STATUS REPORT 2001 OF LINAC AND LASER FACILITY AT UNIVERSITY OF TOKYO

M. Uesaka, T. Watanabe, K. Yoshii, T. Ueda, K. Nakajima, T. Hosokai, K. Kinoshita, H. Iijima, A. Zhidkhov, R. Hemker, N. Hafz, W. Ghaly, K. Nakamura, A. Fukasawa, T. Ohkubo, Y. Kanegae,
Nuclear Engineering Research Laboratory, School of Engineering, University of Tokyo
2-22 Shirakata-Shirane, Tokai-mura, Naka-gun, Ibaraki, 319-1188 Japan

Abstract

We report the current status of S-band twin linac and lasers, including updated results experimental and numerical. We are constructing a photocathode RF gun with a high quantum efficiency cathode of magnesium. As for beam diagnostics by the fluctuation method, we obtained the first results by Cherenkov radiation. Using laser-plasma interaction, production of ultrashort electron and ion acceleration are attempted. In addition, a compact inverse Compton scattering X-ray source is designed.

1 INTRODUCTION

The linac and laser system is operating at the femtosecond ultrafast quantum phenomena research facility. The system mainly consists of S-band twin linac and two lasers. One of the linacs has a thermionic electron gun and an arc-type magnetic pulse compressor and supplies an electron beam with energy of 35 MeV. The other has a laser photocathode RF gun and a chicane-type magnetic pulse compressor and supplies 18 MeV electron beam. Both lasers are Ti:Sapphire lasers utilized CPA method. The power of 12 TW with pulse duration of 50 fs and that of 0.3 TW with 100 fs pulse duration are supplied from the lasers respectively. Using the system, development of the RF gun, diagnostics of picosecond electron pulse, production of ultrashort electron pulse using a plasma cathode laser-plasma ion acceleration and time-resolved X-ray diffraction have been performed. In addition, a compact inverse Compton scattering X-ray source is designed.

2 RESEARCH THEMES IN FI 2001

Eight research themes under the collaboration with other university and institutes mentioned below have been carried out in FI 2001.

- 13L-1 Research of radiation effect for hot and supercritical waters
- 13L-2 Application of radiation to polymers
- 13L-3 Research of ultrafast reaction using pump-probe method
- 13L-4 Development of charge monitor for pulse electron
- 13L-5 Study on multi beam from laser-plasma interaction
- 13L-6 Measurement of bunch length using coherent radiation
- 13L-7 Femtosecond X-ray diffraction
- 13L-8 Femtosecond pulse measurement using the fluctuation method

3 MAGNESIUM CATHODE RF GUN

Magnesium (Mg) photocathode RF gun, which is going to be installed into the 18 MeV linac, has been developing in cooperation with SPring-8, KEK, SHI, Waseda University, BNL and UCLA. Figure 1 is a photograph of the Mg cathode plate. It is known well that the quantum efficiency (QE) of Mg is ~1.6×10^{-3} which is ten times greater than that of Cu. The laser cleaning against deterioration of QE and the optimization of the operating parameters are the subjects to be done.

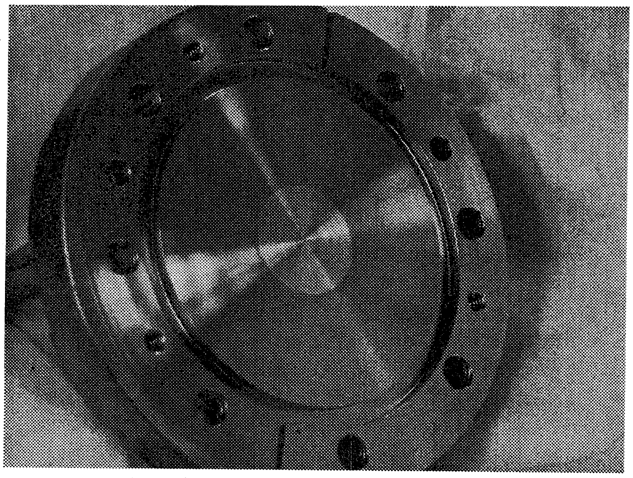

Figure 1: Mg cathode plate

4 DIAGNOSTICS OF PICOSECOND ELECTRON PULSE

Diagnostics of longitudinal bunch length of subpico- and picosecond electron beams by the fluctuation method has been carried out at the twin linacs. The diagnostics method utilizes a statistical analysis of shot-noise-driven fluctuations in incoherent radiation. Experiment was performed on Cherenkov light emitted from 1.0 ps (FWHM), 20 MeV bunch. As a result, the fluctuation method indicated pulse duration four times longer than that by the streak camera [1-2], as shown in Fig. 2. Its discrepancy attributes a spatial effect neglected in the theory. Thus, numerical analysis is extended to 2-dimensional one.

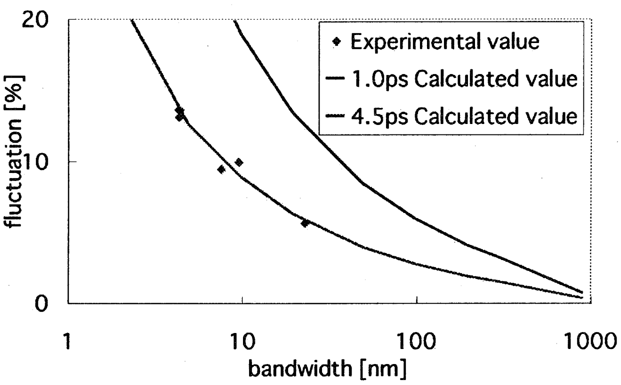

Figure 2: Experimental result

5 LASER PLASMA LINAC (ELECTRON)

The generation of an ultrashort relativistic electron bunch from a strong laser-plasma interaction have been studied by particle-in-cell simulations and observed experimentally. The electron beam was generated from the plasma created by focusing 12 TW laser pulse at the edge of helium gas jet expanded into the vacuum from a pulsed supersonic nozzle. In the interaction of the 12 TW laser pulse with plasma of density of 5×10^{18} cm^{-3} the electron beam generation was taking place due to the transverse injection of some portion of the plasma electrons which constitute a large amplitude plasma wave [3]. Such electron injection and generation took place at the very end of the interaction region with no possible chance for enhanced acceleration because the laser pulse was leaving the plasma into the vacuum. For a relatively higher plasma density at 5×10^{19} cm^{-3}, the electron generation was observed in the simulation at the very beginning of the interaction region. The plasma electrons were gaining higher energies by the huge longitudinal electric fields (created by the laser pulse) as they move through the rest of the plasma following the laser pulse. In the experiment, the electron beam transverse profile and its total charge have been measured in the forward direction (the same direction of the laser pulse) by using imaging plate and Faraday-cup, respectively.

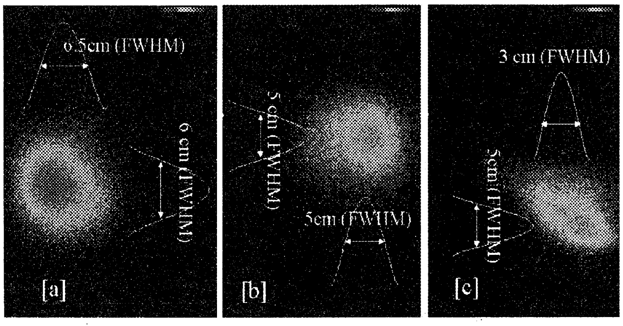

Figure 3: Electron beam profile at 4 TW and various gas pressures ([a] 42.5 bar, [b] 52.6 bar, [c] 62.8 bar)

6 LASER PLASMA ION ACCELERATOIN

Experiment was performed using the 12 TW laser focused into a Cu solid target. $Cu^{12+\sim18+}$ ions having energies greater than 200 keV ware measured (see Fig. 4). The number of ions per shot ~1.1×10^{15} /sr/shot. The pulse duration of generated ions is 10 ps. Those ions have used to ultrafast in situ observation of radiation damage of material. The image of the ions emission, irradiation damage of Cu sample was also obtained.

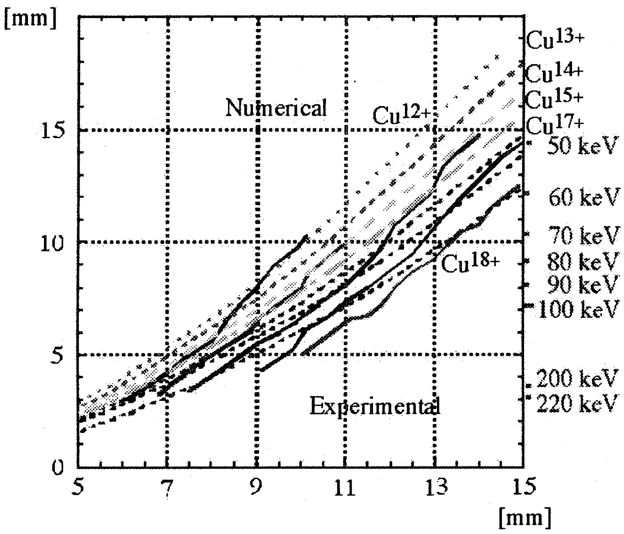

Figure 4: Energy spectrum of Cu ions measured by Thomson parabola.

7 TIME-RESOLVED X-RAY DIFFRACTION

The time-resolved X-ray diffraction experiment was carried out where the 3 TW laser and 10 ps X-ray ware used as pump- and probe-pulses, respectively. The ultrashort X-rays were generated using the intense ultrashort laser interacting with a copper target. Using 10 ps Cu $K\alpha_{1,2}$ X-ray pulses via collision between 10 ps electron beam and a Cu wire, we have obtained diffraction images from several monocrystal semiconductors (Si, GaAs, Ge), ion-crystals (NaCl, KCl) and alkalihalides (CaF_2, BaF_2). However, the change of the X-ray diffraction image could not be observed because of surface damage due to repeated laser irradiation. In order to get more X-ray photons and perform single-shot pump-and-probe analysis, we are going t proceed to laser-plasma X-ray based analysis.

8 COMPACT INVERSE COMPTON SCATTERING X-RAY SOURCE

A compact inverse Compton scattering hard X-ray source based on an X-band linac, which consists of an X-band photocathode RF gun and two X-band travelling accelerating tubes, is numerically designed. Figure 5 illustrates a schematic view of the system. The RF gun has 3.5-cell cavity and produces the electron beam with the charge of 1 nC and the emittance of 2π mm.mrad at

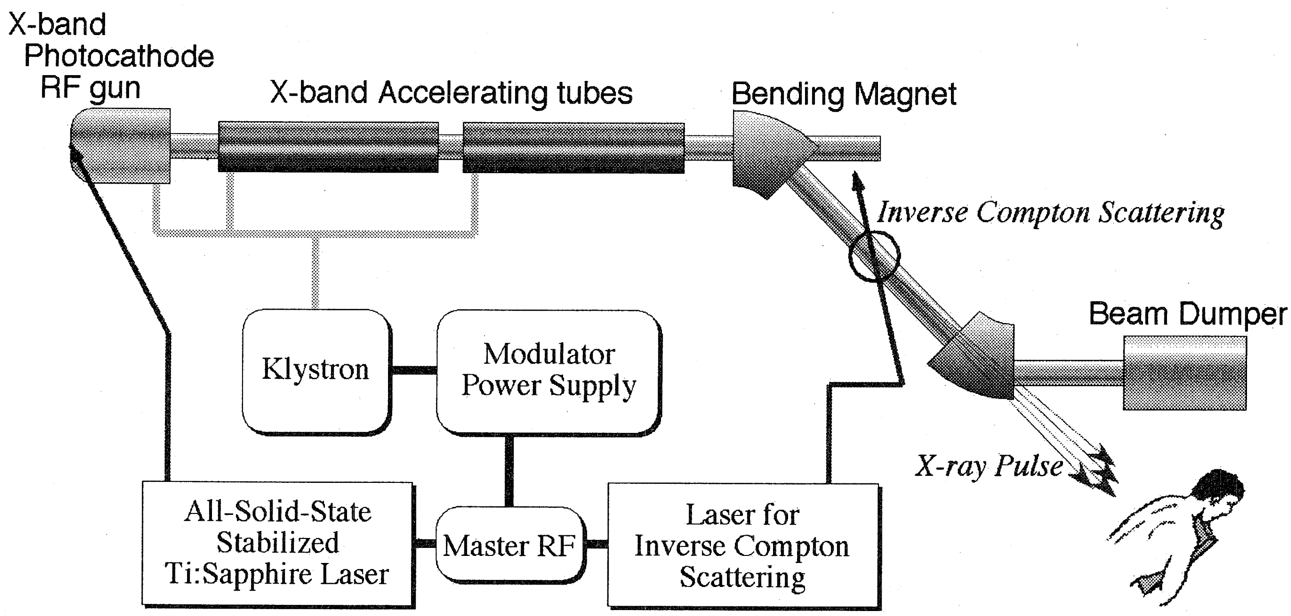

Figure 5: Schematic view of the compact inverse Compton scattering X-ray source

the exit of the gun. At the interaction point these quantities become 0.9 nC and 6π mm.mrad respectively. The beam can be focused into 77×77 mm^2 spot while the laser spot is 50×50 mm^2. Using a laser with the peak power of 10TW and the pulse length of 1ps, this system can generate 1.6×10^9 photons/bunch X-ray flux. To achieve 10^{11} photons within 10 ms which is required for the dynamic angiography, multibunch electron beams and laser multipath optics are needed.

9 FUTURE WORK

New cathodes of RF gun (for example, reflection-type Mg has QE of 0.1%, penetration-type Cs_2Te a few %, diamond 50 %) are considered in cooperation with SPring-8, KEK. For the laser-plasma acceleration, the measurement of 10 fs electron single-bunch is the first attempt in the world. Production of high-flux and low-emittance carbon ion beam with energy of a few MeV is performed using the laser-plasma ion acceleration, in cooperation with JAERI-APR, Kyoto Univ. and Hiroshima Univ. Experiments of time-resolved X-ray diffraction for Si and Ge will be performed. We are planning the dynamical structure analysis of protein with SPring-8 and the time-resolved X-ray holography/imaging with KEK-PF and the department of Applied Physics of University of Tokyo. As for the development of compact hard X-ray source, we propose that inverse Compton scattering hard X-ray sources should be categorized into the forth generation of radiation source, as well as X-ray free electron laser. Both should be developed and utilized complementarily. International collaboration and utilization on advance accelerators is discussed at International Committee for Future Accelerators (ICFA)/Advanced and Novel Accelerator PANEL. We contribute increasingly to advanced beam science and technique from now on.

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