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GENERATION OF SUBPICOSECOND ELECTRON SINGLE PULSE

Takahiro KOZAWA, Toshiaki KOBAYASHI,
Toru UEDA, Mitsuru UESAKA, and Kenzo MIYA

Nuclear Engineering Research Laboratory, Faculty of Engineering,
The University of Tokyo,
2-22 Shirakata-Shirane, Tokai-mura, Naka-gun, Ibaraki 319-11, Japan

Abstract

Generation of subpicosecond single electron pulse with the charge of 1 nC have been succeeded at the S-band (2856 MHz) linear accelerator of the university of Tokyo. 34.8 MeV electron pulses with the pulse width of 10 ps have been compressed by the achromatic magnetic pulse compression system. 890 fs (FWHM) single pulse have been generated with the charge of 1 nC through a 3 ϕ slit. No satellite of the main pulse could be observed.

1. Introduction

The development of short pulse electron accelerator enables direct observation of ultrafast dynamics of electron-matter interaction. In 1977, a 10 ps electron single pulse was first generated at the 35 MeV S-band linear accelerator of the university of Tokyo[1], and then the pulse radiolysis system was established[2, 3]. Since then, ultrafast phenomena such as excitation, ionization and relaxation of atoms and molecules have been investigated in picosecond regime with the time resolution of a few couple of ten picoseconds[2, 3]. In the case of photoinduced reactions, investigation on ultrafast phenomena in femtosecond region have been started by using femtosecond laser. On the other hand, the time resolution of pulse radiolysis remains a few couple of ten picoseconds. Recently, generation of subpicosecond pulse (900 fs, 150 pC/pulse, 7.1 mm X 11 mm) was succeeded at the university of Tokyo[4]. However, the charge was too little to detect radiation-induced reactions. We attempted to generate high intensity subpicosecond pulse.

2. Experimental Setup

2-1. Achromatic pulse compression system

The achromatic pulse compression experiment was carried out at the 35 MeV S-band linac of the utnl twin linacs. This linac has two accelerating tubes (ACCI and ACCII). The experimental setup is shown in Fig. 1. The achromatic pulse compressor consists of two 45° sector magnets and four quadrupole magnets. The upstream sector magnet was also used as an energy analyzer magnet. The longitudinal distribution of electron pulse was modulated for pulse compression by adjusting RF phase of ACCII.

2-2. Induction system

The injector consists of an thermionic electron gun (Y-796) and a d-c biased grid-cathode pulse generator placed on a -90 kV high potential deck, a 476 MHz (1/6 of the main accelerating microwave frequency of

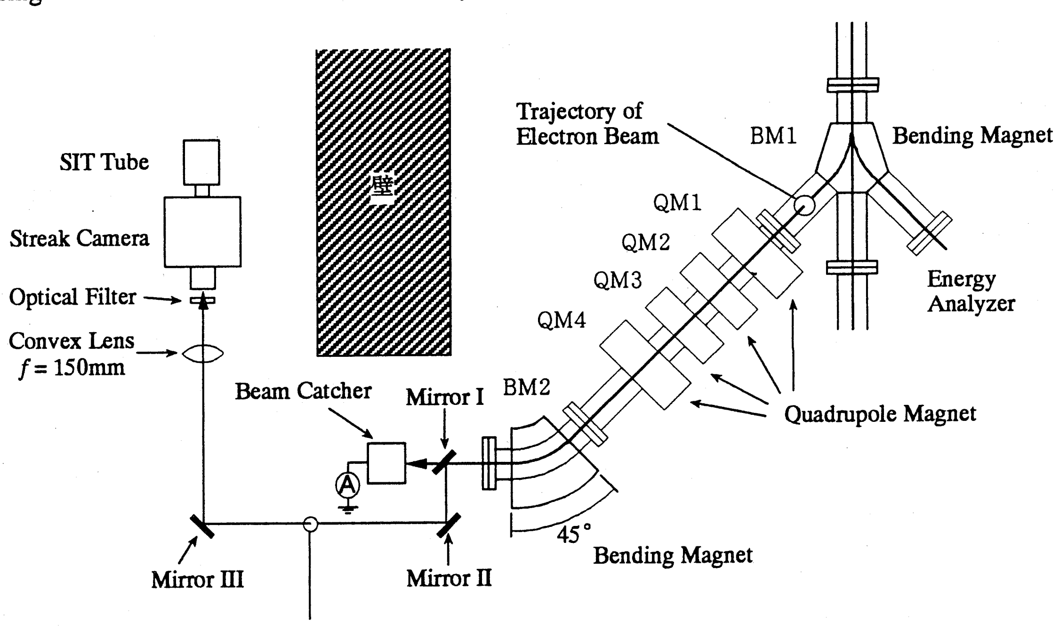

Fig. 1. Magnetic pulse compressor and Cherenkov radiation measurement system.

2856 MHz) subharmonic buncher (SHB), a 2856 MHz traveling wave type 6 cell prebuncher and focusing system. The accelerating potential of the electron gun is provided by 90 kV pulses of 8 μs duration. The duration of flat top is 4 μs. The velocity of the electron beam injected from the electron gun is modulated by the electric field at a gap of the SHB. In order to generate an isolated pulse without satellite, a fast rise-time , low jitter trigger pulse synchronized with the accelerating RF waves is required. Up to now, a single pulse have been generated by the grid pulser, whose voltage is 300 V with the pulse width of 1 ns. A higher voltage pulser was purchased by Kentech corporation. The output voltage of the new pulser is 1 kV and the pulse width is 1 ns. We attempted to increase the charge of emission from the Y796 electron gun using this pulser.

2-3. Measurement of pulse shape
Pulse shape of emission from electron gun with the energy of 90 keV was measured by co-axial beam catcher at a distance of 2.5 cm from the anode. The time-resolution of co-axial beam catcher is less than 50 ps. The charge of emission was measured by faraday cup.

Pulse width of relativistic beam was evaluated by measuring Cherenkov radiation emitted by the relativistic electrons in air at the beam ports. Cherenkov radiation was measured by using a femtosecond streak camera which has a time resolution of 200 fs (HAMAMATSU). The optical measurement system is shown in Fig. 1. All data were acquired by single shot measurement to avoid effects of jitter by accumulation. Beam sizes were measured by using phosphor screens (Desmarquest AF995R) at the beam ports.

3. Results and Discussion

3-1. Magnetic pulse compression at achromatic system
In the magnetic pulse compression experiment, the RF phase in ACCI was tuned so as to minimize the energy spectrum of the pulse. Its energy and energy spread are 19.1 MeV and 0.26 %, respectively. The RF phase in ACCII was tuned so as to accelerate electrons in the early phase of the pulse more than those in the later phase of the pulse. The best RF phase in ACCII was adjusted so as to make the shortest pulse monitoring its width by using streak camera. The peak electric field in ACCII was 10 MV/m. The charge passing through a 3 ϕ slit at the straight beam port was 700 pC/pulse. A typical measured pulse shape of compressed pulse riding on the phase of 72° is shown in Fig. 2. The pulse width is 850 fs and the horizontal

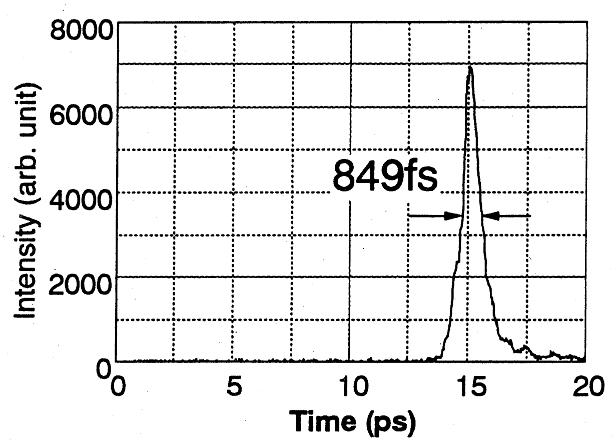

Fig. 2. Measured pulse shape of compressed single pulse generated by using the 300 V grid pulser.

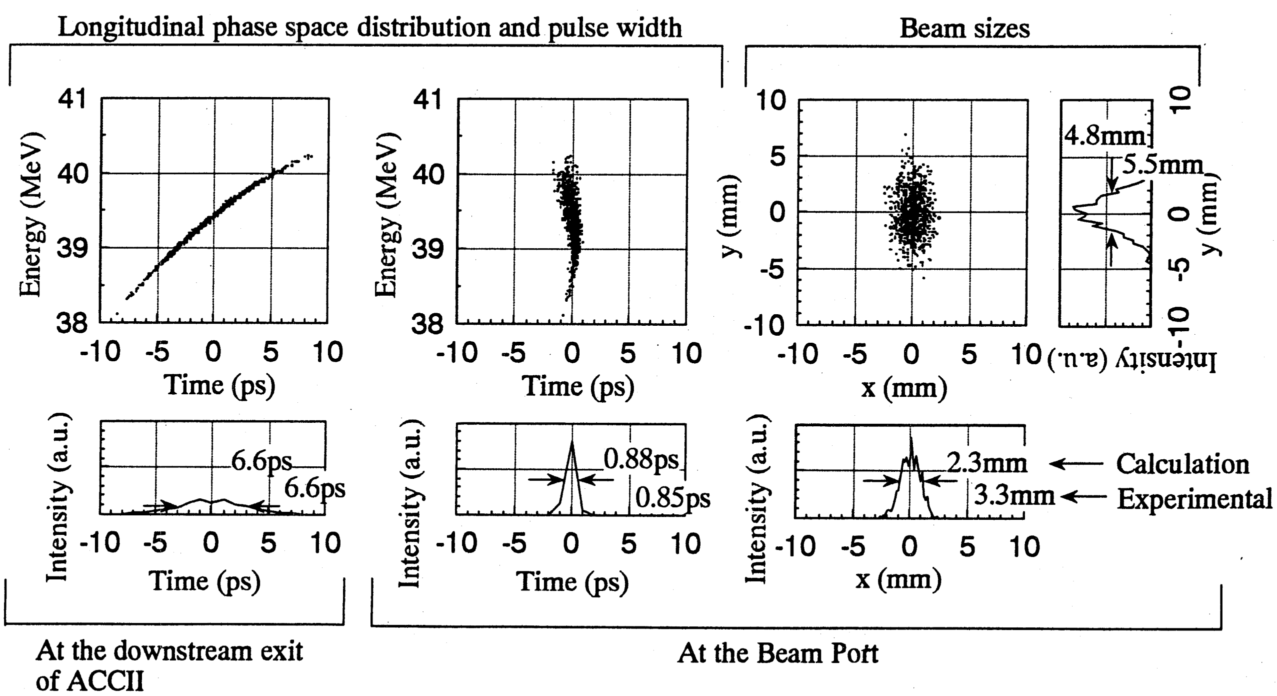

Fig. 3. Calculated longitudinal phase space distributions and beam sizes after energy modulation and after pulse compression.

and vertical beam sizes of the compressed pulse were 3.3 mm and 5.8 mm, respectively. The charge was 208 pC/pulse. Also, 900 fs single pulse with the beam size of 3.3 mm X 3.0 mm was measured at the RF phase of 61.5°. Figure 3 shows the results of simulation. The simulation parameters are 100 πmm mrad as 90 % normalized emittance, 19.1 MeV as the energy and 0.26% as the energy spread at the exit of ACCI. Both the pulse width and the beam sizes are agreed with the experimental results.

3-2. Change of Grid Pulser

By increasing applied voltage to the grid up to 900V from 80V, the emission from Y-796 electron gun was increased up to 11A with the pulse width of 1 ns. With the increase of the emission, the SHB power was increased up to 2.8 kW from 2.0 kW so as to form a single pulse. The electric field of SHB cavity was increased up to 0.029 MV/cm from 0.024 MV/cm. Figure 4 shows the pulse shape at the beam port in the straight direction. The satellite of the main pulse could not been observed within 10 ns before and after the main pulse. The charge of the original pulse passing through 3 ϕ slit was 2 nC/pulse. The charge was increased more than twice. This pulse was compressed by achromatic pulse compression system. Figure 5 shows the typical pulse shape of subpicosecond single pulse with the energy of 34.8 MeV passing through 3 ϕ slit. The charge was 1.04 nC. The charge of the compressed pulse passing through 5 ϕ slit was 1.36 nC. About 20 percent of the initial charge before compression is lost by the energy modulation. Furthermore, a part of the charge is lost at the slit of the beam port.

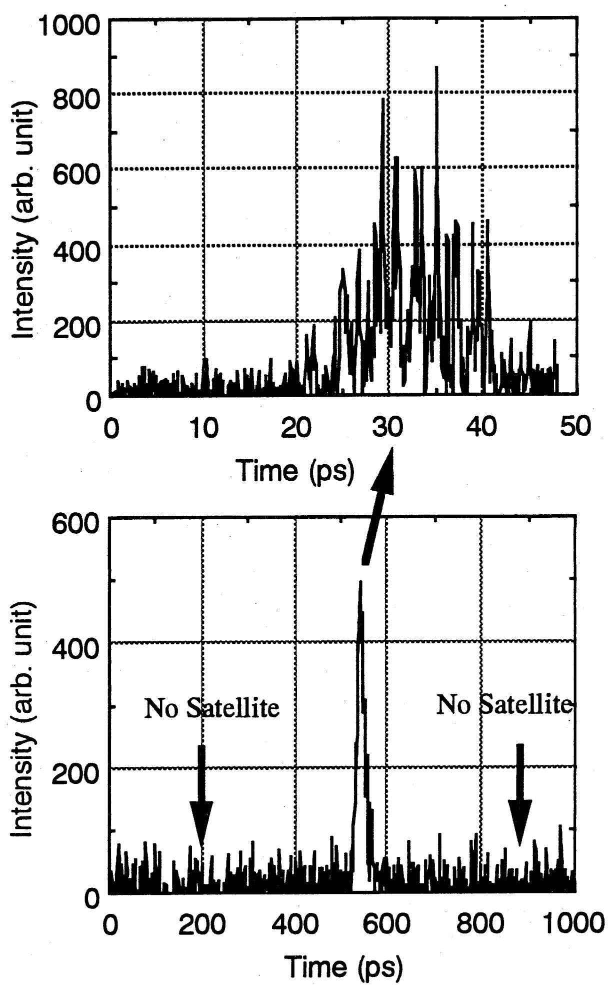

Fig. 4. Measured pulse shape of original single pulse before compression generated by using the 1 kV grid pulser.

4. Summary

34.8 MeV electron pulses with the pulse width of 10 ps have been compressed by the achromatic magnetic pulse compression system at the university of Tokyo. 890 fs single pulse have been generated with the charge of 1 nC through 3 ϕ slit. The satellite of the main pulse could not been observed. Subpicosecond pulse radiolysis system is under construction to investigate radiation chemistry and physics in a subpicosecond time domain.

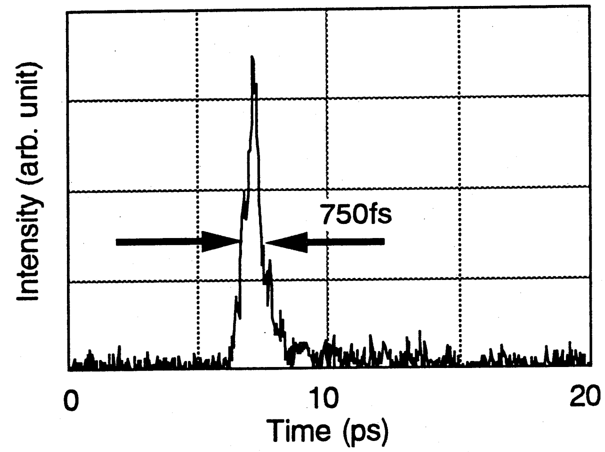

Fig. 5. Measured pulse shape of compressed single pulse with the charge of 1 nC.

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