Development of High Duty Operation RF Photoinjector

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Abstract

A RF photoinjector for the high duty operation was designed and constructed by the BNL/KEK/SHI international collaboration and installed at the S-band linear accelerator of the University of Tokyo. Subpicosecond electron bunches compressed by a magnetic compression is planned to be used for the subpicosecond X-ray generation and the laser acceleration. Preliminary experiments of the RF photoinjector were performed. The measured value of the Cu cathode's quantum efficiency was 5×10^{-5}.

1 Introduction

Technologies to obtain high brightness electron bunches with a low emittance and a short duration have been studied with photocathode RF guns using short pulse lasers in order to apply for new technologies, laser accelerator, FEL, X-ray generation by Compton scattering and so on[1),2)]. More than ten years photocathode development and recent short pulse laser development, the photocathode is emerging as a standard laboratory tool for high brightness electron beam applications.

Laser wakefield accelerator (LWFA) expected as a compact high energy accelerator with high gradient particle acceleration has been studied. JAERI, KEK and the University of Tokyo have studied LWFA using a linac with a thermal electron gun, a magnetic compressor, and a TW laser with 100fs pulse length[3)]. In order to get the low emittance and short bunched electron beam and also to accelerate higher efficiently, a RF photoinjector as a electron source was installed at this time.

RF photoinjector technologies has been integrated in Brookhaven National Laboratory(BNL)[2)]. Recently, 1.6 cell RF photoinjector has been developed by the BNL/SLAC/UCLA collaboration[4)]. Based on this development, the improvement for high duty operation was performed by the BNL/KEK/SHI collaboration. Major improvements were water cooling channels removing RF heat and RF seal structure of a cathode plate. In the following section, the thermal analysis of the RF photocathode and the other systems such as the solenoidal magnet, a laser and diagonostic system is reported. The results of preliminary experiments are also reproted.

2 RF photoinjector system

The RF photocathode injector system shown in Fig.1 consists of a photocathode, a solenoidal magnet, diagnostic system with a faraday cup and a beam profiler, and a adjustable basement. The RF photoinjector developed by BNL/SLAC/UCLA collaboration was installed alomost one year at Brookhaven Accelerator Test Facility (ATF). The data shows that the basic design for the low emittance and the short bunch was confirmed. Improvements for high duty operation are reported as follows.

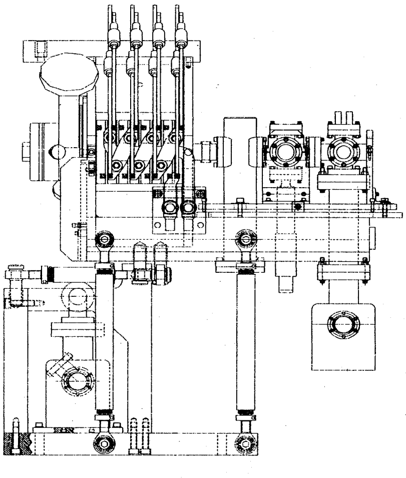

Fig.1 Rf photoinjection system

2.1 Thermal analysis

Major improvements for high duty operation are the seal structure of the photocathode plate and the water cooling channels.

Our RF design power is a 6MW peak with a 3.5 μ pulse width and a 50Hz repetition rate. The RF power loss distribution on the Gun surface was calculated by a SUPERFISH code. Thermal analysis shown in Fig.2 was performed by a program code FLUENT. Considering the heat balance of the gun surface , the minimum cell to cell coupling change and the structure of the gun which has several ports, such as laser ports, waveguide and vacuum port, the position of cooling channels were decided. As a results of thermal analysis, temperature difference of coupling iris is within 3 C so that coupling change is less than 2%.

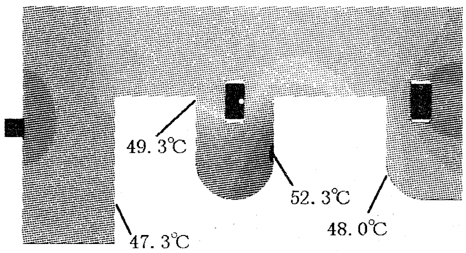

Fig.2 Temperature distribution

2.2 Solenoidal magnet

Single emittance compensation magnet was constructed. The measurement of the magnetic fields at the center and 1 cm away from the center shown in Fig. 4 shows the flat field at the off-axis. The maximum magnetic field is 3 k-gauss and the magnetic field at the cathode surface is 15 gauss. The emittance growth estimated is 0.15 π mm · mrad at the maximum field. A bucking coil is usually used to cancel the magnetic field at the cathode surface. Considering the construction of the bucking coil and the space for changing the cathode plates, it was decided that the bucking coil was not needed in our case.

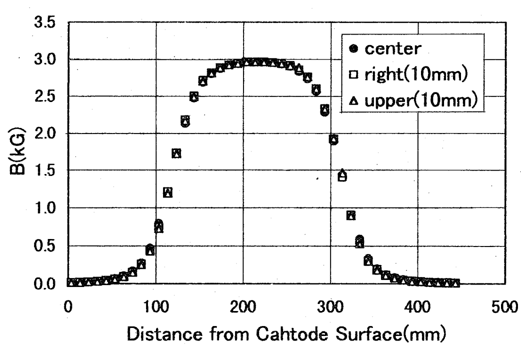

Fig.3 Magnetic field of solenoidal coil

2.3 Laser

A Nd:YLF all solid laser was constructed for a driver of the photocathode. A oscillator is LW131 manufactured by Lightwave Electronics. A regenerative amplifier manufactured by Sumitomo Heavy Industries, Ltd. is pumped by two diode laser. All solid laser allows for compactness and stability. The forth harmonics of fundamental of Nd:YLF is illuminated on the cathode. The FWHM pulse width of the second harmonic was measured to be 25ps which implys that one of the forth harmonic was 18ps.

2.4 Diagnostic

A faraday cup, a phosphor profile monitor and a Al mirror for the observation of the cathode surface are installed as diagnostic tools. Charge signals from the faraday cup made of was measured by an oscilloscope directly and calibrated by a current moniter. The phospher screen was used for the measurement of the bunch length. Prompt light from the Desmarquest phosphor screen is measured by a femtosecond streak camera(FESCA) with a 200fs resolution.

3 Preliminary experiment

Preliminary experiment of the RF photoinjector system was performed using the diagnostic system between the RF photoinjector and the a linac.

The 79MHz RF for the mode locked Nd:YLF laser and the 2856MHz RF for the linac were generated from the 119MHz RF of a master oscillator. Trigger signals synchronizing the linac RF pulses and the FESCA with illuminating light were picked up from the laser.

UV light illuminating the photocathode was quadrupled from the 1057nm fundamental of the Nd:YLF laser by two BBO nonlinear crystals. UV light was injected to the photocathode with an oblique angle, because P-polarization component is well known to enhance the quantum efficiency.

The quantum efficiency versus the laser injection phase and polarization angle was measured by the faraday cup. Pulse length was also measured to use the prompt fluorescence from the Desmarquest by the FESCA.

3.1 QE measurement

The electron charge versus the laser injection phase is shown in Fig.4. The laser energy was 40 μ J. The phase at maximum charge indicates the peak field, because the electrons emitted at the high field is enhanced by the Schottkey effect[5]. The quantum efficiency at the peak charge is 5×10^{-5}.

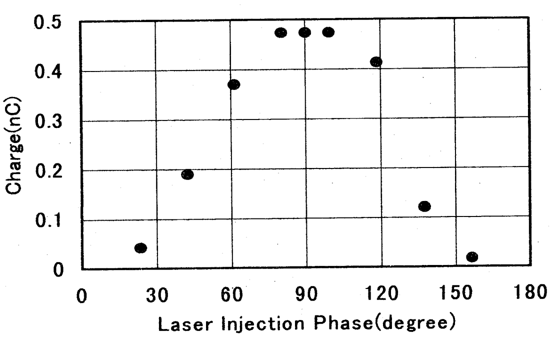

Fig.4 Electron charge emitted from the cathode versus laser injection phase

The electron charge emitted from the cathode is dependent on the polarization of the illumination light. The electron charge versus the polarization of light is shown in Fig.5. The polarization of light was changed with a 1/2 λ plate. It can be seen that available charge is maximized at a polarizer angle of 97 degree which corresponds to P-type polarized light on the cathode.

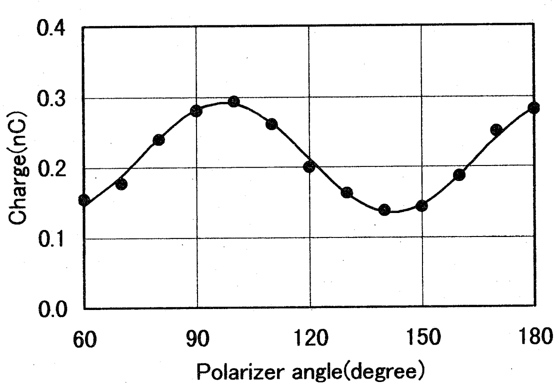

Fig.5 charge emitted from the cathode vs. Polarizer angle

3.3Pulse length

The pulse length measurement was performed by the FESCA using the prompt fluorescence from the Desmarquest phosphor screen. The bunch length versus the laser injection phase is shown in Fig.6. The data of 100 shots accumulated and single shot are shown. It can be seen that the jitter of system such as laser fluctuation is around 10ps. Due to the laser power limitation, this experiments was not performed with the electron charge constant, but the laser power constant. The charactristics of the prompt fluorescence from the Desmarquest has not been recognized well, however,it was confirmed that this method was a convinient tool in this bunch region. The bunch length measurement in the subpicosecond region with the prompt fluorescence and the Cherenkov radiation will be performed after accelerating by the linac.

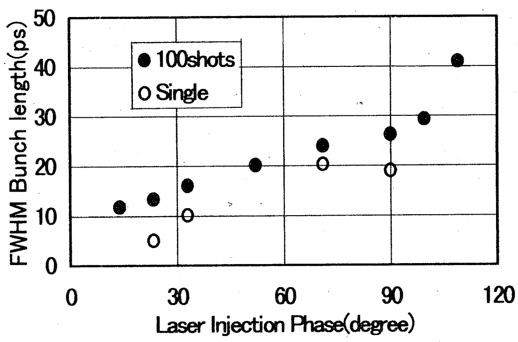

Fig.6 Electron bunch length vs. laser injection phase

4. Summary

The RF photocathode injector designed and constructed by the BNL/KEK/SHI collaboration was installed in the University of Tokyo. It was confirmed that the system of the RF photocathode injector was working. At next steps, electron emitted from the photoinjector is accelerated with the S-band linac, so more characteristics of the RF photoinjector such as the energy, the emittance, and the bunch length, will been studied.

Reference

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