# FIRST RESULTS OF THE CAESIUM TELLURIDE PHOTO-CATHODE FOR ATF RF-GUN

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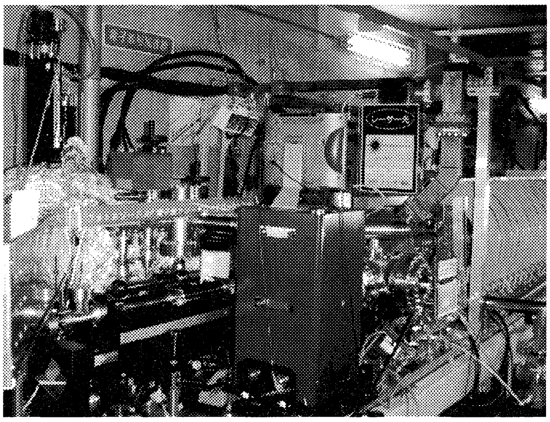
*Abstract*

Injector system of the Accelerator Test Facility (ATF) in KEK was changed from ordinal thermionic gun and buncher system to the laser driven RF gun system. Caesium telluride (Cs-Te) was chosen as the cathode material for ATF RF gun because of its higher quantum efficiency. Photo-cathode preparation system is designed to have an evaporation unit of Cs-Te and a loading unit of cathode into the RF gun. All of actions in this system are done in UHV without any vacuum breaks. It minimizes the any chances of damage on the Cs-Te cathode caused by oxygen. In this paper, we describe the results obtained through the recent ATF operations.

## INTRODUCTION

Studies for the multi-bunch beam are performed in the ATF damping ring to establish the technologies required in the GLC project [1]. This multi-bunch beam is consist of 20 bunches in a train with a 2.8 ns bunch spacing. Designed intensity of each bunch is $2x10^{10}$ electrons at maximum. However, the operational beam intensity was limited less than half of design's because of the limitation of the radiation level. Beam loss was caused by a longer energy tail and an energy jitter, caused by the old thermionic-gun and buncher system. In order to fix these issues, we decided to change the injector system to a laser driven RF gun system. The multi-bunched laser pulses will generate multi-bunch beam. Typical laser intensity of our system is around a few μJ/bunch. Therefore, the quantum efficiency of the cathode material should have about 1% to generate the ATF beam. We selected the caesium telluride because of its higher quantum efficiency, around a few %, and the recent results done by CERN [2] and DESY [3] linear collider R&Ds. Materials used in other RF guns, such as Copper or Magnesium, may not be used because their quantum efficiency is less than 1/100 of Cs-Te's. If we use these materials, we have to prepare the very expensive huge power laser system and it may not be stable.

To keep the higher quantum efficiency of Cs-Te, we have to keep it in UHV. An oxygen exposure loses the quantum efficiency of Cs-Te dangerously. We constructed the Cs-Te cathode load-lock system for ATF RF gun as shown in Picture 1. This system consists of two units, the evaporation unit of Cs-Te and the cathode-loading unit into the RF gun. Different from other RF gun systems [2][3], all of our components are connected as a vacuum system in situ. It means that there is no chance to have a contamination of air or oxygen after forming the Cs-Te cathodes. We could reproduce a cathode quickly without a UHV startup time that is required to install the cathodes formed in another place. This advantage was actually powerful for the ATF experiments done in the last operation period.



Picture 1: Cs-Te photo-cathode load-lock system at the RF gun section in ATF.

## CATHODE FORMATION

As shown in Fig. 1, we have a hole at the center of the half-cell's end plate. Cathode plug is installed to close it. Therefore Cs-Te cathode should be formed on the surface of the plug faced in the half-cell cavity.

The Cs-Te cathode formation in our system will be done as follows.

(1) Surface cleaning by 5 keV of Ar ion beam.

(2) Te layer formation by evaporation.

(3) Cs layer formation on the Te layer by evaporation.

The surface cleaning will be done when we install new plugs into the system or to clean up the previously formed

Cs-Te layer. The sputter depth is about 50 nm. Tellurium is evaporated from small pieces in a tungsten heater, and the thickness on the plug is monitored as the same amount on an equivalent target. Typical thickness of Te is about 5 nm in ATF. Caesium is evaporating by heating a caesium dispenser [4] and its amount is controlling by monitoring the increase of the quantum efficiency [5].

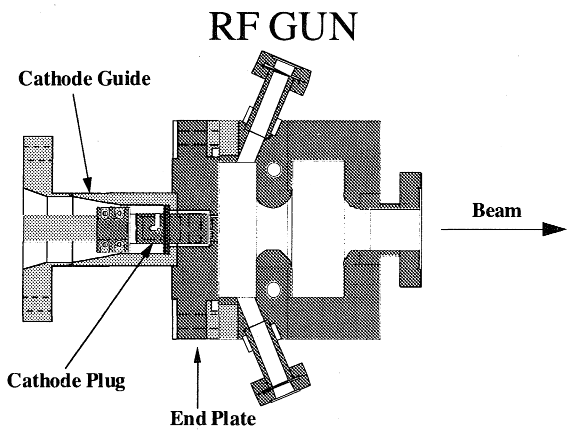
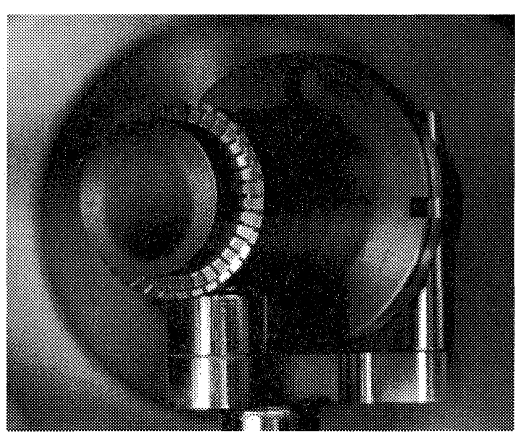



Figure 1: Cross section of the ATF RF gun. Cs-Te cathode plug is loaded from left side.

## *Base material of cathode, Cu and Mo*

We have tested copper [2] and molybdenum [3] as a base material of the Cs-Te cathode. Quantum efficiencies of the formed Cs-Te layers are 5% and 15% for copper samples and molybdenum samples, respectively. In addition, we have found damages on the surfaces of both samples. They may be caused by the RF break down and look like craters with a size of several microns. Copper samples seem to have bigger craters than that of the molybdenum's. Chemical boundary of the copper surface seems to be softer and we guess it will affect the purity of the Cs-Te compositions [6].

As a result of these initial experiments, we decided to use the molybdenum plugs for the standard ATF beam generations. Picture 2 shows the Mo plug with the Cs-Te cathode on the surface.



Picture 2: Mo plus with Cs-Te cathode.

## *Initial Quantum Efficiency*

Fig. 2 shows an example of the quantum efficiency growth during the caesium evaporation on a molybdenum plug. Quantum efficiency was quickly increased and dropped sharply. It caused by a faster Cs evaporation compare to the Cs-Te formation and it made a caesium rich surface at a moment. Quantum efficiency was still increased after stopping the Cs evaporation. This means Cs rich surface was disappeared by increasing the Cs-Te formations. Finally the quantum efficiency of Cs-Te cathodes has a quite higher value, more than 15%.

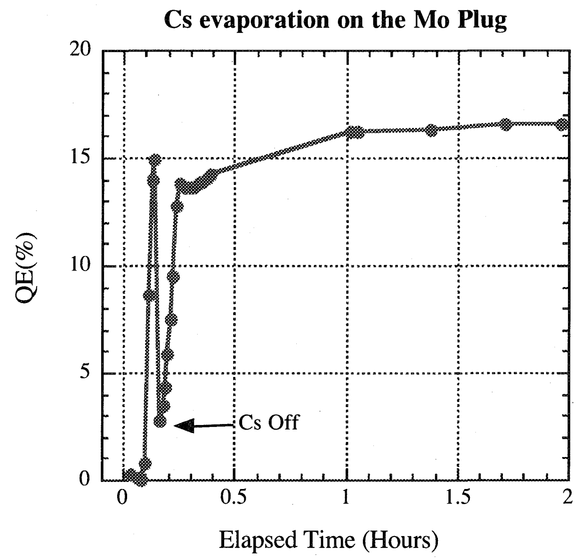



Figure 2: Growth of the quantum efficiency at the Cs-Te formation.

# BEAM OPERATION

We have tested Cs-Te cathodes for the electron beam generation. These beams were used both for the RF gun studies and for experiments with the ATF damping ring.

## *Quantum Efficiency with RF fields*

The dropping of the quantum efficiency with RF fields was observed as shown in Fig. 3. Quantum efficiency was decreased about a day to a stable level around 1%.

This behaviour was observed for all of samples after the Cs-Te formation. Cathode transfer may affect the vacuum purity. So we repeated the transfer between the Cs-Te evaporation chamber and the RF gun but it leads no such decrease. This behaviour is actually caused by RF fields. Vacuum pressure in the RF gun was not changed during the RF operation, even if it was in an initial period or a stable period.

From March 2003, we had a chance to use a cathode for five weeks of ATF operation. It shows no significant decrease of the quantum efficiency after reaching a stable level.

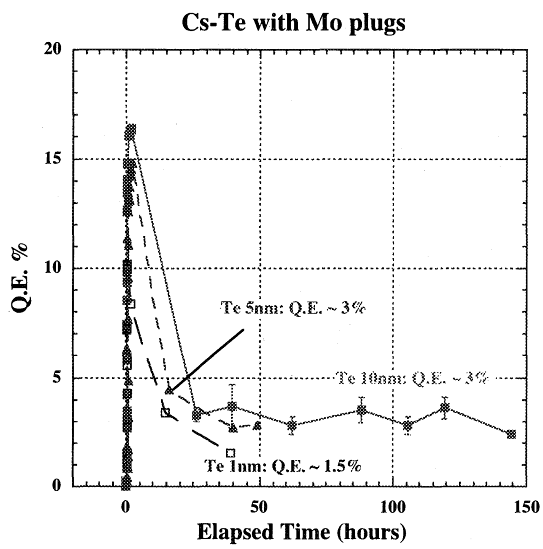



Figure 3: Dropping of the quantum efficiency with RF fields.

### *Dark Current*

The dark current of the RF gun is an issue. We measured it by using a faraday cup installed just after the system. Fig. 4 shows the history of the dark current. Dark current decreases by increasing a RF operation time. About a hundred hours after, dark current is not hard for ATF operation. Compare to the RF gun experiments done in 2001, it was a single bunch beam generation with a used RF gun from Tokyo University, present RF gun has 1/10 of old one. This is explained as a result of fine machining of the RF gun surface with the X-band structure technologies.

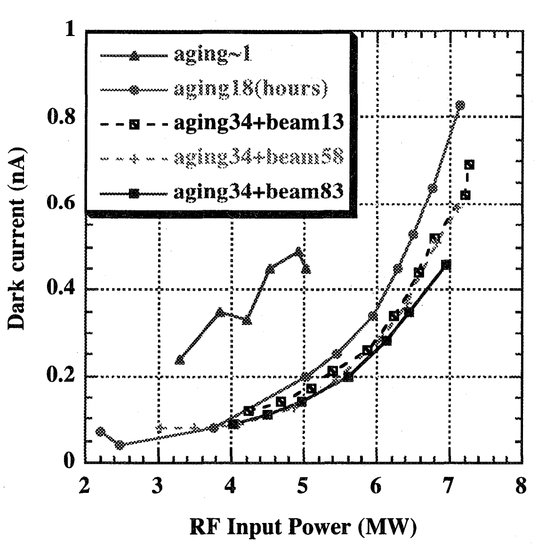



Figure 4: Dark Current of the ATF RF gun.

As described before, the end plate of the half-cell cavity has a hole to install a photo-cathode. There is a ring gap with 0.5 mm distance after installing a cathode plug. A contactor mounted on the cathode head-side insured the electric contact between the cathode and the end plate. We have no data for dark current with a simple end plate for comparison however we can say the gap is not an issue at present.

## SUMMARY

Multi-bunch beam generation by the Cs-Te photo-cathode with a laser driven RF gun was performed at ATF since October 2002.

We constructed a Cs-Te cathode preparation system and could reproduce a cathode quickly without any vacuum breaks. It was a powerful advantage to perform ATF studies in the last beam operation.

The quantum efficiency of Cs-Te on the Mo plugs reaches about 15% when it was formed. It was also found that the above higher quantum efficiency is decreased with the RF field and dropped into a stable level about 1%. We confirmed this stable quantum efficiency was not changed at least five weeks operation.

The beam quality of ATF was improved by installing the RF gun system. The beam tail was reduced so the beam loss was reduced. We can operate the multi-bunch beam with designed beam intensity. We use this RF gun system as an operating accelerator component.

## ACKNOWLEDGEMENTS

We would like to thank other members of ATF group. We also would like to express our gratitude to Professors Y. Kamiya and S. Enomoto for their continuous encouragement.

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