

GENERATION AND APPLICATION OF HIGH QUALITY PHOTOELECTRON BEAM AT WASEDA UNIVERSITY

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Abstract

Low emittance and ultra-short electron beam is very useful tool in a various research fields, such as the physical chemistry investigation in ionization and excitation processes of various materials. Research of high quality electron beam generation has been started at Waseda University. The high quality electron beam is produced by laser driven RF gun and it will be use to generate high intensity X-ray using Inverse Compton scattering with high brightness short pulse laser beam. In this paper, we report the laser driven RF gun system and the plan of X-ray generation at Waseda University.

1 INTRODUCTION

High quality electron beam generation project has been approved the grant of the Ministry of Education named "High-Tech. Research Centre Project" and the project has started at Waseda University. In this project, high quality electron beam will be generated by a laser driven photo-cathode rf-gun and it will be used for a pulse radiolysis experiment and high brightness X-ray generation experiment using Inverse Compton scattering process between electron beam and the high quality electron beam.

The laser driven rf-gun is one of most suitable system to generate the high quality electron beam. The rf-gun system is rapidly developing in the world as an electron source of FEL experiment such as SASE and HGHG. The ultra short and high quality electron beam is available to the sub-picosecond pulse radiolysis experiment to observe the ultra-fast physical and chemical phenomena. Furthermore, we plan to use a picosecond and sub-picosecond pulsed X-ray as a probe light in the pulse radiolysis to get high time resolution. Because the time resolution of pulse radiolysis depend on the difference of speed between a pumping source (electron beam) and probe light in the sample. As first step, we will perform the picosecond pulsed X-ray generation experiment in 2000-2001.

2 EXPERIMENTAL OVERVIEW

2.1 RF-gun system

Rf-gun system is composed of the BNL type 1.6 cell S-band rf cavities with Mg cathode [1][2] and a

stabilized laser and rf power source. Using Mg cathode, which had developed at Brookhaven National Laboratory, we can get higher quantum efficiency than Cu cathode. We will apply a high accelerating field to reduce an emittance growth due to a space charge effect for a high current beam. However, we may suffer increased dark current due to field emission under the high gradient operation. In order to reduce the dark current, we have used a diamond turning method to a manufacturing of rf-gun cavities [3].

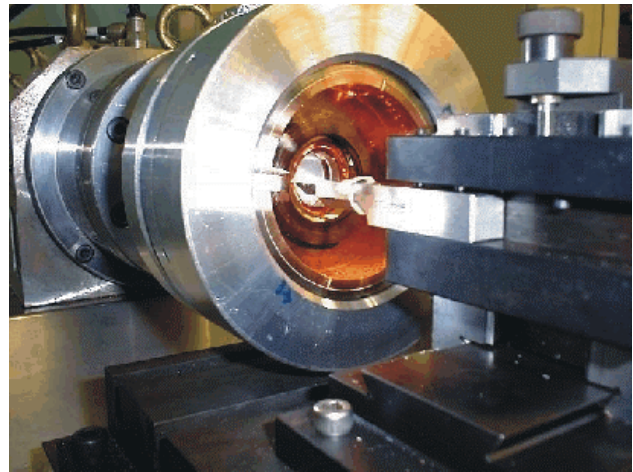


Figure 1 Machining of rf-gun cavity

The electron beam is emitted from the photo-cathode using irradiation of UV laser light (262 nm), therefore the electron beam can be controlled by the injection timing, a laser beam profile in transverse and longitudinal direction.

Main parts of rf source for the rf-gun consists of 10 MW S-band klystron (Tomson: TV2019B6) and a small pulse modulator (Nissin Electric Co., Ltd.). This small pulse modulator has good stability and flatness of the output pulse. The amplitude jitter of output voltage was about 0.38 % (p-p) for 20000 pulses and the pulse flatness was 0.25 % (within $>1.5 \mu\text{s}$ pulse flat-top).

On the other hand, we have started the simulation work using MAGIC code [4] for the BNL type S-band rf-gun and we will optimise the operation parameter.

2.2 Laser System

All solid state picosecond Nd:YLF laser system (PULRISE-V), which was developed by SHI (Sumitomo

Heavy Industries, ltd.), is used for the irradiation of cathode of rf-gun system and the pulse radiolysis and X-ray generation experiment. Table 1 shows the specification of the PULRISE-V. This PULRISE-V has an active compensation system against a temperature change and time jitter from reference rf signal (2856 MHz). Therefore, we will achieve the small timing jitter between the laser light and electron beam down to sub-picosecond. It is sufficient small time fluctuation for the pulse radiolysis experiment with the picosecond time resolution.

A fluctuation of air on the laser optical path affects the laser intensity and spatial profile, so that we will put the laser system in irradiation room and the optical path length of laser light from the laser main body to cathode of rf-gun is less than 2 m.

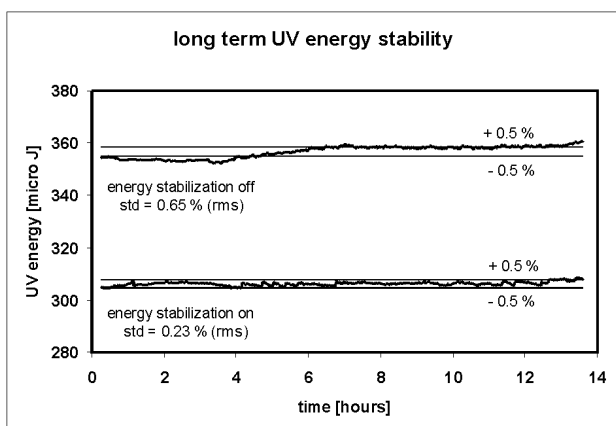


Figure 2 Long term energy stability with and without energy stabilization system

Table 1: PULRISE-V Specifications

Specification	
Laser Medium	Nd:YLF
Pulse Width: IR (1047 nm)	11.6 ps
Pulse Energy: IR(1047nm)/UV(262nm)	3.0/0.3 mJ
Repetition Rate	1-25 Hz
Time Jitter from Reference RF Signal	0.5 ps
Pointing Stability	< 50 μ rad
Divergence	< 2.0mrad
Beam Profile	TEM ₀₀
Energy Stability (UV,Long term:10hours)	< 0.5 % RMS
Energy stabilization ON	
Energy Stability (UV,Short term:10000 shots)	< 0.6 % RMS

2.3 X-ray Generation

One of the most promising approaches to ultra-bright pulsed X-ray sources is the Laser Synchrotron Source (LSS). It is based on Inverse Compton scattering via

interaction between pulsed laser beams and picosecond electron bunches [6].

The vacuum interaction chamber for the Laser Compton scattering experiment will be designed and the crossing angle between laser light and electron beam is adjusted rotating a mount table of parabolic mirrors. In the case of head-on collision (zero crossing angle), the laser pulse and the electron bunch propagate along the same axis in the opposite direction and collide at the focal point. The laser beam is focused and re-collimated inside the chamber with two off-axis parabolic mirrors with focal lengths of 150 mm and a 5 mm diameter hole drilled along the beam axis. These holes are necessary for the propagation of the electron beam and backscattered X-rays. To bypass the holes, the laser beam is transformed from the Gaussian spatial profile to a “donut”-shaped profile using an axicon telescope located outside the chamber. The 3 mJ, 11 ps (FWHM) pulsed Nd:YLF (IR:1047nm) laser beam is introduced through the window and focused at the centre of the chamber. After interaction, laser beam is reflected from another parabolic mirror and is extracted from the chamber. In the case of other crossing angle, the laser beam is focused at same interaction point using parabolic mirrors.

The 10 ps (FWHM), 0.5-3.0 nC electron bunches produced in the photo cathode RF gun are focused at the middle point of the interaction cell to the $\sigma = 100 \mu\text{m}$ spot. The timing jitter between the Nd:YLF laser and electron bunches is negligible in comparison with the electron pulse width since source of UV for the photo cathode illumination of the rf-gun and IR for the Compton scattering is same laser light. The electron beam and the Nd:YLF (IR) laser beam parameters are given in Table 2.

A dipole magnet separated the electron bunches and the scattered X-ray beam after the interaction point. The total number of back-scattered photons with 1nC electron bunch is expected to 6×10^4 photons/pulse. Maximum energy of the generated photon is 0.48 keV and Figure 4 shows the angular distribution and energy of the generated photon.

Table 2: Electron beam and Nd:YLF laser parameters

Electron bunch	
Beam energy	5.0 MeV
Bunch charge	1 nC
Bunch length (FWHM)	10 ps
Beam size at focal point (σ_x/σ_y)	100/100 μm

Nd:YLF laser	
Wave length	1.047 μm
Energy/pulse	3 mJ
Pulse length (FWHM)	10 ps
Beam size at focal point (σ_x/σ_y)	30/30 μm

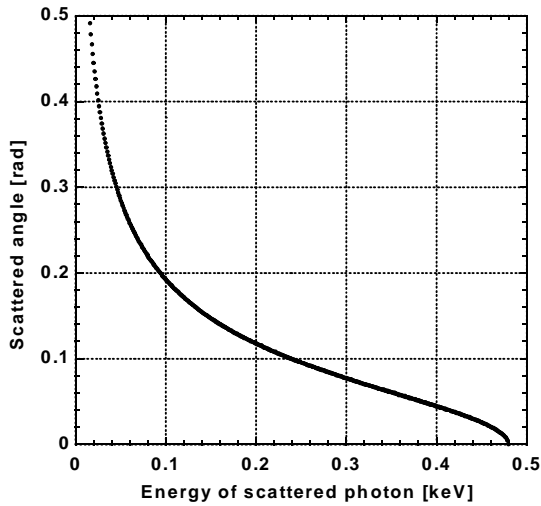


Figure 3 Angular distribution of generated photons

3 SUMMARY

We have started the construction of compact pulsed electron beam facility at Waseda University. The system may be one of smallest pulse radiolysis system with the time resolution around 10 ps. In this year, we will start the operation of rf-gun system and measure the characteristics of electron beam precisely and X-ray

generation will be performed using Inverse Compton scattering.

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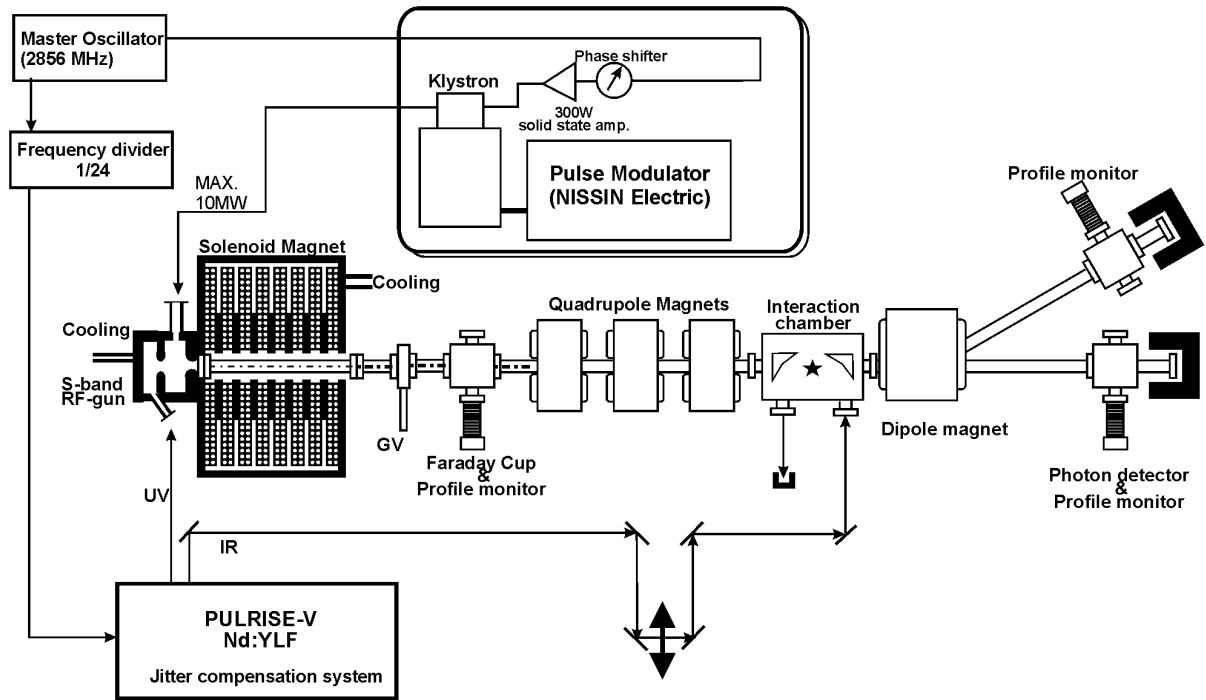


Figure 4 Photo-cathode rf-gun system and beam line layout at Waseda University