

DEVELOPMENT OF A MULTI-BUNCH PHOTO-CATHODE RF GUN SYSTEM

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Abstract

A multibunch photo-cathode RF gun system has been developed as an electron source for the production of quasi-monochromatic X-rays based on inverse Compton scattering. This system consists of a photocathode RF gun, a cathode system, a laser system, a beam diagnostic section, and a control system. The gun produces 100 bunches with a 2.8 ns bunch spacing and 5 nC bunch charge. We report on the RF gun system with 4 bending dipoles of a chicane, which makes the laser injection to the cathode with perpendicular angle possible.

INTRODUCTION

We plan to produce a high flux x-ray for medical use with the compact system consisted of a S-band linac, a small storage ring [1], a mode-locked laser and a Fabry-Perot optical cavity [2]. The multi-bunch electron beam is necessary in this system. We have employed a laser-driven photocathode RF gun as a high intense electron beam source to produce the high flux x-ray. A RF gun test bench (RFGTB) is under construction at Assembly Hall in KEK to conduct the acceleration test of the high intense beam with low emittance and low energy spread.

A schematic layout of the RFGTB is shown in Fig.1. We use 357 MHz passively mode-locked laser and a Cs₂Te cathode that has high quantum efficiency (QE) of about 1% to generate the multi-bunch beam with 2.8 ns bunch spacing. 100-bunch electron beam of up to 7MeV with 5 nC bunch charge will be generated by the multi-bunch photo-cathode RF gun.

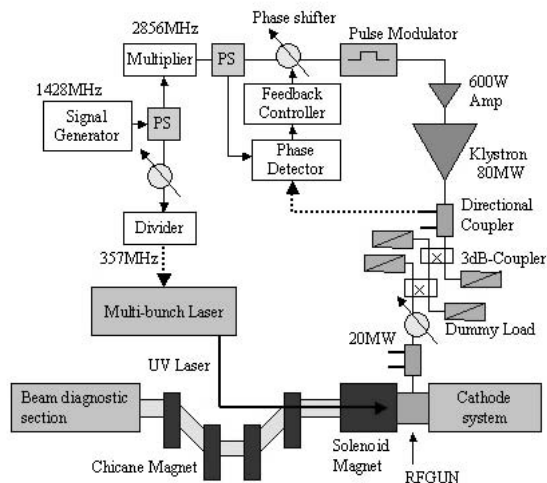


Figure 1: A schematic layout of the RFGTB

The UV light is injected to the cathode surface with perpendicular angle of 90 degree from the bump of 4 bending dipoles of a chicane. Beam dynamics studies have been done on the RF gun. Beam parameters are shown in Table 1.

Beam energy (max.)	7MeV
Bunch charge(max.)	5nC/bunch
Number of bunches(max.)	100/pulse
Repetition rate (max.)	12.5Hz
RF frequency	2856MHz
Bunch frequency	357MHz
Bunch separation	2.8ns
Photo-cathode	Cs ₂ Te
QE (aim)	>3%
Laser energy (aim)	>3μJ/bunch
Laser wavelength	266nm
Laser width (FWHM)	10ps
RF pulse width (max.)	4μs
RFGUN input power (max.)	20MW
Solenoid magnetic field (max.)	3.2kGauss
Chicane magnetic field	500Gauss

Table 1: Beam parameters.

EXPERIMENTAL SETUP

Photo-cathode RF GUN

The RF gun cavity is the same as 1.6 cell BNL GUN IV being used at injector of the Accelerator Test Facility (ATF) in KEK[3][4][5]. The end plate of the half-cell cavity has a hole with a diameter of 16mm to install a cathode plug in it. Fig. 2 shows the cross section of the RF gun and the cathode plug.

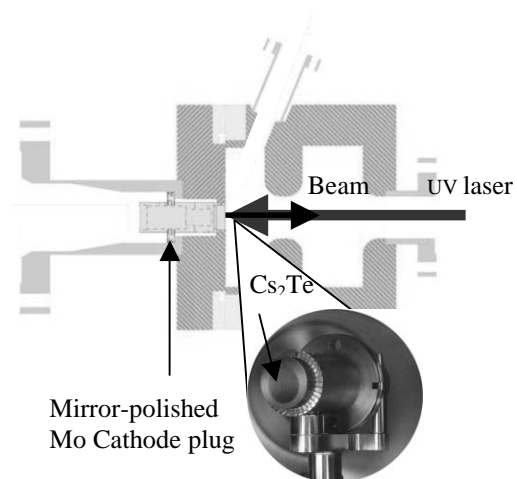


Figure 2: Cross section of the RF gun and the cathode plug.

The longitudinal accelerating field E_z has been measured as a function of the position in the RF Gun cavity using a frequency perturbation technique. The Q value was 10000. The shunt impedance was 66 M Ω /m. Fig.3 shows the on-axis electric field distribution in the RF gun cavity at the RF cavity power 15 MW. The peak RF input power of the RF gun can be up to 20 MW.

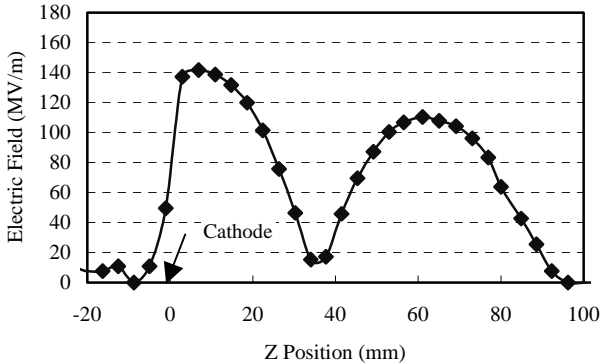


Figure 3: Electric field distribution in the RF gun cavity at the RF cavity power 15MW.

Cathode System

The cathode system consists of a loading chamber, a transport chamber, and an evaporation chamber. QE degrades rapidly by the oxygenation. This system allows to change and to transport the cathode plug without breaking the high vacuum. We load the cathode plug by the mover of the loading chamber. 5 cathode plugs can be stored in the preparation chamber with the transport chamber. Cesium is evaporated on a 10 nm thick Tellurium layer on the Molybdenum substrate of the plug in the evaporation chamber. The plug is transported to the loading chamber from the evaporation chamber by the transport chamber.

Laser system

A laser system consists of a mode-locked Nd:YVO4 oscillator with an output power 7W at 1064nm and two flash-lamp-pumped amplifiers with an end mirror.

The oscillator is 357 MHz passively mode-locked diode-pumped solid-state laser using semiconductor saturable absorber mirrors (SESAMs). Two pockels cells are used to select a portion of a 357 MHz pulse train. A wavelength of 1064 nm infrared (IR) light has 60 μ J each. The amplified pulse is spatially filtered and then frequency quadrupled to a wavelength of 266 nm ultraviolet (UV) light with pulse energy of over 3 μ J. The UV light of 2.4 μ J generates bunch charge of 5nC assuming QE of 1%.

Beam Diagnostic Section

Fig.4 shows the schematic view of the experimental setup. We will measure the emittance with slits and the wire scanner, the bunch length with a streak camera and a OTR system, bunch-by-bunch beam energy with an energy analyzer magnet and a beam position monitor. These quantities will be measured as a function of beam parameters and solenoid magnetic field among others.

Control System

Fig.5 shows the RFGTB control system. Since the system to be controlled is small-sized one, costly solutions were not acceptable. We adopted a PC-based control system with Experimental Physics and Industrial Control System (EPICS) [6].

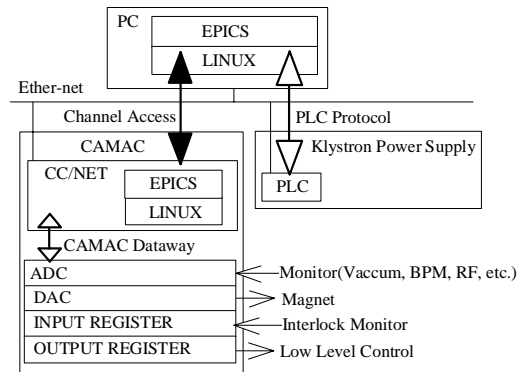


Figure 5: The control system of RFGTB

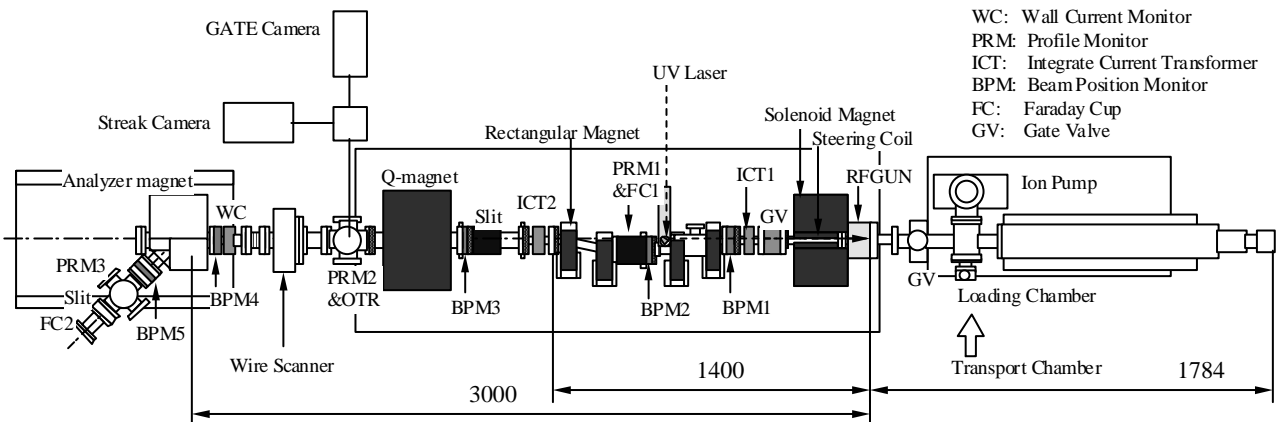


Figure 4: Schematic view of experimental setup

The control system comprises of three hardware components: a desktop PC, a Programmable Logical controller (PLC) and a CC/NET which is a special CAMAC controller with a PC/104 CPU board installed in it [7]. They communicate by Ethernet[8]. Each of the PC runs EPICS 3.14.4 on Linux operating system. The PC interfacing the PLC controls the klystron modulator. It also runs a graphical user interface and a data archiving tool of EPICS. The CC/NET controls the klystron RF power. A sequence control program of EPICS was developed for automatic RF conditioning.

SIMULATION

We simulated the beam trajectory for the beam line of the RFGTB with the chicane magnets by the general particle tracer code (GPT). In the simulation, bunch charge was fixed to 2 nC. Here, the laser injection phase of 90 degree corresponds to the maximum electric field 140MV/m on the cathode. The beam energy was 6MeV.

Launching the electron beam in the small laser injection phase compresses the bunch length in the RF gun cavity because the beam energy gain of the tail is higher than one of the head [9]. The simulation result shows that the beam can be transported to the end of the beam line without increasing the bunch length within the laser injection phase of 20 degree, as shown in Figs.6 and 7. In the same condition, the normalized emittance does not grow worse, as shown in Fig.8.

SUMMARY AND FUTURE PLAN

We have prepared the test bench to study the multi-bunch photo-cathode RF gun. The gun produces 100 bunches with a 2.8 ns bunch spacing and 5 nC bunch charge. The simulation shows that the bunch charge of 2 nC can be transported without greatly increasing the bunch length and the normalized emittance in the laser injection phase of 20 degree. We will start the beam test after RF conditioning of the RF gun cavity in July this year.

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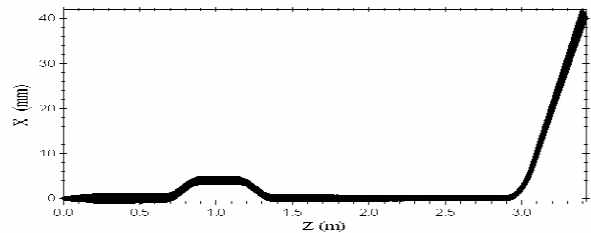


Figure 6: Horizontal beam trajectory as a function of a position from the cathode

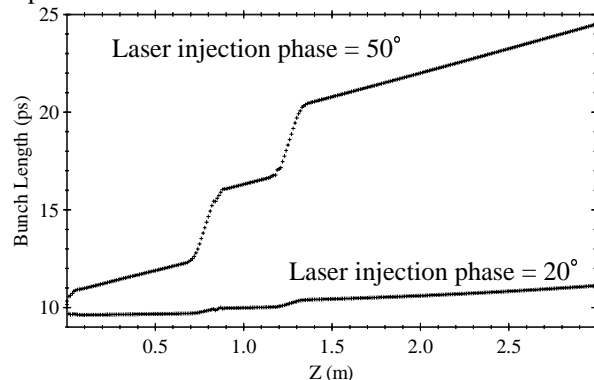


Figure 7: Electron beam bunch length as a function of a position from the cathode.

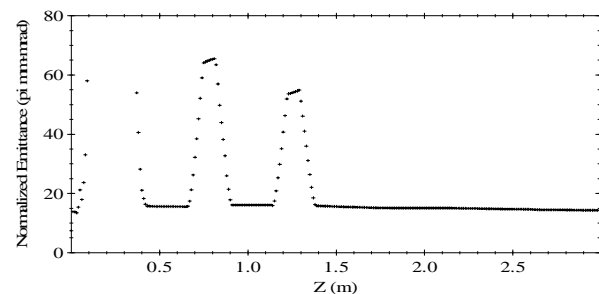


Figure 8: The normalized emittance in the laser injection phase of 20 degree.