MAGNETIC PULSE COMPRESSION FOR FEMTO-SECOND SINGLE PULSE

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ABSTRACT

The experiment on magnetic pulse compression aiming at generation of a femto-second single pulse was performed by using the S-band linac of University of Tokyo. First, the longitudinal phase space distributions of electron beams riding on different RF phases was precisely investigated by measuring pulse shape and energy spectrum by the femto-second streak camera and energy analyser magnet, respectively. The magnetic pulse compression system consists of the two accelerating tubes, one benging magnet and two focusing magnets. Finally, the magnetic pulse compression was confirmed and 1-2 pico-second Cerenkov radiation pulses emitted by a certain part of electrons existing in the beam were measured.

1. INTRODUCTION

The research on magnetic pulse compression to generate a femto-second relativistic electron beam single pulse has begun at the S-band linac of University of Tokyo since 1992. Femto-second single pulse will be utilized to investigate ultra-fast and basic process of interaction of an electron beam with matter such as excitation, ionization, relaxation and especially to verify molecular dynamics in radiation damage of material. An increase of energy spread of a beam which is accompanied with the magnetic pulse compression was observed in 1992 [1]. Since then the femto-second streak camera has been introduced for direct measurement of the pulse compression. Experimental results on the measurement of pulse shapes of original and compressed beams are presented and discussed in this paper.

2. EXPERIMENTAL SETUP

The S-band twin linac and measurement system of beam characteristics are schematically depicted in Fig.1. It is very important to tune up the RF phase in ACC1 and ACC2 for the magnetic pulse compression. For the purpose the pulse shape and energy spectrum of an original single pulse were first precisely measured at the end of the 28L line with no RF phase shift between ACC1 and ACC2. Cerenkov radiation which the electron beams emit in air was detected by the femto-second streak camera which has a time resolution of 600fs (Courtesy of Free Electron Laser Institute,INC). We chose a slit width of 30μm. An optical band-pass filter which is centered at 465nm and has a half width of 12.5nm was used to avoid broadening of pulse due to optical dispersion. Next, the magnetic pulse compression was performed in the system which consists of the two accelerating tubes (ACC1, ACC2), one bending magnet (BM) and two quadruple magnets (QM) as shown in Fig.2. The connection of the waveguides between the accelerating tubes and klystrons was changed so that the klystrons can feed RF power independently into ACC1 and ACC2 with tunable phase shift. Pulse compression was measured by using the same femto-second streak camera. Since the mean energy of an electron beam accelerated by only ACC1 is limited up to 19MeV, we attached a xenon gas (1 atm) chamber to the end of the beam line to increase the intensity of Cerenkov radiation. Another optical band-pass filter which is centered at 450nm and has a band width of 25nm was chosen in the balance of the pulse broadening and signal-to-noise ratio.

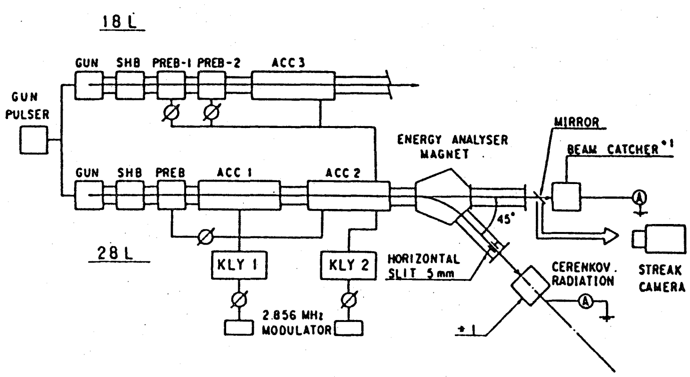


Fig.1 S-band twin linac and measurement system of beam characteristics.

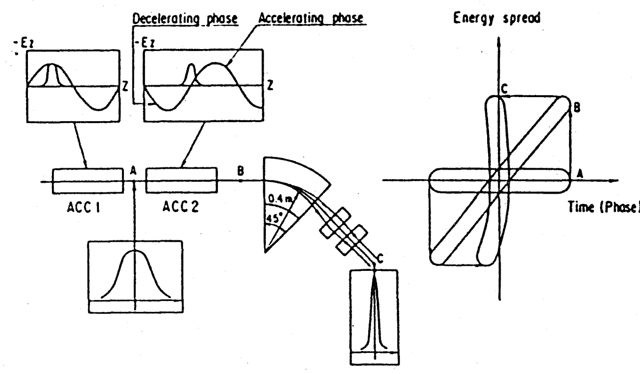


Fig.2 Schematic drawing of magnetic pulse compression system and transformation of beam region in a longitudinal phase space.

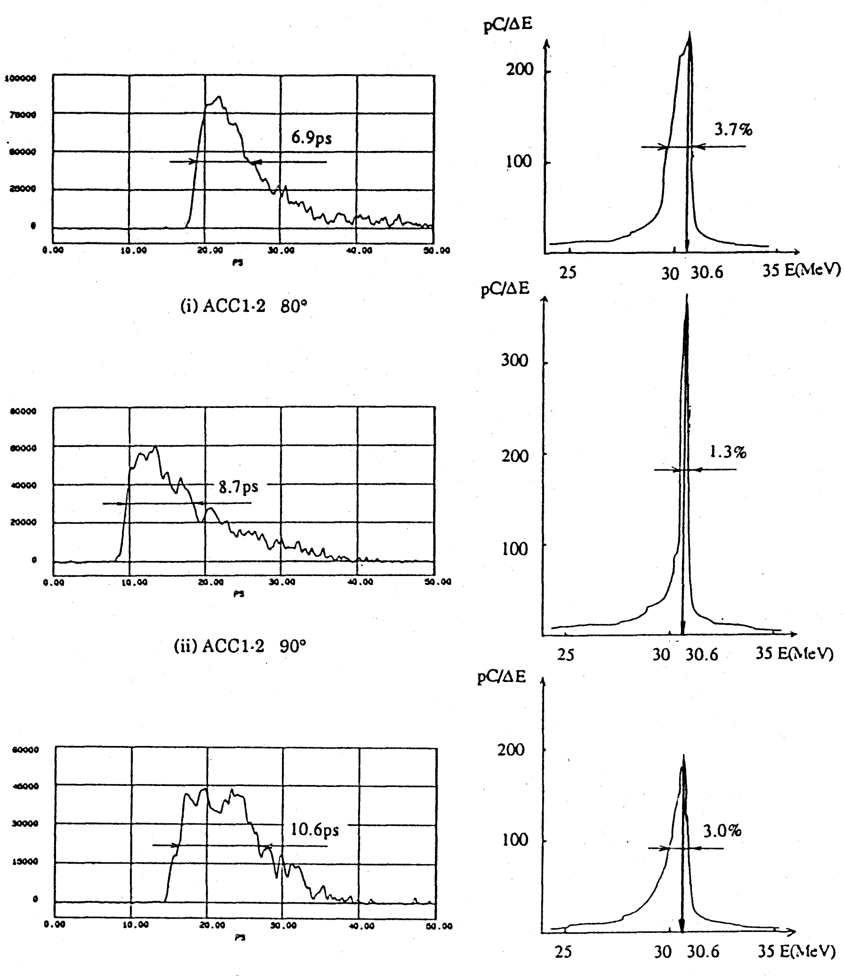


Fig.3 Measured pulse shapes and energy spectra of the beams riding on the RF phases of 80°, 90°, 100° in ACC2.

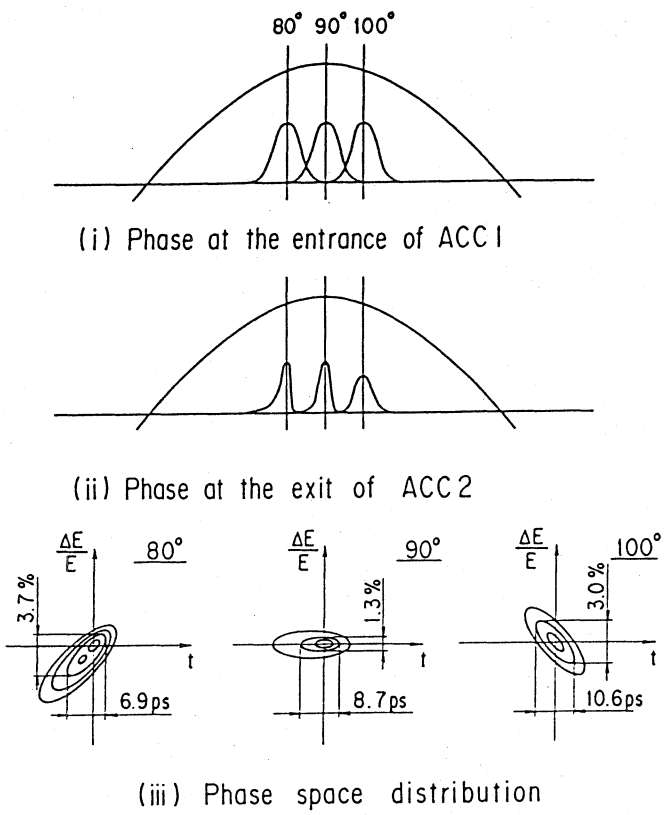


Fig.4 Variation of phase space distributions of the beams riding on the RF phases of 80°, 90°, 100° in ACC1 and ACC2.

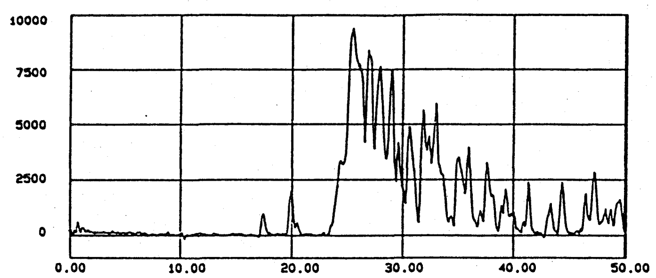
3. RESULTS AND DISCUSSION

Measured pulse shapes and energy spectra of the beams riding on 80°, 90° (crest), 100° of the accelerating RF phase in both ACC1 and ACC2 are shown in Fig.3. The pulse shapes were obtained by one shot. The beam riding in front from the crest of the RF phase has a pulse width of 6.9ps (FWHM) and a long tail. Its energy spectrum has another lower and small peak. As the RF phase at the center of the beam increase, the electrons in the tail tend to be transfered to the center of the bunch. From the above results the longitudinal phase space distributions of the beams can be estimated as shown schematically in Fig.4. We determined to use the beam riding on the crest for the magnetic pulse compression, which has the best energy spectrum and the most electric charges.

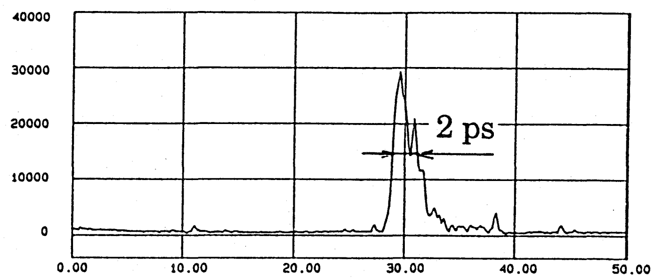
In the magnetic pulse compression experiment, the RF phase in ACC1 was tuned so as to make a beam ride on the crest while the RF phase in ACC2 was tuned so as to accelerate electrons in the early half of the beam and to decelerate those in the later half. We varied the RF power fed into ACC2, that is, the peak electric field and measured a pulse width by one shot. Measured pulse shapes in case of 0, 40% RF power fed into ACC2 are shown in Fig.5. FWHM of the compressed pulse is 2ps. On the other hand, the tracking analysis yielded that an original 10ps single pulse is compressed to a 4ps single pulse in the corresponding case as shown in Fig.6, where the measured data of 19MeV,1% energy spread and 100π mm•mrad horizontal and vertical emittances were used. The measured compressed pulse width is a half of the calculated one. There could be several sources of this discrepancy. The beam trajectory does not necessarily coincide with the axis of the beam line. A certain amount of electrons are lost at the inner wall of the vacuum chamber. The small mirror (10 x 10 mm^2) located in the xenon chamber reflects only a part of Cerenkov radiation. We are going to form an almost achromatic magnet assembly by adding another bending magnet and a tunable horizontal slit in order to enhance the pulse compression efficiency, to reduce the beam loss and to evaluate the relation of pulse width, electric charge and emittance.

4. CONCLUDING REMARKS

The magnet pulse compression experiment was performed at the S-band linac and the compressed pulse width was directly measured by using the femto-second streak camera. The magnetic pulse compression and the possibility to generate a few pico-second single pulse were confirmed. We are going to improve and upgrade the system aiming at generation of a femto-second single pulse.



(i) 0% RF power



(ii) 40% RF power

Fig.5 Measured Cerenkov radiation pulses emitted by the original and compressed beams.

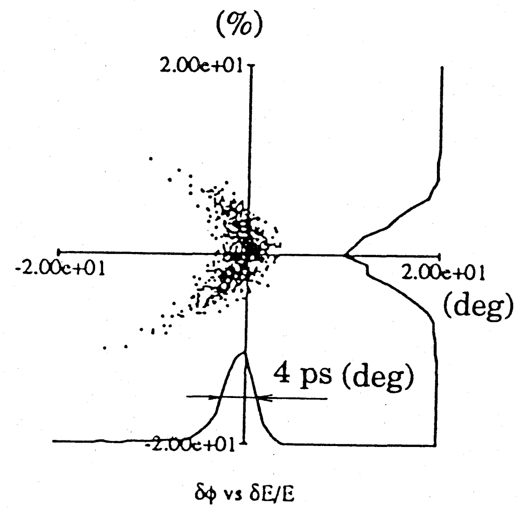


Fig.6 Calculated phase space distribution in case of the peak electric field of 4.2MV/m.

ACKNOWLEDGEMENT

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REFERENCE

[1]M.Uesaka, et al., Proc. of the 17th Linear Accelerator Meeting in Japan, Sendai, 1992, pp.70-72 (in Japanese).