FREE ELECTRON LASER 1996
G. Dattoli, A. Renieri (eds)
1997 Elsevier Science B.V.

# Development and Production of Photo Cathodes for the CLIC Test Facility

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**ABSTRACT**

For more than five years, the CLIC Test Facility (CTF) has used photo cathodes (illuminated by laser) as intense sources of electrons. These cathodes are mounted in an RF gun at 3 GHz and subjected to high electric fields, greater than 100 MV/m, in order to produce a beam charge of more than 10 nC in less than 10 ps. Traditional photo cathodes developed for photo multipliers have been shown to be unsuitable for our application. After having tested several types of photo cathode, metallic, semi-conductor or impregnated, we have selected two, compatible with the specifications of the photo injectors and, at the same time, with the technical performance of our laser installations. One of them, in caesium telluride, allows the production of high charges, but must be transferred under vacuum from the production laboratory to the RF gun. The other, in caesium iodide, covered with a fine layer of germanium, produces smaller charges, up to several nC but, in contrast, it can be exposed to the air for short periods. After having recalled the main characteristics of the photo cathodes that we have tested, including the first test of a GaAs photo cathode in an RF gun, this note describes in more detail the two cathodes which were selected and their use in an RF gun.

## 1. Introduction

The CLIC Test Facility (CTF) is foreseen to produce and test two different electron beams : one, at high charge (up to 1µC), called the "drive beam" produces 30 GHz radio frequency power. The other, at lower charge (1 nC), is accelerated by the 30 GHz electric field produced by the first one, and is called the "probe beam". In the first step (CTF1) only one photo injector was used to study both beams. This configuration was able to demonstrate the two beams acceleration scheme, principle of the Compact Linear Collider (CLIC) [1]. A summary of results with the CTF1 in 1995 is reported in [2]. In a second step, called CTF2, two different electron beams are used to study the feasibility of the CLIC scheme. The electron source for each beam is a 3 GHz RF gun equipped with a laser driven photo cathode.

## 2. Photo cathode specifications

For the drive beam, the QE (the ratio of the emitted electrons to the incident photons) must be greater than 1.5% at 262 nm during at least one week with an electric field of 100 MV/m. For the probe beam, the QE must be greater than 0.01% at the same wavelength during at least one month with an electric field of 70 MV/m. The produced charges must be linear with the laser energy up to 1µC (48 pulses of 21 nC) for the drive and 2 nC for the probe beam. In both cases, the response time must be lower than a few ps.

## 3. Photo cathode tested in the RF gun

In the RF gun photo cathodes at high electric field, up to 127 MV/m, to produce short (10 ps) and intense (up to 2 kA) electron bunches. were used. We have tested metallic cathodes [3] but the quantum efficiency QE is rather low and only a magnesium cathode would be a candidate for the probe beam.

In a context of an informal collaboration with the Stanford Linear Accelerator Center we have tested gallium arsenide photo cathodes. One, with a 10 nm caesium layer was tested up to 60 MV/m, and the second, without caesium, up to 87 MV/m. The results are reported in [4].

Between December 1990 and October 1993 we used CsI photo cathodes because they are transportable in the air [5]. Unfortunately, the photo emission threshold is quite high (6.3 eV) involving the use of the fifth harmonic of a Nd:YLF laser (λ=209 nm). This wavelength was too impractical, so we decided to move at the fourth harmonic (λ=262 nm). At this wavelength many alkali photo cathodes are able to produce high charges. For this reason we tried many of them in the photo emission lab [3]. Finally we selected two of them compatible in QE and lifetime with our laser equipment and CTF specifications. We chose the caesium telluride for the drive beam for its high QE at 262 nm and long lifetime, but it needs a vacuum transportation. The second one, for the probe beam, is a caesium iodide cathode with a coating of germanium which is able to be transported in the ambient air but gives a relatively low QE at 262 nm. For these two photo cathodes complete results are reported in [6].

### 3.1. CsI+Ge photo cathodes

A thin 2 nm coating of germanium over a CsI cathode decreases the QE at 213 nm by a factor of 10, but increases it at 262 nm from $7x10^{-5}$ up to 0.13% [3]. This coating does not change the air exposure property of the CsI. To improve the sticking coefficient, 200 nm of aluminium are deposited on the copper cathode plug before the 350 nm of CsI layer which is covered by 2 nm of germanium. These photo cathodes are stored in a desiccator. Finally they are installed, in ambient air, in the RF gun and baked out at 150°C. These cathodes need a delicate conditioning process, with high electric field and laser pulses to remove the oxide of the surface without destroying the thin germanium layer. After 10 to 15 hours of this process the QE rises up to 0.2% under an electric field of 70 MV/m. We have observed a saturation effect at 22 $nC/cm^2$ where the QE decreased by 40% and the electron pulse lengthened from 10 ps to 22 ps. At probe beam working point, maximum 4 $nC/cm^2$, we did not observe any saturation effect and the response time is fast. We did not have enough time to measure accurately the time constant $\tau$ (time descend to $QE_{max}/e$) but it seems longer than one week.

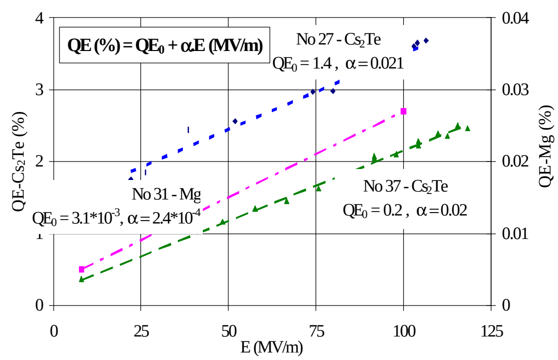
### 3.2. Caesium telluride photo cathodes

Ten nanometers of tellurium are deposited at room temperature on different substrates (Cu, Mo, Mg). The caesium is evaporated with the substrate heated at 110°C until the photo emission reaches a maximum. This photo cathode is an insulator; $\rho$ is greater than 100 GΩ/square and $\varepsilon > 50$. Due to the coalescence effect, the specular reflectivity varies from 7 to 15%. The photo emission threshold is about 3.5 eV and the QE is generally between 5% and 10%. These data were measured at $\lambda$=266 nm. The cathodes are very robust compared to the alkali antimonide photo cathodes. Main contamination comes from oxygen [7].

We have observed a satisfactory behaviour in the RF gun up to 127 MV/m. At this electric field, the starting QE is close to 10%. We have seen a fast QE drop the 50 first hours with $\tau \approx 40$ hours, followed by a slower decrease with $\tau \approx 350$ hours. The response time is less than few ps; the time resolution was limited by the streak camera. Finally we have observed an electric field dependence of the QE (see figure 1). This effect, probably a Schottky effect [8], seems to be independent of the $Cs_2Te$ photo cathode aging.

Between November 1993 and December 1995 we have used 15 $Cs_2Te$ photo cathodes in the RF gun. The mean starting QE, measured at 8 MV/m in a DC gun, was 5% ($\sigma$ = 1.7%). The mean lifetime was almost 30 days with an electric field of 106 MV/m during 213 hours ($\tau$ = 12 days). The storage time constant is greater than two years.

Fig. 1 : QE versus the applied electric field for $Cs_2Te$ and Mg photo cathodes




## 4. Conclusion

Both $Cs_2Te$ and CsI+Ge cathodes fulfill the drive and probe beams CTF2 specifications. The conditioning process before using the CsI+Ge cathode is delicate and the lifetime should be verified. The fabrication process of $Cs_2Te$ cathodes is relatively easy and only the caesium quality is critical. These cathodes have demonstrated a good behaviour in the rf gun environment.

## 5. References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