CONSTRUCTION OF A THERMIONIC RF GUN LINAC SYSTEM FOR ULTRASHORT ELECTRON PULSE GENERATION

W.K. Lau, J.H. Chen, J.Y. Hwang, A.P. Lee, C.C. Liang, T.H. Wu, NSRRC, Hsinchu, Taiwan
N.Y. Huang, National Tsing Hua University, Hsinchu, Taiwan
W.C. Cheng, National Chiao Tung University, Hsinchu, Taiwan

Abstract

A 15-30 MeV S-band linac system that equipped with themionic cathode rf gun is being constructed at NSRRC for generation of ultrashort relativistic electron beam. According to simulation studies, high quality GHz repetition rate electron pulse of about 30 pC as short as 100 fsec can be produced. This system will be used as the driver linac for novel light source experiments such as ultrafast head-on inverse Compton scattering (ICS) X-ray source, high power wake-field microwave source and high efficiency THz free electron laser in the near future. The progress of our construction work is presented.

INTRODUCTION

Ultrashort relativistic electron beam can be used to generate coherent THz and ultrafast X-rays. An S-band linac system that employs thermionic cathode rf gun as electron source and alpha magnet as bunch compressor for 20-30 MeV femtosecond electron beam [1,2] is being built for light source R&D at NSRRC. According to our design study, we expected that the system will deliver thousands of GHz-rep-rate femtosecond electron pulses in one macropulse with properties as summarized in Table 1.

Table 1: System Parameters of the Thermionic RF Gun Linac for Generation of Ultrashort Electron Pulses

Frequency of microwave linac	2998 MHz
Macropulse repetition rate	10 Hz
Macropulse duration	~ 1 μsec
Micropulse repetition rate	2998 MHz
Number of bunches in a macropulse	~ 3000
Bunch charge	30 pC
Electron pulse duration	100 fsec RMS
Electron energy	15 ~ 29.5 MeV
Energy spread	0.3 %
Normalized emittance	3.7 mm-mrad
Electron transverse beam size	30 μm RMS

An ultrafast head-on ICS X-ray source driven by such electron beam have been designed [3] and experiments will be carried out in the near future. Feasibility of using this beam to drive a high efficiency THz free electron laser and a 30 GHz power extraction structure for high power microwave generation are under studied. In this report, our progress in construction such high brightness beam facility is presented.

THE THERMIONIC RF GUN LINAC SYSTEM

The layout of the NSRRC S-band ultrashort electron linac for light source research is shown in Figure 1. Due to the limitation of available space in NSRRC, it shares the same 90 cm concrete shielding wall with the 1.5 GeV Taiwan Light Source (TLS) booster synchrotron. However, it can be operated only when the booster is shut down during machine study time or maintenance period to avoid interruption of booster operation. The 3 GHz high power microwave generator is located outside the booster room and high power microwave will be delivered to the accelerator system through the S-band waveguide distribution. A teststand for laser driven photo-cathode rf gun also located in the booster room shares the same microwave system with the linac system. We will use the 3.5 mJ, 800 nm Ti: Sapphire amplifier of the photoinjector drive laser system for the first head-on ICS experiment. A waveguide phase shifter will be installed for linac phase adjustment. By adjusting the linac phase, bunch compression can be done not only by the alpha magnet but also by velocity bunching in the rf linac.

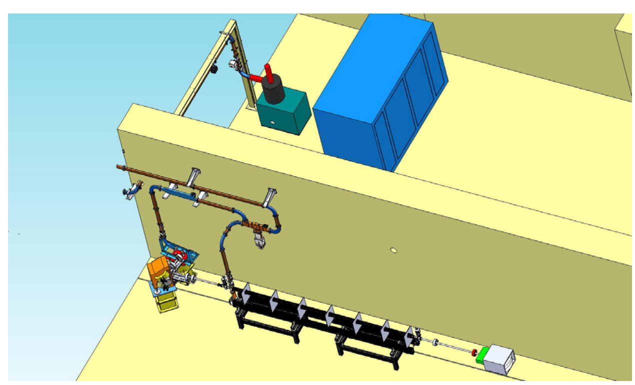

Figure 1: The layout of the NSRRC ultrashort electron beamline for ICS experiment.

Thermionic Cathode RF Gun

The thermionic cathode rf gun is a 2998 MHz, 1.5-cell side-coupled standing wave structure in which high gradient accelerating field is setup for beam acceleration. It is modified from the original 2856 MHz SSRL design except the nose cone around the 0.25" thermionic dispenser cathode have been removed to avoid excessive beam focusing near cathode. Accelerating gradients in the half cell and full cell of the gun cavity will be set at 25 MV/m and 50 MV/m respectively. The electron pulses generated from the rf gun will have nearly linear distribution in longitudinal phase space so that bunch compression is made possible with an alpha magnet located between the electron gun and linac section. Futher optimization of gun geometry for ultrashort bunch is still in progress. A prototype is being built for preliminary test in the following months.

The Alpha Magnet System

An alpha magnet has been fabricated in house and tested preliminarily up to 450 guass/cm with adequate cooling(Figure 2). Further characterization of field properties is required.

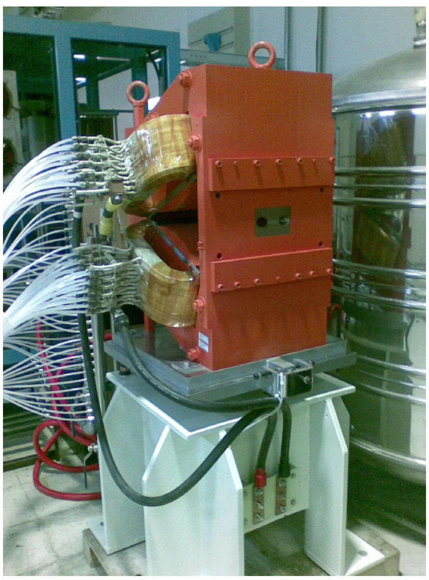

Figure 2: The alpha magnet fabricated in house for bunch length compression

The vacuum chamber for the alpha magnet has been built and tested (Figure 3). A motorized collimator has been built and will be installed in the vacuum chamber for beam selection before injecting into the linac for acceleration.

Figure 3: The vacuum chamber for alpha magnet; a collimator will be installed inside

Quadrupoles for beam focussing at gun exit is not really needed because the divergence of selected higher energy particles is small and lower energy particles will be filtered out by the collimator in any case. A quadrupole triplet is located at the upstream of the rf linac for beam matching and beam loss can be avoided. After the linac, the compressed electron beam will be focused into a tiny beam spot in the ICS interaction chamber. All these quadrupole magnets have been fabricated and tested.

High Power Microwave System

The 2998 MHz high power microwave system consists of a 35 MW, Thales TH2100A pulsed klystron which is powered by an 80 MW line-type high voltage pulser (Figure 4). Installation of this high voltage pulse has been completed recently and it is now under high voltage test. The klystron and focusing magnets has X-ray shields that meet radiation safety requirements when operating outside the concrete wall of the TLS booster room. A driver amplifier system with the one kilowatt Thales TH2047 klystron for the high power TH2100A pulsed klystron has been installed and tested successfully (Figure 4). This microwave system is synchronized with the photoinjector drive laser system (as described in the introduction of this paper). This synchronization is good for future experimental studies on laser-beam interactions (e.g. head-on ICS X-ray, see the following section).

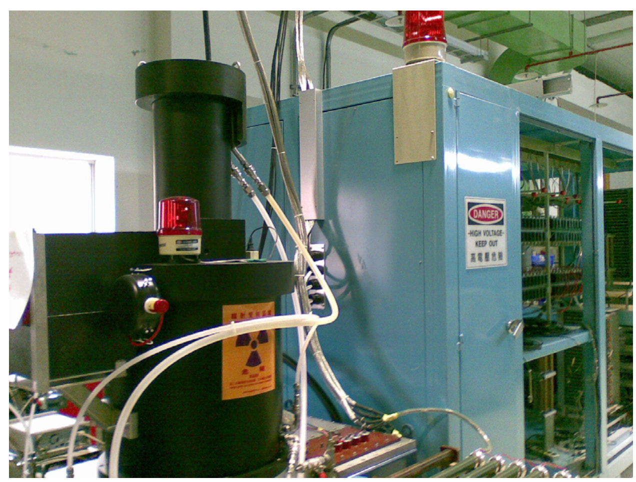

Figure 4: The 35 MW S-band pulsed klystron (with X-ray shielding) and modulator.

RF Linac

The linac sections used in this system are a 5.2 m, 2998 MHz constant gradient traveling-wave structures operating at $2\pi/3$-mode. This structure is similar to the DESY LINAC-II design and is manufactured by Research Instruments GmbH. It has 156 cells that provide shunt impedance of ~50 MΩ/m but with the last 6 cells coated with Kanthal layer as collinear microwave absorber. High power microwave is coupled to the first cell at one arm with the opposite arm shorted. All three linac sections have arrived NSRRC and high power test on one of these structures is scheduled to this summer.

FIRST ULTRAFAST X-RAY SOURCE EXPERIMENT

This driver linac system is able to produce tightly focused ultrashort electron pulses for production of high flux sub-hundred femtosecond hard X-rays via head-on ICS. A 3.5 mJ, 800 nm laser will be used for our first experiment on head-on ICS ultrafast X-ray. The total peak flux obtained from this laser-beam interaction can be as high as 1.3×10^{18} photons/s within a ~18.8 mrad radiation cone by using this laser focused to the same focal size at the interaction point [3]. Properties of the backscattered X-ray pulses are briefly listed in Table 2.

Table 2: Parameters of the backscattered X-ray pulses in the NSRRC ultrafast head-on ICS X-ray experiment

Photon energy	17.4 keV
Pulse duration	67 fsec
Photons per pulse	$5\text{x}10^4$
Peak photon flux	1.3×10^{18} γ/s
Brightness	3.16×10^{15} $\gamma/(\text{s-mm}^2\text{-mrad}^2)$

SUMMARY

We reported our effort to construct a 15-30 MeV S-band linac system that equipped with themionic cathode rf gun is being constructed at NSRRC for generation of ultrashort relativistic electron beam. High quality GHz repetition rate electron pulses of about 30 pC bunch charge and bunch length as short as 100 fsec can be produced. This system will be used as the driver linac for future novel light source R&D. Our first experiment ultrafast X-ray source experiment will be on head-on inverse Compton scattering (ICS) which will be carried out after the completion of this thermionic rf gun linac system by the end of this year.

REFERENCES

[1] P. Kung et. al., Phys. Rev. Lett., Vol. 73, p. 967-970, 1994.
[2] S. Rimjaem et. al., Nucl. Instr. And Meth. A 533, p. 258-269, 2004.
[3] N.Y. Huang et. al., these proceedings.