UPGRADE OF CARTRIDGE-TYPE EXCHANGEABLE NA_2KSB CATHODE RF GUN

Y. Nakazono, M.Kunihiro, A. Sakumi and M. Uesaka Nuclear Professional School,
the University of Tokyo, Ibaraki, Japan

Abstract

Photocathode RF gun with cartridge-type cathode exchanging system produces high-brightness low-emittance sub- or femto second electron bunches. A cathode without breaking the vacuum of RF gun was replaced and a high quantum efficiency (QE) photocathode such as Ce_2Te or Na_2KSb was used. Using the photocathode LINAC system, the application for observation of physico-chemical reactions by pulse radiolysis system in a time-range of picoseconds and sub-pico seconds was investigated. The important factors for the fast radiation chemistry are the pulse length of the beam, the synchronization between beam and laser and the electro beam current. Na_2KSb photocathode is the workable cathode and has been widely used for photomultipliers which can be driven by visible light. The workfunction of Na_2KSb is 2.0 eV, which is the sum of the energy gap 1.0 eV and the electron affinity 1.0 eV. A Na_2KSb photocathode was installed into RF cavity and the RF was aged. After aging for 12h, the UV light (266 nm ; third harmonic of Ti:Sa laser 800 nm) and 400nm visible light (second harmonic) were brought in the Na_2KSb cathode. The maximal charge was 3.1 nC at 266 nm and 1.6 nC at 400 nm. The saturation of the beam current caused by space charge limit was observed. The saturation charge at 400 nm was half of that at 266 nm. The life time of the cathode was measured. The half life time of the cathode was 100h. The damping of the quantum efficiency occurred rapidly and it reached 1/5 after 280 h. The QE remained about 0.1% after 500 h.

INTRODUCTION

The RF gun driven by photocathode has been developed and researched because of the high energy, low emittance and shorter pulse. They fulfilled a great roll in application for metical and industrious field as an injector for high energy accelerators. Experiments to clarify the femto second quantum phenomenon for the pulse-radiolysis of radiation chemistry have been conducted at the Nuclear Professional School of the University of Tokyo in figure 1 and 2. The modification to improve the quality of electron beam for linear accelerators driven by the electron gun with photocathode is required.

PHOTOCATHODE RF GUN

Photocathode RF gun with cartridge-type cathode exchanging system produces high-brightness low-emittance sub- or femto second electron bunches. We can replace a cathode without breaking the vacuum of RF gun and use a high quantum efficiency (QE) photocathode such as Ce_2Te or Na_2KSb.

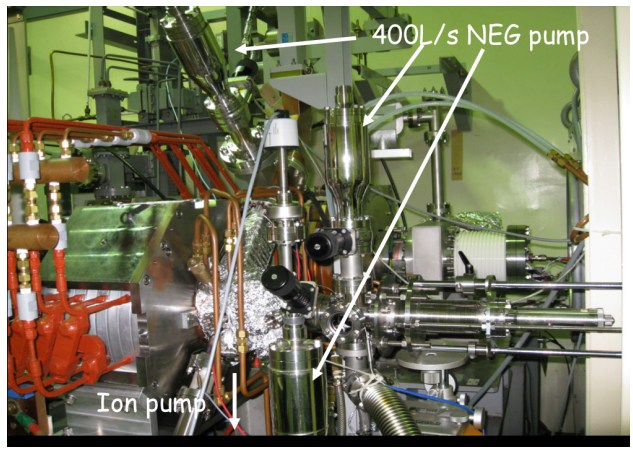

Figure 1: Photograph of the beam line around the RF gun with the photocathode system

The photocathode RF gun is the equipment to accelerate electrons generated by irradiation with photoelectric effect. The semiconductor photocathodes such as Cs-Te should be kept in ultra high vacuum from fabrication the membrane to introduction to RF gun. The cartridge type system was used at the linac at the University of Tokyo with Spring-8 and Hamamatsu Photonics K.K.. The evaluation of Cs-Te photocathode with cartridge system was fulfilled at Spring-8. The QE of Cs-Te is about 3-4 %.

18MEV S-BAND LINAC AT UNIVERSITY OF TOKYO

Using the photocathode LINAC system, we investigate the application for observation of physico-chemical reactions by pulse radiolysis system in a time-range of picoseconds and sub-pico seconds. The important factor for such as fast radiation chemistry is pulse length of the beam and synchronization between beam and laser but also the electro beam current.

The purpose of the present study is to improve the quality of the electron beam from the linac and RF gun, which produces electrons.

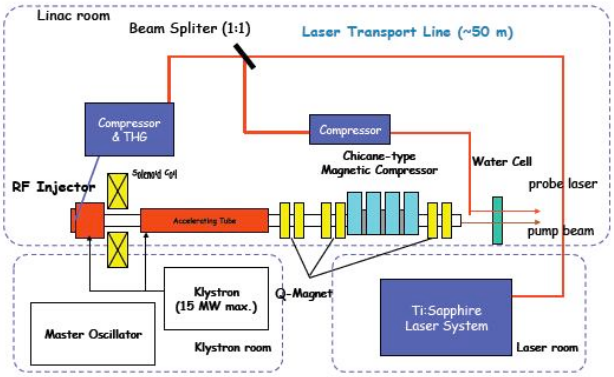

Figure 2: Schematic of S-band linac

NA_2KSB PHOTOCATHODE

Na_2KSb photocathode is the workable cathode and has been widely used for photomultipliers which can be driven by visible light shown in figure 3. The workfunction of Na_2KSb is 2.0 eV, which is sum of the energy gap 1.0 eV and the electron affinity 1.0 eV.

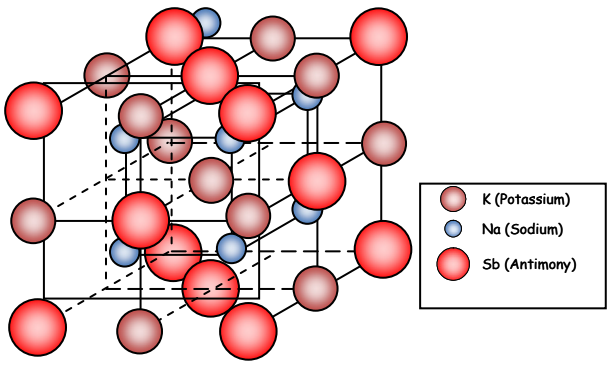

Figure 3: Crystal structure of Na2KSb

EXPERIMENTAL RESULTS

We installed Na_2KSb photocathode into RF cavity and did RF aging. After aging (about a half day), we irradiated the UV light (266 nm ; third harmonic of Ti:Sa laser 800 nm) and 400 nm visible light (second harmonic) for commissioning Na_2KSb cathode. The cathode surface after 800 h operation by a microscope were observed with Discharge caused deterioration of surface and much dark current mearsured during operation (20 nA).

RESULTS AND DISCUSSION

The maximal charge is 3.1 nC at 266 nm and 1.6 nC at 400 nm. The saturation of the beam current caused by space charge limit was observed. The saturation charge at 400 nm is half of that at 266 nm. We also measured the life time of the cathode. The half life time of the cathode is 100 h. The damping of the quantum efficiency occurred rapidly and it reached 1/5 after 280 h. The curve became slowly and quantum efficiency remained 0.1% until 500h

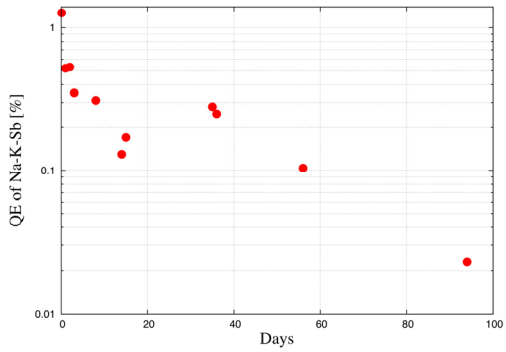

Figure 4: Quantum efficiency of the Na_2KSb system photocathode.

The quantum efficiency of the Na_2KSb system photocathode decreased as time passed shown in figure 5. The QE gradually decreased during 100 days with the linac operation. It showed a gradual QE drop in more than 3 months from about 1% to 0.01%.

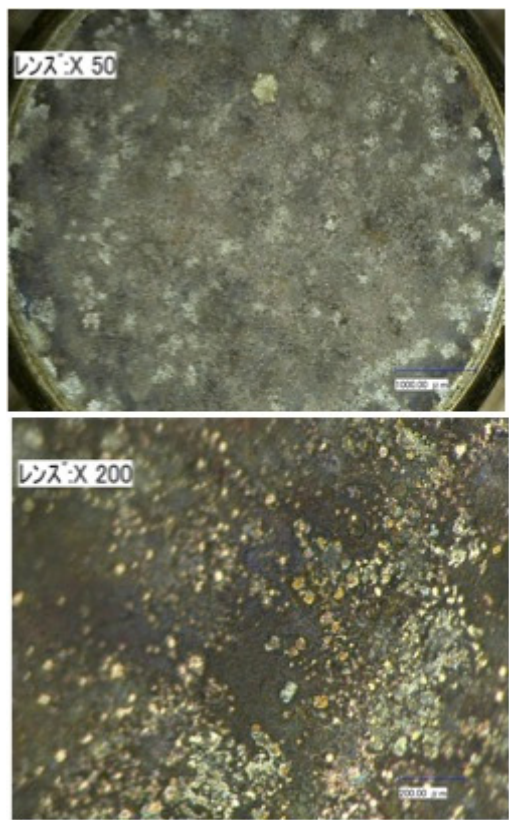

Figure 5: Optical microscope images for the surfaces of photocathode after induced RF electrical field, which the RF gun was located at the each right side of them.

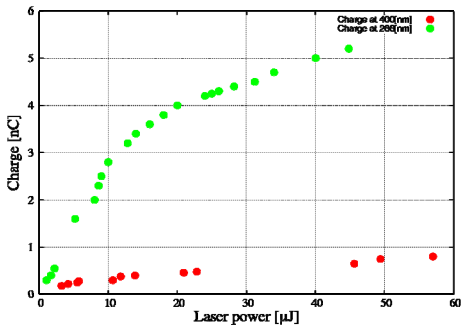

Figure 6: Quantum efficiency of the Na_2KSb system photocathode.

The QE changes during 90 h with the linac operation. It showed QE is about 0.15% for 266 nm wave length and 0.045% for 400 nm shown in figure 6.

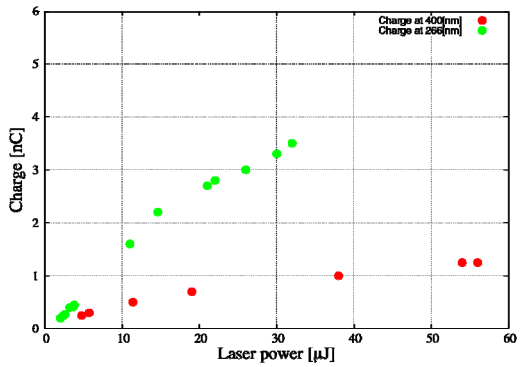

Figure 7: Result of Na_2KSb photocathode experiment in 200 h after injected.

QE was 0.066% for 266 nm and 0.02% for 400 nm, respectively. Figure 7 shows the value of the charge for each laser power is lower than that of after 90 h.

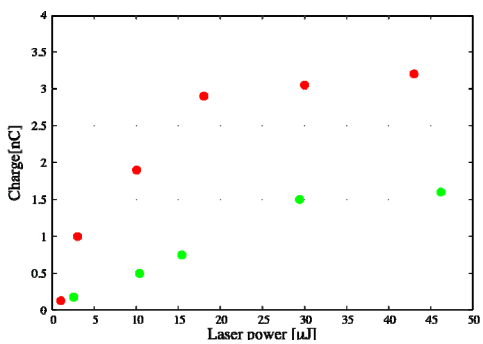

Figure 8: The result of Na_2KSb photocathode experiment in 90 days after injected.

Many sparks were observed during the experiment to measure 400 nm. The charges for each laser wave length show were saturated more than 20 μJ shown in figure 8.

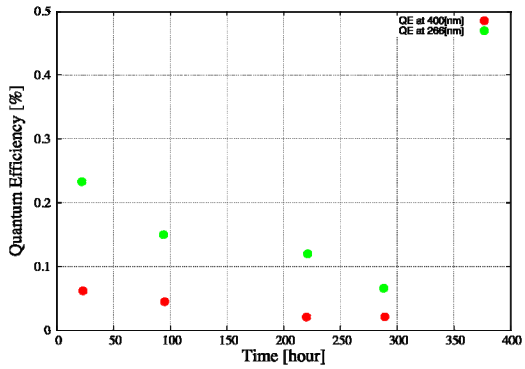

Figure 9: Measurement for amount of charges with Na_2KSb photocathode.

The result of Na_2KSb photocathode experiment in 220 h after injected shown in figure 9. There seems to be difference between 266 nm and 400 nm in view of the saturation of charges effect.

CONCLUSION

The maximal charge was 3.1 nC at 266 nm and 1.6 nC at 400 nm. The cartridge type cathode of Na_2KSb drove the linac by visible light with RF gun. The saturation of the beam current caused by space charge limit was observed. The saturation charge at 400 nm was half of that at 266 nm. The life time of the cathode was measured. The half life time of the cathode was 100 h. The damping of the quantum efficiency occurred rapidly and it reached 1/5 after 280 h. The QE remained about 0.1% after 500 h. The quantum efficiency and maximum charge of Na_2KSb photocathode were measured. The charge of 3.1 nC at 266 nm and 1.6 nC at 400 nm was observed. The new side-couple π/2 mode S-band RF gun was designed.

REFERENCES

[1] M.Uesaka et al., Radi.Phys. Chem, 60 (2001).
[2] Y.Muroya et al., Nucl. Instr. and Meth. A, 489 (2002)
[3] H. Moritani, Master thesis, Univ. of Tokyo (2007)
[4] J.Sasabe et al., Proc. 2005 Nucl. Instr. and Meth. A, 528(2004).
[5] H.Dewa et al., Proc of the 28th Linear Accelerator Meeting in Japan, 2003
[6] J.Sasabe et al., Nucl. Instr. and Meth. A. 528 (2004) p.382-386
[7] N.Terunuma et al., Nucl. Instr. and Meth. A. 613 (2010) p.1-8
[8] K.Kambe et al., "Electromagnetic Heat Design of S-Band Linac", Proceedings of Particle Accelerator Society of Japan (2009)
[9] K.Miyoshi et al., Particle Accelerator Conference 2009
[10] Hamamatsu Photonics K. K. Evaluation Report