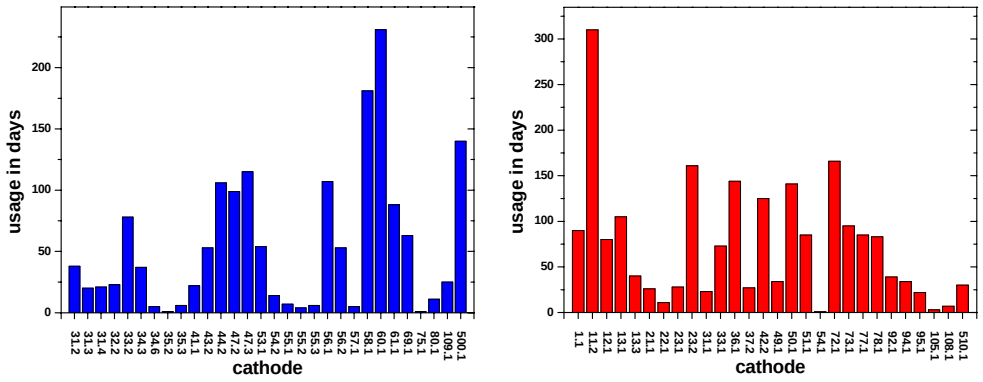

Figure 1: Statistics for the usage of Cs2Te photo cathodes: left at PITZ, right at FLASH

Cathode studies at gradients up to 60 MV/m

Accelerating gradients at the photo cathode up to 60 MV/m are a necessary step toward achieving the required emittance for the European XFEL project [1]. A new L-band photoelectron gun (prototype 3.2) has been installed for use with a 10 MW klystron at PITZ. This gun has been conditioned starting in April 2007 up to a maximum gradient of about 60 MV/m. The gun was tuned for resonance at 1.3 GHz, and stable operation has been achieved with 100 μs RF pulses with a repetition rate of 10 Hz [6]. Three Cs_2Te photo cathodes have been used in this gun cavity so far.

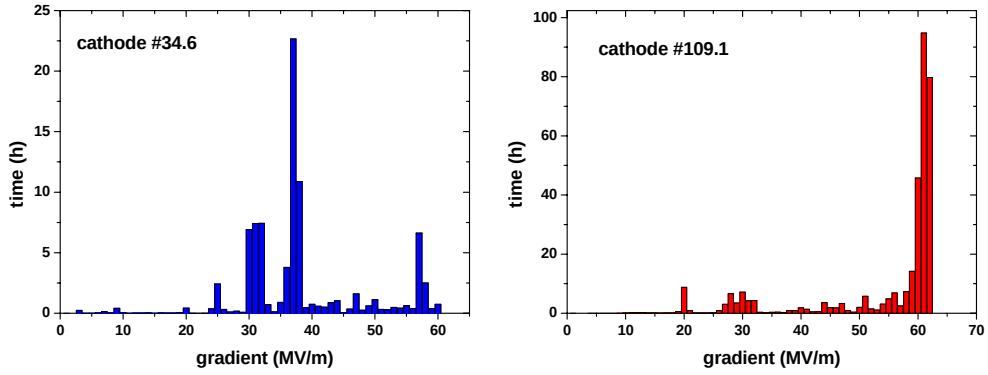

Figure 2: Time as cathode usage vs. gradient at photo cathode: left for #34.6, right for #109.1

In figure 2 the histories of cathode #34.6 (left) and cathode #109.1 (right) are presented as function of the accelerating gradient. Cathode #109.1 was used until the extracted charge per bunch decreased below 0.5 nC even with the maximal laser pulse energy of about 4.7 μJ. For over 230 hours gradients of approximately 60 MV/m were applied to the cathode.

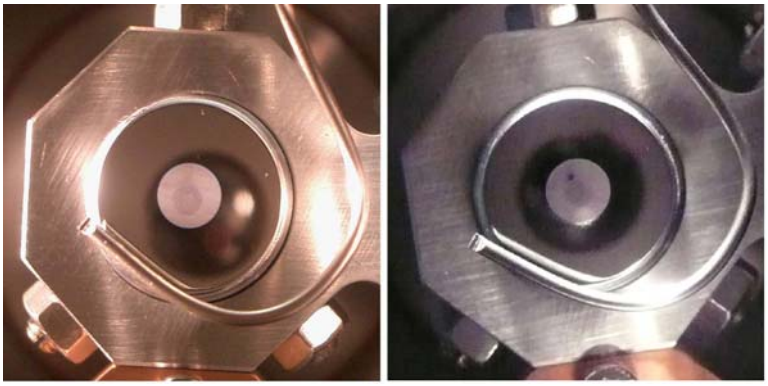

Figure 3: Photographs of cathode #109.1 taken in the transport box connected to the PITZ RF-gun, left: 24.06.2007, right 10.07.2007

Photographs taken in the transport box connected to the RF-gun are presented in figure 3 at two different dates. Before the usage (left side of the figure) no clear features of the Cs2Te film in comparison to other cathodes are visible [3]. After usage with gradients up to 60 MV/m a dark spot on the surface appears. The source of this damage is considered to be the same as for molybdenum cathodes used for conditioning of the RF-gun, where the surfaces of the plugs show a high density of defects [6].

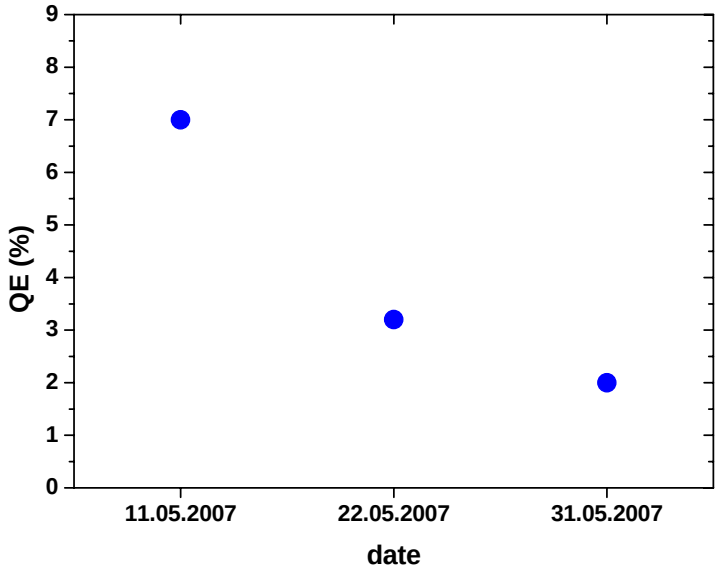

Figure 4: QE history of cathode #34.6 operated with gradients up to 60 MV/m

As described above, photo cathodes used at gradients up to 45 MV/m have lifetimes of about 56.5 days under conditions necessary for a user facility like FLASH. At PITZ, where the RF-gun is currently operated at 60 MV/m with 10 Hz repetition rate, the lifetime decreases dramatically. In figure 4 the quantum efficiency of cathode #34.6 for different dates is presented. A reduction in the QE from about 7 % to 2 % in approximately 14 days is clearly visible. In addition, the cathode was not permanently in the RF-gun. As shown in figure 2 this cathode was used with gradients higher than 40 MV/m only for several hours. In figure 5 statistics of the QE degradation of cathode #42.3 are presented. The quantum efficiency reduces from 10 % to 2 % within 100 h. The dashed red line represents a QE of 0.5 %.

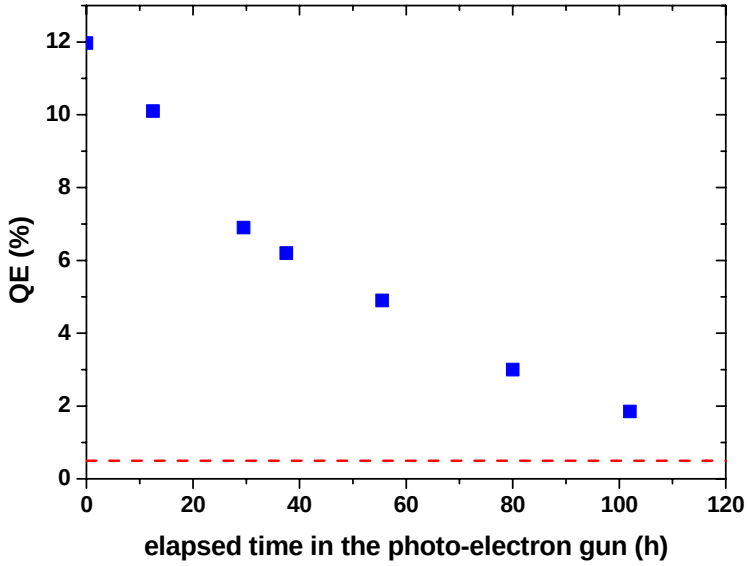

Figure 5: QE history of cathode #42.3 operated at gradients of about 60 MV/m

One reason for these surprisingly short lifetimes of the photo cathodes could be the unexpected high dark current in the current electron-gun at PITZ. As example dark currents of up to 12 mA were measured with cathode #34.6 and accelerating gradients at the cathode of 60 MV/m [6]. For higher statistics and a better understanding of the QE reduction, further investigations are necessary.

Conclusions and Outlook

In this report reliability studies of Cs2Te photo cathodes used at FLASH and PITZ are presented. Typically these cathodes are used for about 55

days at FLASH and 30 days at PITZ. For the usage in RF-guns with gradients up to 45 MV/m these times are sufficient for the operation of a short wavelength free electron laser in the self-amplified spontaneous emission regime. Recent investigations on cathodes used with accelerating gradients up to 60 MV/m at PITZ show a rapid decrease of the lifetime. For a better understanding of this phenomenon the studies will be continued towards higher statistics.

To understand the decrease of QE during operation in an RF-gun, XPS measurements on the chemical composition and work functions of fresh and used cathodes were performed at BESSY (BESSY GmbH, Berlin, Germany) and are currently being analyzed. The results of these studies will be presented elsewhere [7].

References

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