L-band Photocathode RF gun at KEK-STF

H Sugiyama¹, Y Takahashi², H Hayano¹, J Urakawa¹, S kashiwagi³, G Isoyama⁴, R Kato⁴, N Sugimoto⁴ and M Kuriki⁵

¹Accelerator Laboratory, High Energy Accelerator Research Organization (KEK), 1-1 Oho, Tsukuba, Ibaraki 305-0801 Japan.
²The Graduate University for Advanced Studies, School of High Energy Accelerator Science, 1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan.
³Research Center for Electron Photon Science, Tohoku University, 1-2-1 Mikamine, Taihaku-ku, Sendai 982-0826 Japan.
⁴Institute of Scientific and Industrial Research (ISIR), Osaka University, Mihogaoka 8-1, Ibaraki, Osaka 567-0047 Japan.
⁵Graduate School of Advanced Sciences of Matter, Hiroshima University, 1-3-1 Kagamiyama, Higashihiroshima, Hiroshima 739-8530 Japan.

E-mail: harues@post.kek.jp

Abstract. The superconducting RF test facility (STF) in KEK is a facility to promote R&D of the International Linear Collider (ILC) cavities and cryomodule. L-band photocathode RF gun has been developed at KEK-STF as an electron beam source for cryomodule test scheduled in autumn of 2011. The RF cavity of the gun will be operated with a 1.3 GHz RF frequency, 1 msec RF pulse width, 5 Hz repetition rate at normal conductivity. The cavity was prepared by collaborative work with DESY and FNAL, and fabricated by FNAL. The RF conditioning of the cavity has been started since April 2010. A cesium telluride thin film as a photocathode material has been adopted, and the preparation equipment for cesium telluride has been newly designed and constructed. By using this new system, a fabrication and a performance estimation of the cesium telluride thin film as a photocathode are the next step of the research.

1. Background
The superconducting RF test facility (STF) in KEK is a facility to promote R&D of the International Linear Collider (ILC) cavities and cryomodule [1]. In STF, the “S1-Global cryomodule experiment” which is aiming to achieve ILC high gradient cavity performance by the international collaborative effort using DESY, FNAL and KEK cavities, is under execution [2]. After the S1-Global experiment finished in 2010, the construction of STF phase 2 accelerator will start in 2011. The phase 2 accelerator consists of an RF gun electron source, superconducting capture cavities, and ILC cryomodule. An L-band photocathode RF gun that will be used there has been developed at KEK-STF as a low emittance and high charge electron source, which has ILC, beam structure for charge and bunch spacing.

2. Overview of RF gun at KEK-STF

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The cavity of RF gun has 1.5 cells and a resonance frequency at 1.3 GHz was fabricated by FNAL under KEK-FNAL collaboration, and the used design was based on DESY RF gun under DESY-FNAL collaboration. The RF gun used a photocathode on the cathode plug in the cavity end plate. The cathode plug is inserted from the backside of the cavity end plate. And a cesium telluride thin film is deposited on the cathode plug. The cesium telluride preparation chamber is connected in the back of the cavity. The solenoid magnets are placed around the cavity. To cancel the magnetic field on the point of cathode, there is a backing coil in addition to a main coil in the solenoid. A ceramics RF window is used in the waveguide to keep vacuum in the cavity. There are ion pumps connected to the waveguide; one is 100-litre/sec evacuation and the two are 200 litre/sec evacuations for the pumping of the cavity. Also there is an ion pump of 200 litre/sec evacuation for the preparation chamber. During a deposition of cesium telluride thin film, the cavity can be separated from the preparation chamber by a gate valve. The cathode plug is movable between the cavity end plate and the preparation chamber by the motor driven push rod behind the preparation chamber.

**Figure 1.** Overview of L-band RF gun at KEK-STF

### 3. RF conditioning of the gun cavity

An RF conditioning of the cavity was carried out at up to 1.7 MW of PF power, 1 msec of the pulse width, 5 Hz of repetition rate, from April to May of 2010. The conditioning is performed to keep the vacuum in the cavity less than $10^{-6}$ Pa when the power reached at 1.7 MW. Fig 2 shows a conditioning history of a day for a power of 1.7MW. The green line shows forward RF power into the cavity, and the sky blue line is for the reflected RF power. The reflection was kept well small as the forward power went to 1.7 MW. The red line shows vacuum level of the cavity. It was also kept well below $10^{-6}$ Pa with spike sometime, however, the vacuum level of the preparation chamber (blue line) was not spiky.

**Figure 2.** A conditioning history of a day

**Figure 3.** Chiller water temperature vs RF Power.
The RF power was tuned on with 1.3 GHz at 51.5 degree C of the cooling water temperature. However, a detuning of the cavity occurred due to a thermal action by applied RF power. Therefore the set point of the temperature of the chiller was required to let down as a power rise. The targeted power 3.5 MW (corresponding to 40 MV/m on the cathode surface) needs 43 degree C of the chiller water temperature as shown in Fig 3. The chiller that is used seems to be sufficient to reach the target RF power. The conditioning of the cavity in now suspended to carry out the S1-Global experiment. The resuming of the conditioning is scheduled on April of 2011.

4. Cesium telluride preparation chamber

The cesium telluride preparation chamber is connected to the RF cavity backside directly. The motor driven manipulator for a transfer of the cathode plug to the RF cavity has a stroke of 500 mm. The cesium telluride thin film is fabricated on the surface of the cathode plug directly in the preparation chamber. The tellurium and cesium sources are mounted on a vertical manipulation shaft in series. The thickness of a tellurium film can be maintained with monitoring by a quartz thickness meter (INFICON, SQM160) and with a current control of a heating wire for tellurium. A cesium deposition can be carried out in control a photocurrent. The quantum efficiency is measured using an UV-LED (central wavelength on 261 nm, PicoQuant, PLS 265-10) and with a pico-ammeter incorporated a voltage source (> +/- 500 V, Keithley, 6487). The in-situ measurement for the quantum efficiency of the cesium telluride thin film photocathode can be carried out in the preparation chamber after the fabrication, and then the film on the surface of the plug can be installed to the RF cavity without air exposure. The wasted thin film can be removed by a heating wire inside the plug at a temperature of 550 degrees C. The temperature can be monitored using a radiation thermometer (IMPAC, IPE140) that has a range from 30 to 1000 degrees C through a sapphire glass. The commissioning of the preparation chamber is underway for cathode plug cleaning and for cesium telluride deposition.

5. Cathode plug

The cathode plug and the cathode periphery equipments are required to be made from non-magnetism materials. The cathode plug is made from a molybdenum block. The molybdenum has a large reflectivity for an UV light. A part of the UV light goes through out the thin film, and then reflected light on the molybdenum surface goes back to the thin film again. A molybdenum surface is suitable for the substrate of the thin film photocathode with UV light driven. In this system, the wasted thin film will be cleared off using a heating up the cathode plug at 550 degree C directly. Usually an RF
contact of the cathode plug is made from beryllium copper alloy. However, the contact that made from beryllium copper alloy is lost elasticity by heated up to around 400 degrees C. Hence, in this system, a beryllium copper as a material of RF contact cannot be adopted. Considering this effect, we adopt an Inconel750X that is high temperature tolerant for a material of an RF contact.

6. Summary
The L-band photocathode RF gun has been developed at KEK-STF for beam source of the cryomodule test. The 3.5 MW RF power is targeted for beam operation, and now is conditioned up to 1.7 MW. The conditioning will resume on April 2011. The cesium telluride preparation chamber and the cathode plug are already fabricated. The fabrication and the performance estimation for the cesium telluride thin film as a photocathode are under commissioning.

Acknowledgements
This research was partially supported by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Scientific Research(C)-226040140017.

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