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Project Outline of High Quality Electron Beam Generation at Waseda University

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Abstract

High quality electron beam generation project has been started at Waseda University under the grant of Ministry of Education, named High-Tech Research Center Project. In the project, we will install a laser photo-cathode RF Gun system with 1.6 accelerating structure cells of s-band and a stabilized RF power source. This RF Gun is expected to produce single electron bunch up to 1 or 2nC with around 10ps pulse duration.

1. INTRODUCTION

Ultra-short and low emittance electron beams are indispensable tool for the physical chemistry investigation in ionization and excitation processes of various kind of materials. Further, high quality X-ray beam with the pulse length of the pico- to femtosecond rime region can be generated by the Inverse Compton scattering process between high-brightness short pulse laser light and the high quality electron beam.$^{(1\text{-}4)}$

One of the most suitable way to generate the high quality electron beam is considered to apply a photo-cathode RF gun system. Recent rapid progress of the photo-cathode RF gun system conducted by the collaboration$^{(5)}$ among the BNL (Brookhaven National Laboratory), KEK (High Energy Accelerator Organization and SHI (Sumitomo Heavy Industries, ltd.) promises us to generate high quality electron beams to demonstrate the pulse radiolysis experiment at the picosecond time region. We have started the simulation work about the characteristics of electron beam obtained from the RF gun developed by above three organizations. In this paper we will present the project outline at Waseda University and some recent results by the simulation using the MAGIC code which can calculate the time domain electron beam trajectory under electromagnetic field.

2. RF GUN

2.1 RF gun system

The system is composed of four major parts such as stabilized RF power source, klystron, excitation laser and RF gun cavity. The electron is emitted from photo-cathode by the irradiation of UV laser light in the RF gun, so that the electron beam can be controlled by the injection timing, spot-size and pulse duration of laser pulse. In Fig. 1, the side view of the RF gun is shown.

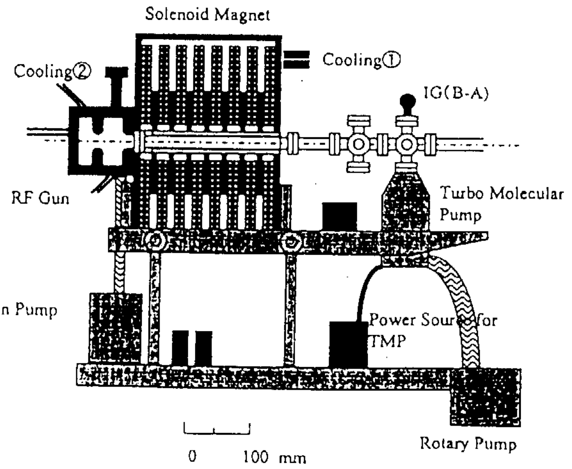

Fig. 1 Side view of the Laser Photo-cathode RF gun system

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2.2 Simulation of RF gun

RF gun using for our simulation is based on BNL gun IV type, 1.6 cell s-band cavity structure. Fig. 2 shows cross-sectional view of the RF gun with the π mode resonance at 2856.25MHz calculated by the MAGIC code using the cavity parameters listed in Table 1.

Table 1 RF gun cavity parameters

Full cell diameter:	83.6 mmϕ
Full cell length:	36.08mm
Half cell diameter:	82.52mmϕ
Half cell length:	22.01mm

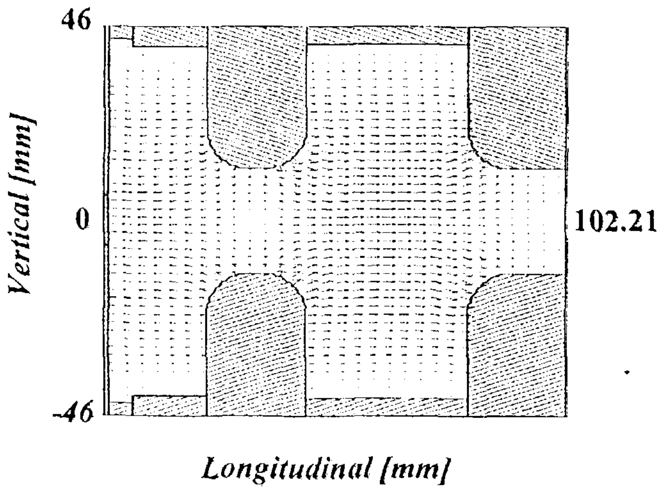

Fig. 2 The cross-sectional view of the RF cavity Resonated at 2856.25 MHz at π -mode

For the first step of the electron beam simulation, we have checked the availability of the code through the calculation of output bunch lengths of electron beam by changing the injection phase of laser light. Fortunately, we have the reference data, which has been demonstrated at University of Tokyo [5] obtained for the same type of RF gun.

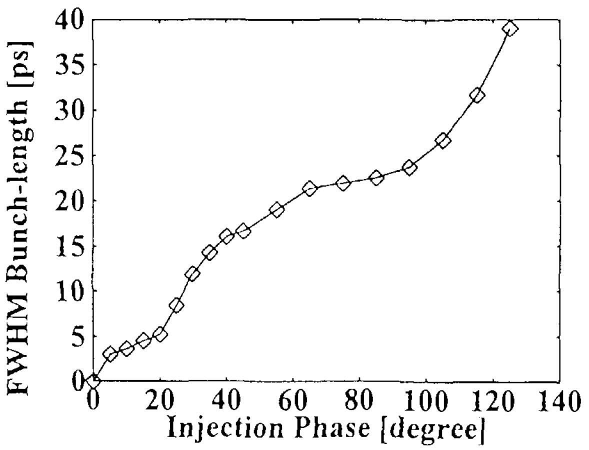

Fig. 3 Bunch length simulation from the RF gun (at laser pulse length of 20 ps)

Fig. 3 shows the bunch length dependence of the output electron beam from the RF gun by changing the injection phase of laser light with the pulse length of 20ps.

Fig. 4 is the data obtained by Univ. of Tokyo group using the 20ps laser light [5]

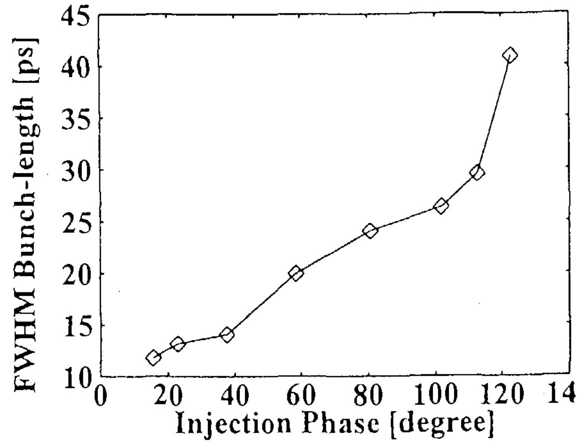

Fig. 4 Experimental bunch lengths of electron obtained from RF gun (5) (at laser pulse length of 20ps)

. As the result, the MAGIC code is to be applicable for the simulation of characteristics of electron beam from the RF gun. In the next step, we have calculated the output electron beam characteristics, especially for getting the low emittance, using the parameters listed in Table 2.

Table 2 RF gun parameters to obtain low emittance electron beam

Wavelength of Laser light :	266nm
Pulse length of laser light :	10ps
Laser spot size:	1.2mmϕ
Maximum acceleration gradient:	100 MV/m
Resonance Frequency:	2856.25MHz
Energy Gain :	5.07MeVat 1nC
:	5.09MeV at 100pC

The emittance is one of the most important parameters to evaluate the quality of electron beam. If we get a low emittance beam, it means that the electron beam can be focused in small area using Q magnet system. When we use the general thermionic electron gun which is widely used for linear accelerators, the emittance of electron beams is considered to be the order of 100 πmm·mrad. On the other hand, in the case of the RF gun, we can expect lower emittance less than 1/10 of that of thermionic gun. This is due to the high field of RF cavity and the small diameter of laser light.

We have calculated and demonstrated the very low emittance from RF gun in two cases. One is the case of 100pC acceleration and the other is the case of 1nC acceleration. Fig. 5 shows the output electron beam emittance with the chare of 100pC from the RF gun under the condition listed in Table 2. In the case, we obtain the normalized RMS emittance of 0.5 πmm·mrad. Fig. 6 shows the output electron beam emittance with the carge of 1nC. In the case, we obtain the normalized RMS emittance of 3 πmm·mrad.

In the cese of 1nC acceleration, emittance is slightly larger tnan the cese of 100pC. This is due to the space charge effect in the electron bunch. Above two cases are calculation for the single bunch 10ps electron beams.

In the RF gun, we can get shorter electron bunch length down to 1ps. However, in the higher charge case, emittance is coming large.

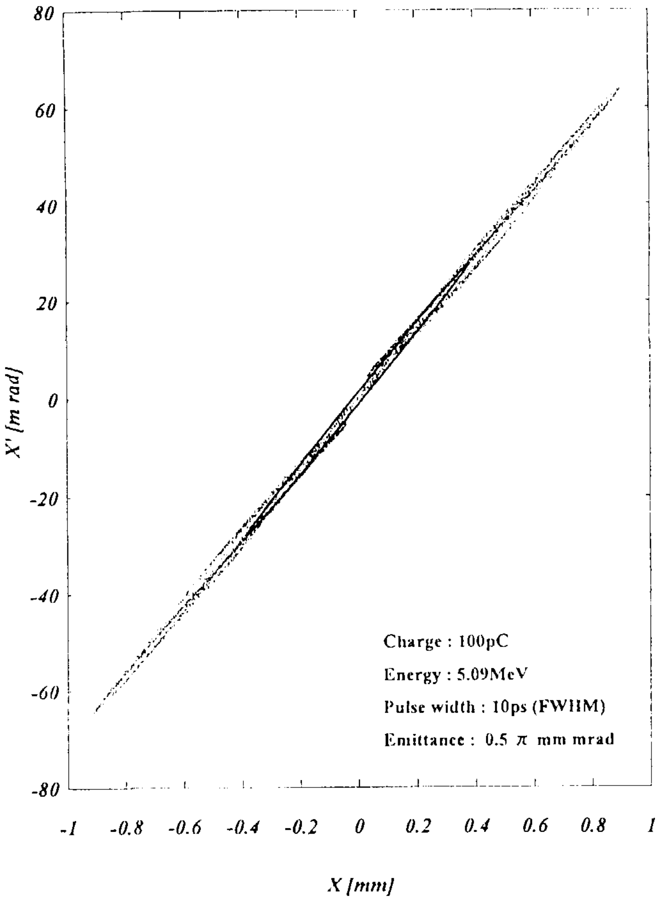

Fig. 5 Emittance of output electron beam from RF gun with the electron charge of 100pC

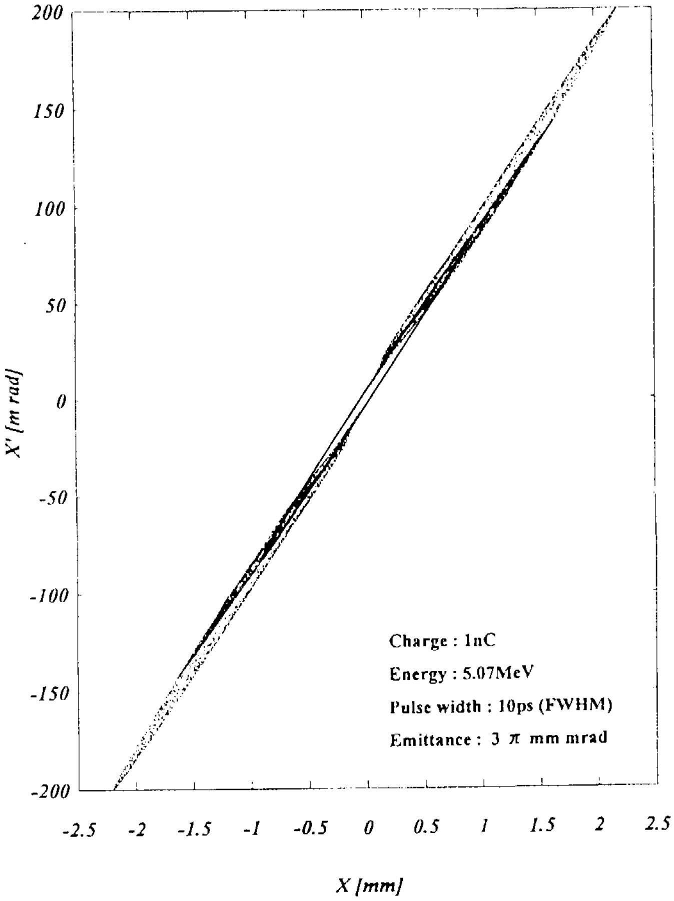

Fig. 6 Emittance of output electron beam from RF gun with the electron charge of 1nC

3. LASER SYSTEM

All solid-state picosecond Nd:YLF laser system, which will be made of SHI, has been selected for the irradiation of the cathode in the RF gun system. The laser is synchronized with RF (2,856MHz) which is applied to RF gun cavity.

This laser system has an active control system for the compensation against the temperature change. Therefore, we will achieve the small timing jitter between the laser light and electron beam down to 500fs, which is sufficiently small timing jitter for the pulse radiolysis experiment with the picosecond time region.

The specifications of the laser is listed in Tbale 3

Table 3 Specifications of the Laser System

Laser:	Nd:YLF
Pulse length:	12ps (1047 nm)
	5ps (262 nm)
Energy:	2mJ (1047 nm)
	0.2mJ (262 nm)

4. ROOM LAYOUT OF THE SYSTEM

All the system will be installed in the new building which is now under construction at Kikui-cyo campus of Waseda University. The layout of the system is shown in Fig. 7.

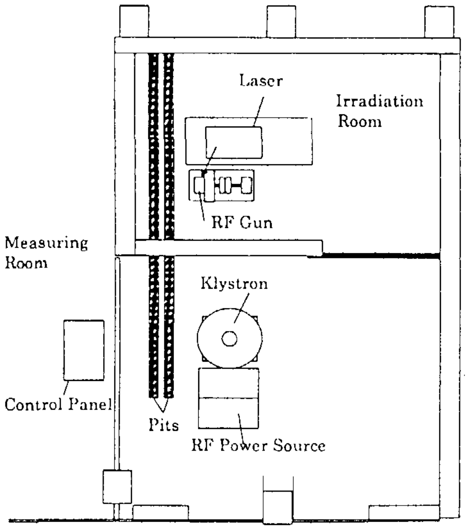

Fig. 7 Room layout of the RF Gun system

The laser system and RF gun system are located in irradiation room and the power source such as RF power source and klystron system are located in the next room. The power of the klystron is to be 10MW for the pulse output, which is sufficient power to generate the acceleration gradient in the RF gun cavity up to 100MV/m.

5. SUMMARY

We have started the construction of compact pulsed electron beam facility at Waseda University. The system may be one of the smallest pulse radiolysis system with the time resolution around 10ps. In next year we will start the installation of the system and get first beam. After the characteriZation of election beam, we will start the pulse radiolysis experiment.

6. ACKNOWLEDGEMENT

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7. REFERENCES

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