# BEAM MEASUREMENT EXPERIMENT OF X-BAND LINAC FOR COMPTON SCATTERING X-RAY GENERATION

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*Abstract*

We are developing an X-band linac system for monochromatic X-rays source. The monochromatic X-ray is obtained by Compton scattering. Our system has an X-band (11.424 GHz) 3.5-cell thermionic cathode RF gun, traversing wave accelerating tube and a Q-switch Nd:YAG laser with a wavelength of 532 nm. We adopt a laser pulse circulation system. The RF gun can generate multi-bunch electron beam. We aim to generate 1 usec 30 MeV electron beam and collide it to circulated laser pulse. In this paper, we describe the details of the system and report on upgrade of the RF gun and experimental result of beam transportation test.

## INTRODUCTION

X-rays of 10–40 keV are widely used in medical science, biology, and materials science. Example techniques that use such monochromatic X-rays are dual-energy X-ray CT[1] and subtraction imaging using a contrast agent and dual energy X-rays. Intense high energy (10–40 keV) X-rays are generated by the synchrotron radiation (SR) light source. However, most SR sources are too large to be widely used for monochromatic X-rays. To realize the wider use of monochromatic X-ray, several facilities are developing Compton scattering X-ray sources that consist of an electron linac (linear accelerator) and a laser system. However, most of them use scattering between an ultra-short single electron bunch and an ultra-short single laser pulse to obtain a short-pulse X-ray beam. Therefore, they suffer lack of X-ray intensity up to $10^8$ photns/sec.

In order to improve X-ray intensity, we are developing a system using multiple scattering between a multi-bunch electron beam and a long-pulse laser beam at the University of Tokyo. Our system consists of a 30 MeV X-band (11.424 GHz) multi-bunch electron linac with thermionic RF-gun and a Q-switch Nd:YAG laser (1.4 J/10 nsec, 532 nm). To demonstrate the proposed X-ray source, an X-band linac beam-line for a proof-of-principle experiment has been completely constructed [2], [3] and [4].

Fig.1 shows the schematic view of X-band multi-bunch linac at the University of Tokyo. The X-band electron linac is used for the compact X-ray source. The wavelength of the X-band (11.424 GHz) is just 1/4th that of the S-band (2856 MHz). However, the maximum field gradient of ~40 MV/m yields remarkable compactness. A multi-bunch electron beam is generated by a 3.5-cell X-band thermionic cathode RF gun, is collimated and compressed by an alpha magnet, and is accelerated by an X-band travelling type accelerating tube. The electron beam is bent by achromatic bends and is focused at the collision point. The thermionic cathode RF-gun can generate a high-current (200 mA peak and 2 uA source average under 10 pps operation) multi-bunch ($10^4$ bunches in 1 usec) electron beam. A 0.7 m long X-band accelerating structure is adopted in this system.

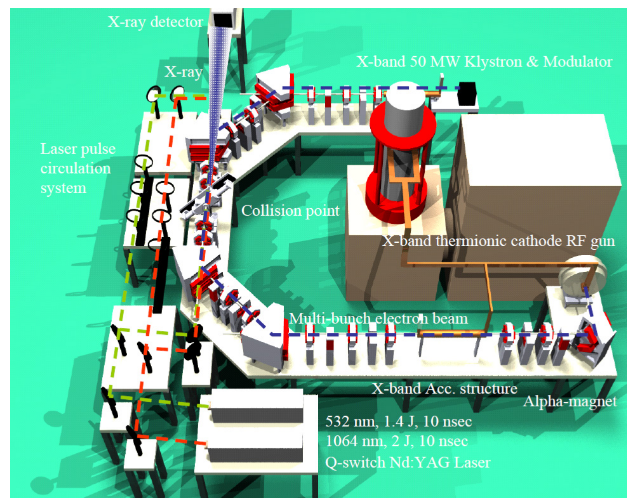


Figure 1: Schematic view of linac system at the University of Tokyo.

## UPGRAGE OF RF GUN

We use thermionic cathode RF gun for electron beam generator. However, we had been often faced with a trouble that was due to the breakage of a tungsten spring at the RF gun cavity. A tungsten spring was installed around the cathode rod for the purpose of cathode rod supporting and RF shielding to the coaxial structure around the cathode rod. Fig.2 shows the sectional view of the RF-gun cavity. The tungsten spring had two roles, one was the RF shielding and the other was cathode rod supporting. If 2 MW RF power feeding, the tungsten spring is broken. As the result, the resonant state of the RF gun cavity was changed and detuned. So far, we had tested the several materials for the RF contact. Despite this, we could not realize stable operation at high power RF input to the gun.

Therefore we changed the gun structure to cut RF power in front of tungsten spring [5] and [6]. We adopted a choke structure around the thermionic cathode to

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separate the two roles such as choke structure for RF shielding and tungsten spring for cathode rod supporting. Fig.3 shows a result of numerical calculation of choke structure by using SUPERFISH. The width and the distance of the choke structure are customized to minimize the magnetic field at the coaxial structure around the cathode rod.

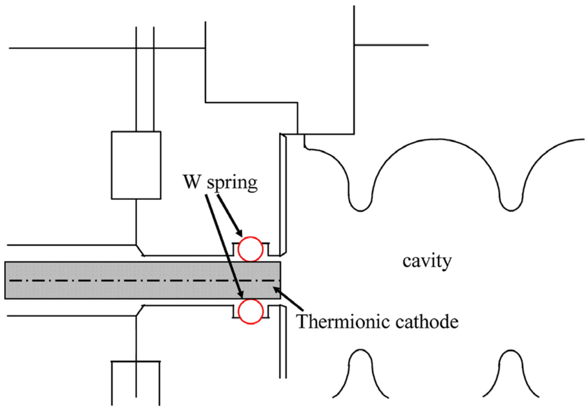


Figure 2: Sectional view of the RF-gun cavity.

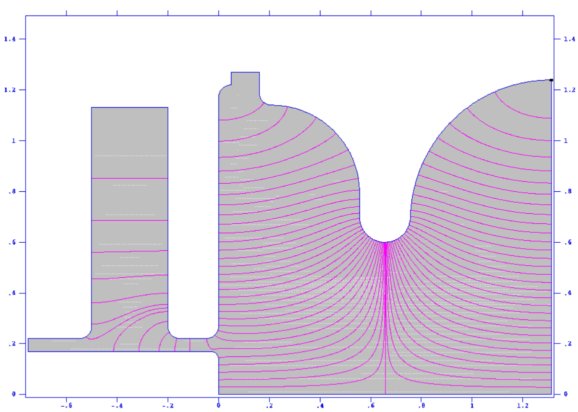

Figure 3: Design of the choke structure around the thermionic cathode calculated by SUPERFISH.

A new designed RF gun was manufactured and we tested it. We confirmed stable beam generation in high power RF input and succeeded in measurement of beam energy.

## BEAM MASUREMENT

We succeeded in obtaining beam energy spectrum generated from the RF gun and beam transportation to end of beam line by using new RF gun.

### *Beam Spectrum Measurement at the RF Gun*

The beam goes through α-magnet before injected to accelerating tube. This α-magnet has movable slit to stop the beam. Fig.4 is schematic figure of the a-magnet and slit. We can obtain beam energy with position of movable slit and B-field of alpha magnet.

We carried out beam spectrum measurement with 3 MW 250 nsec RF pulse. Fig.5 and Fig.6 is result of this measurement. Fig.5 is beam current in a pulse of each energy band. Fig.6 is energy spectrum. Highest beam energy is 2.5 MeV and energy spread is 0.3 MeV (FWHM).

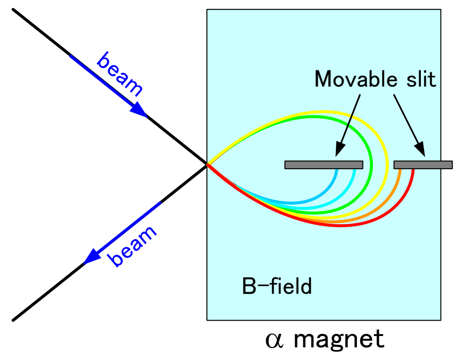


Figure 4: Schematic figure of the α-magnet and slit

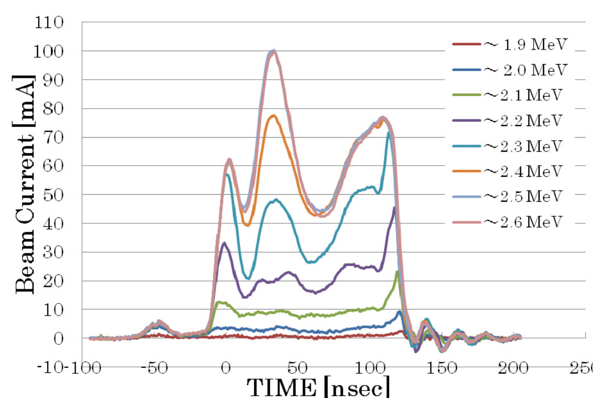


Figure 5: Beam current of each energy band from the RF gun in a pulse.

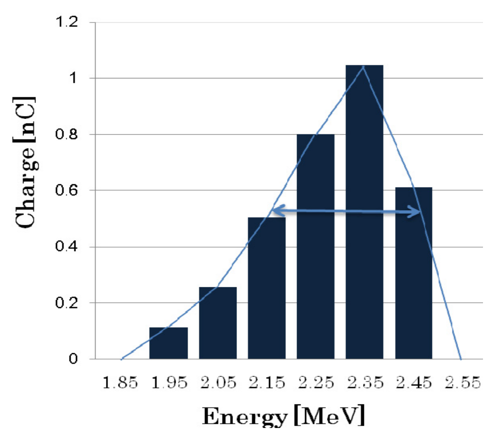


Figure 6: Beam energy spectrum at the RF gun.

### *Beam Transportation Experiment*

The beam line had several problems such as charge up at ceramic duct and error magnetic field at a-magnet. We succeeded in beam transportation to end of beam line for the first time last year.

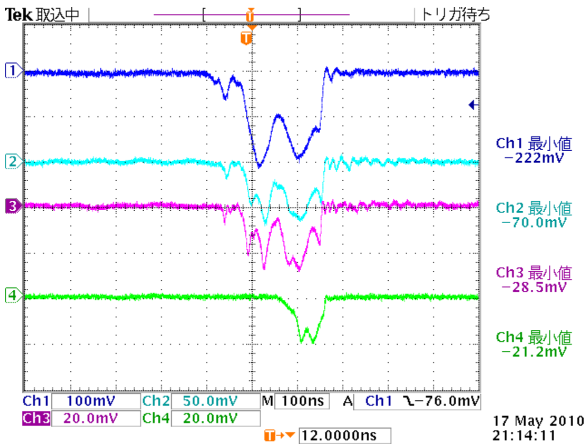


Figure 7: Beam current measurement of beam transportation experiment. (Ch.1 is input to a-magnet. Ch2 is exit beam from a-magnet. Ch.3 is exit beam from accelerating tube. Ch.4 is at beam dump.)

Fig.7 is latest beam transportation experiment result of beam current measurement. The RF gun generates 220 mA beam and 20 mA beam is transposed to beam dump.

We also measured a beam size at collision point by using alumina fluorescent screen. As a result, beam size is 0.56 mm in horizontal and 0.70 mm in vertical. Fig.8 is beam profile at collision point. We have to optimize transportation magnet parameter, because our final goal of beam size is 0.1 mm

## CONCLUSION

Compact Compton scattering X-ray source based on X-band linac and Nd:YAG laser are under demonstration at the University of Tokyo. So far, we have demonstrated the beam generation, and acceleration.

The thermionic cathode RF gun was upgraded and succeeded in stable operation in high power test. The RF gun generates 2.5 MeV electron beam with energy spread is 0.3 MeV (FWHM). We could transport 20 mA beam to beam dump.

Currently we are working on preparation of X-ray generation experiment such as laser system setting and optimization beam line magnet parameter. We aim to X-ray generation at this year.

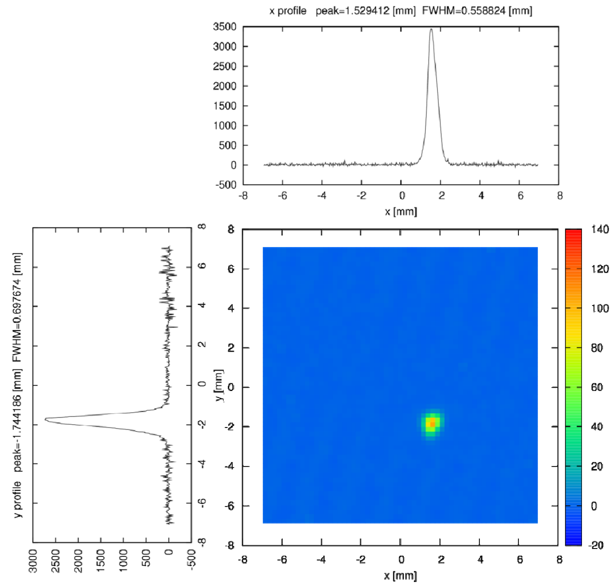


Figure 8: Beam size measurement at collision point.

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