HIGH CHARGE MG PHOTOCATHODE RF GUN IN S-BAND LINAC AT UNIVERSITY OF TOKYO

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Abstract

Aiming to generate a electron bunch with tens nC, a Mg photocathode RF gun, which is manufactured especially by precise machining and diamond polishing in order to decrease a dark current, has been constructed and installed to an S-band linac at Nuclear Engineering Research Laboratory, University of Tokyo. Quantum efficiency of the Mg cathode is measured to be 1.3×10^{-4} before laser cleaning. 4 nC/bunch is obtained for 210 μJ laser (265 nm). Horizontal and Vertical emittance are measured to be 80 πmm-mrad and 40 πmm-mrad. Electron energy and compressed-bunch duration is measured to be 22 MeV and 0.7 ps (FWHM) respectively. Radiation chemistry experiment is started using the RF gun.

1 INTRODUCTION

Pulse radiolysis method is a useful and powerful technique for studying chemical reactions. At Nuclear Engineering Research Laboratory (NERL), University of Tokyo, intensive researches using the pulse radiolysis method have been carried out not only in aqueous solutions but also in organic liquids and polymeric systems [1]. Especially, the chemical reactions of hot, room temperature and critical water in a time range of picosecond and sub-picosecond are interesting phenomena. The pulse radiolysis method in the ultra-short-time range has been realized in a S-band linac with a photocathode RF gun as shown in Fig. 1. The S-band linac, which provides an electron bunch as a pump-beam, consists of the photocathode RF gun, an accelerating tube and a chicane-type bunch compressor. Driven laser for RF gun and a probe-laser are generated from a Ti:Sapphire laser, which produces a laser light with wavelength of 795 nm, energy of 30mJ/pulse, pulse duration of 300 ps and repetition rate of 10 pps. The laser light is split in order to realize precise synchronization between the pump-beam and the probe-laser. A third harmonic generator (THG) is provided the driven laser whose wavelength is 265 nm, energy is a few hundred μJ/pulse and pulse duration is a several picosecond.

So far, a Cu was used as the photocathode of RF gun [2]. We achieved to generate the electron beam with maximum charge of 7 nC/bunch, lowest emittance of 6πmm-mrad and shorter bunch width of 240 fs (FWHM) using the RF gun. The synchronization between the

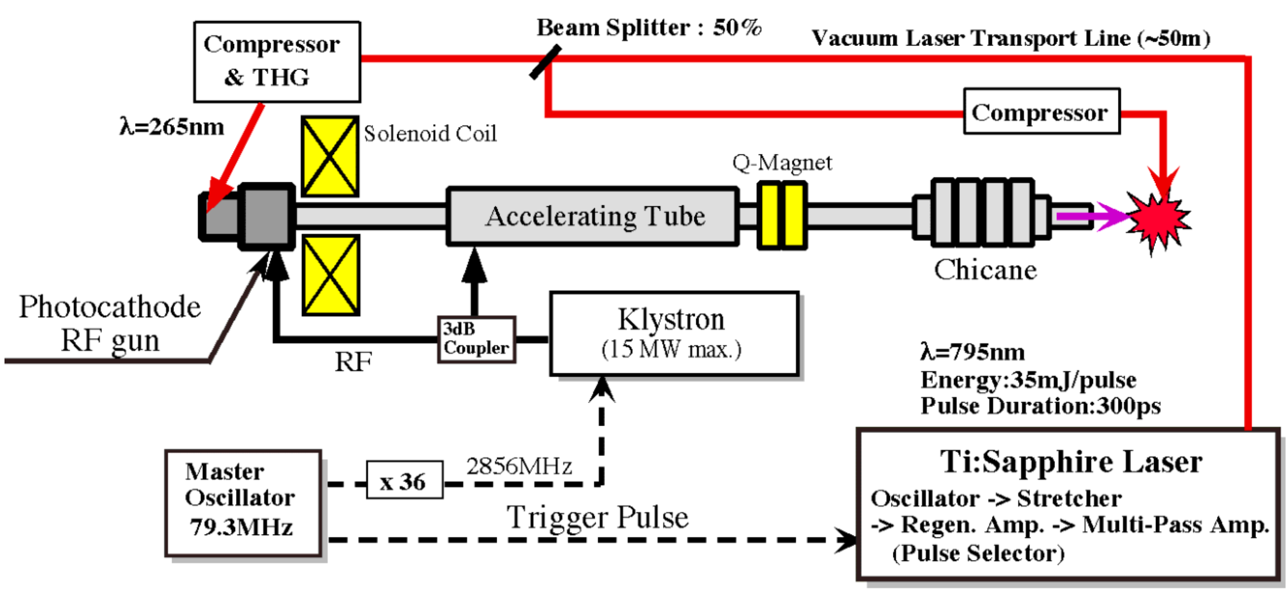

Figure 1: S-band linac system for sub-picosecond pump- and probe-type radiation chemistry.

pump-beam and probe-laser was measured to be 320 fs (rms) for a few minutes and 1.9 ps (rms) for a few hours [3]. Although a performance of the Cu photocathode RF gun was achieved as mention above, various stabilities have to be improved. For example, it is difficult to provide a few nC high charge until sub-picosecond short bunch width. The beam with the charge of less than 1 nC/bunch and the bunch width of larger than 1 ps was generated stably. In this case, the signal-to-noise ratio for the pomp-and-probe experiment was not enough. The synchronization should be stable for the longer time to accomplish the chemical reaction of the water experiment. For that reason, we started to construct a new RF gun with Mg photocathode. A quantum efficiency (QE) of the Mg, which is in the order of 10^{-3}, is 10 times larger than one of Cu, so that dense electron bunch is able to be produced. In addition, we have improved an air conditioner in the linac room, because we considered that the instability of the synchronization was caused by a fluctuation of temperature in the room.

In this article, we report updated performance of the Mg cathode RF gun and new results.

2 MG PHOTOCATHODE RF GUN

2.1 RF gun cavity

The Mg photocathode RF gun (BNL Gun-IV type) has been constructed in cooperation with SPring-8, KEK, SHI, Waseda University and BNL. To decrease a dark current, the inner wall of the cavity was diamond-precise machined and the cathode plate was polished using diamond powders whose sizes are 3μm and 1μm in diameter. Roughness of the cavity wall and the cathode plate are tens nanometer and less than 1 μm respectively. The gun was baked for 7 days at 150 °C and 48 hours at

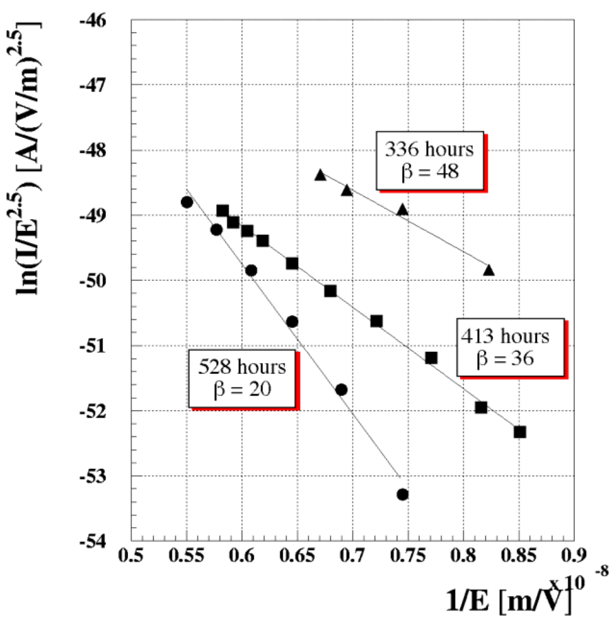

Figure 2: The Fowler-Nordheim plot.

120 °C before and after installation to the linac. A vacuum condition is kept to be less than 5×10^{-10} Torr during gun operation. The aging of the gun was carried out carefully for 528 hours (22 days). Figure 2 shows the Fowler-Nordheim plot. Each point indicates the measured value after each aging (triangle points indicate after 336 hours, squares are after 413 hours and circles are 528 hours). The enhancement factor β calculated by the fitting are 48, 36 and 20, respectively. In case of the Cu cathode, for which aging was performed rapidly and many discharges were occurred, β was typically 80-100. The dark current is measured to be 600 pC/pulse for RF power of 6.6 MW, pulse width of 2 μs and repetition rate of 10 pps at present.

2.2 Quantum Efficiency

The charge was measured using the Faraday cup set downstream of a solenoid coil (see Fig. 1). The charge as a function of the driven laser energy is shown as Fig. 3.

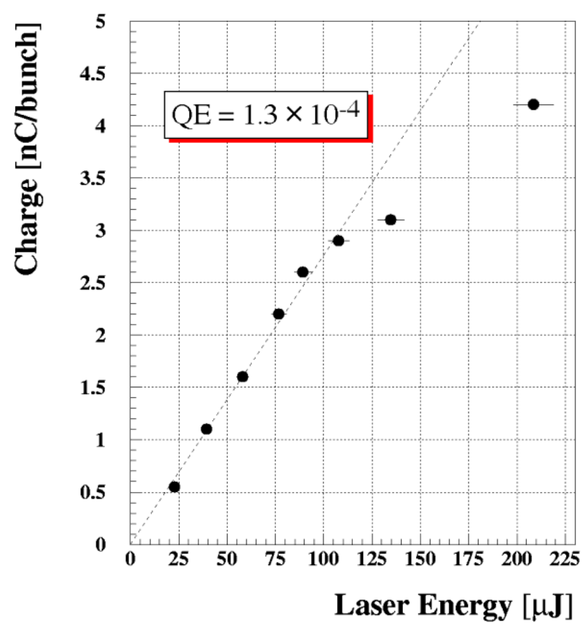

Figure 3: The charge as a function of the laser energy.

During the measurement, the RF power is 6.6 MW, the RF pulse width 2 μs, the repetition rate 10 pps and a spot size of the laser larger than 3 mm in diameter. Magnitude of the solenoid coil, which is in the range of 1.0-1.8 kGauss, and the RF phase for the cathode laser injection are optimized to charge-maximum. A dash line as shown in Fig. 3 is a fitting result of QE, where 5 points up to 100 μJ/pulse are used for fitting. The QE is calculated to be 1.3×10^{-4}, which is as same as that of Cu (1.6×10^{-4}). Generally the QE of the Mg without a treatment for the surface, such as the laser cleaning, is in the order of 10^{-5} due to the oxide-layer on the surface [4]. Our Mg cathode was kept in helium gases immediately after diamond polishing, and the cathode was in the air for almost 2days for installation. Therefore, we may consider that QE is higher owing to few oxide-layer. However, it is 1/10 as smaller as the expected value currently.

QE looks saturated over 3 nC/bunch. Distance between the end of solenoid coil and the Faraday cup is about 50 cm and this drift space has 2 cm diameter. Consequently the high charge is cut off by the beam duct.

3 BEAM TEST

3.1 Beam Energy and Emittance

Energy of the electron beam is measured using a magnetic analyzer. The energy is 22 MeV for the RF power of 6.6 MW feeding.

Normalized emittance (rms) was measured by the quad scanning using the Q-magnet set downstream of the accelerating tube. The results are obtained to be approximately horizontal emittance of 80 πmm-mrad and vertical emittance of 40 πmm-mrad. On this occasion, the charge is 2 nC/bunch and the bunch duration was approximately 10 ps (FWHM). Now we don't conclude a reason of such high emittance, but we may consider that a bad shape of the laser profile, which is not Gaussian, makes the emittance grow.

3.2 Bunch Compression

The electron bunch is compressed using the chicane type magnet assembly (see Fig. 1). The compressed bunch passes through the Xe chamber in which the electron bunch emits the Cherenkov light. The bunch duration is observed using the streak camera (Hamamatsu, FESCA), via the Cherenkov light. Figure 4 shows a typical streak image of single bunch, where the bunch duration is measured to be 0.7 ps (FWHM).

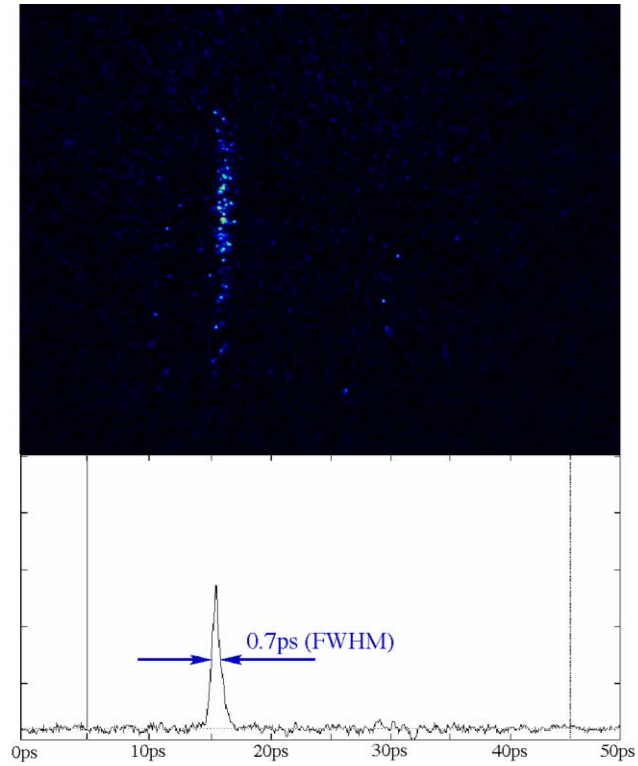

Figure 4: Streak image of the Cherenkov light.

4 CONCLUSION AND DISCUSSION

The Mg photocathode RF gun, which is performed precise machining and diamond polishing in order to decrease the dark current, has been constructed and installed to the S-band linac. QE of the Mg cathode is measured to be 1.3×10^{-4}, before laser cleaning. However, we wish to generate higher charge beam with tens nC/bunch. The energy of 22 MeV, the horizontal emittance of 80 πmm-mrad, the vertical emittance of 40 πmm-mrad and the bunch duration of 0.7 ps are measured.

The synchronization is studying and measuring now. To attain the dense electron bunch due to high quantum efficiency of the Mg cathode, the laser cleaning system has to be adopted, and the magnetic optics after the RF gun should also be reconsidered. Therefore, we are investigating the cleaning system and the optics. After the synchronization study, the pump and probe experiment for the chemical reaction in water will start.

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