GENERATION OF HIGH-INTENSITY TWO-BUNCH ELECTRON BEAMS WITH THE L-BAND LINAC AT ISIR FOR FELS AND THE OTHER APPLICATIONS

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Abstract

Study has been made to generate high-intensity two-bunch electron beams with the 38 MeV L-band linac at The Institute of Scientific and Industrial Research in Osaka University. By using a grid pulser newly developed for a triode electron gun, a high-intensity two-bunch beam has been generated at a charge per bunch of 19 nC. The time interval between the two bunches is changeable and has been made 37 ns in this experiment. In the first mode for acceleration the difference between the energies of the two bunches has been 0.6 MeV at energies of about 27 MeV, which has made it possible for the two bunches to be seperated with a bending magnet. The energies of the two bunches have agreed in the second mode. The possible applications of the two-bunch beams are discussed.

Introduction

The 38 MeV L-band linac at The Institute of Scientific and Industrial Research (ISIR) in Osaka University has been constructed in 1978. The high-intensity picosecond single-bunch beam generated with this linac has a charge of 67 nC in maximum [1]. The beam has been applied to analyzing ultrafast phenomena. The stroboscopic measurement in the pulse-radiolysis method requires both an electron bunch and a pulsed light emitted from an electron bunch, with actually no time jitter between them. In order to generate two electron bunches a twin linac system has been developed and successfully operated in Tokyo University [2]. It would be more simple if two electron bunches generated with a linac are seperated positionally.

Recently, the single-bunch beam of the ISIR linac has been used for free-electron lasers (FELs) [3]. The FEL gain of the single-bunch beam is extremely high (about 5000). For amplifying the FEL with two electron bunches, they should have the same energy and the time interval coresponding to the round-trip time of the FEL optical cavity [4].

The purpose of this work is to generate two high-intensity electron bunches for FELs and the other applications.

Accelerator System of the ISIR Linac

A schematic diagram of the ISIR linac is shown in Fig. 1. The accelerator system has been optimized for generating the high-intensity single-bunch beam. The linac is equipped with a high-current triode electron gun (Model-12, ARCO), three subharmonic prebunchers (SHPBs) (two at the twelfth subharmonic of the fundamental frequency and one at the sixth) and fundamental bunchers. To the SHPBs rf is supplied from different three sources. The rf modulators with 5 and 20 MW klystrons supply rf to the fundamental bunchers and the accelerating waveguide, respectively. The envelope of the pulsed rf is flat over 4 μs. The rf filling time of the accelerating waveguide is 2 μs.

Electron Gun System for Gerenating Two-Pulse Beam

Grid pulsers are installed in a gun tank filled with pressurized SF_6 gas. For generating the single-bunch beam pulsed electrons with a pulse length of 4.5 ns are injected from the gun at an energy of 100 keV and a peak current of 10-30 A. For the electron-gun pulser relatively high peak voltage (2 kV in maximum) is required. The short pulser consists of an avalanche pulser generating a pulse at a peak

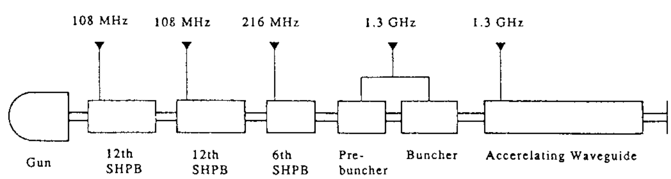

Fig. 1 Schematic diagram of the ISIR linac.

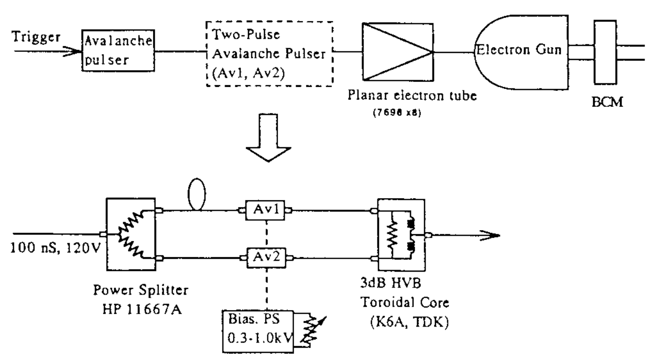

Fig. 2 Schematic diagram of the gun pulser to generate two pulses.

Table 1 The characteristics of the accelerated beams.

Accelerator Frequency	1300 MHz
Energy	27 MeV (the first mode)
	17.1 MeV (the second mode)
Energy Spread	2-3%
Pulse Width	45 ps
Bunch Spacing	37 ns
Total Charge	40 nC

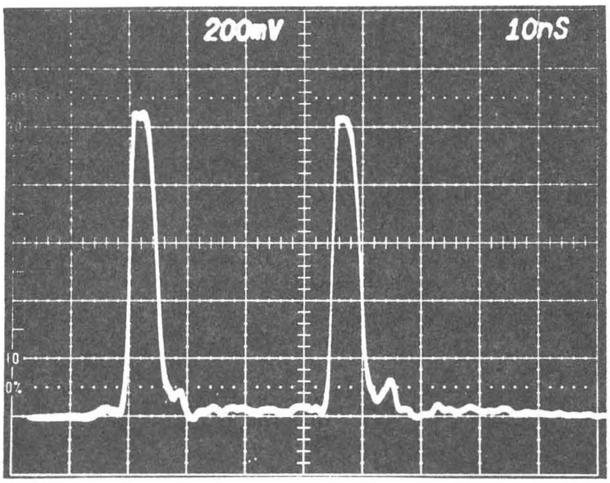

Fig. 3 The shapes of the two output pulses of the grid pulser.

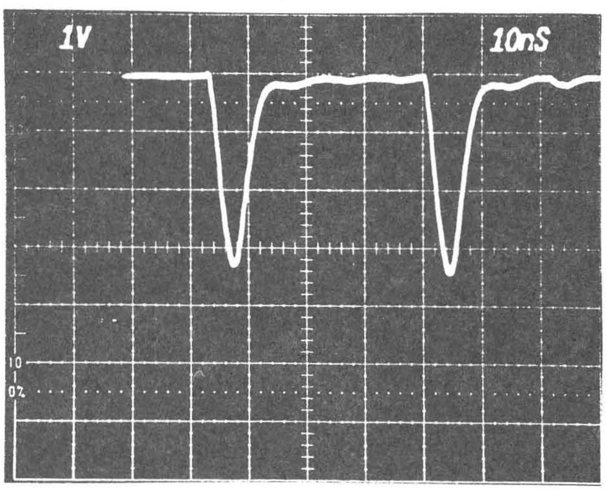

Fig. 4 The waveforms of the two-pulse beam emitted from the gun.

voltage of 120 V and planar electric tubes for amplification. The pulser developed for the present purpose is schematically shown in Fig. 2. A single pulse generated with the avalanche pulser is devided into two, as shown in this figure. The two pulses are mixed with a 3 dB hybrid of a troidal core. The delay time of the second pulse from the first one corresponds to the length of the coaxial cable and is continuously changeable. The time interval between the two pulses should be an integral multiple of a rf period of the first SHPB, 9.2 ns. In the present experiment the interval is made 37 ns, which corresponds to the round-trip time of light in the optical cavity of the FEL system at ISIR. Figure 3 shows the shapes of the two pulses after being amplified with the planar tubes.

Figure 4 shows the waveforms of the two-pulse electron beam injected from the gun, measured with a beam current monitor placed after the gun. The gun high-voltage is 96 kV. The peak current of the beam is 16 A.

Results for the Measurement of the Characteristics of the Two-Bunch Beam

The characteristics of the accelerated beam are listed in Table 1. There are two modes for acceleration. In the first mode the timing of the injection of the electron beam on the rf pulse for acceleration is after the rf filling time of the accelerating waveguide. The energy of the second bunch becomes lower than that of the first one because of the decrease of the rf power due to the beam-loading effect. The two-pulse beam is injected from the gun at a peak current of 14 A. The conditions of the bunchers are nearly the same as those for generating the single-bunch beam. The energy for acceleration is about 27 MeV. The beam current monitor placed after the accelerating waveguide shows that two bunches are accelerated at nealy the same charge. The energy spectrum of the beam thus obtained is shown in Fig. 5(a). The energies of the two bunches at the peaks are 27.3 and 26.7 MeV. When the beam is deflected with a bending magnet, the orbits of the two bunches are seperated. Figure 6 shows the beam profile observed with a screen monitor placed after the 45° bending magnet and three quadrupole magnets. As shown in this figure, the two bunches are well focused and seperated. The distance between the centers of the two bunches is 15 mm on the monitor.

In the second mode the energies of the two electron bunches agree when the timing of the injection of the electron beam on the rf pulse for acceleration is within the rf

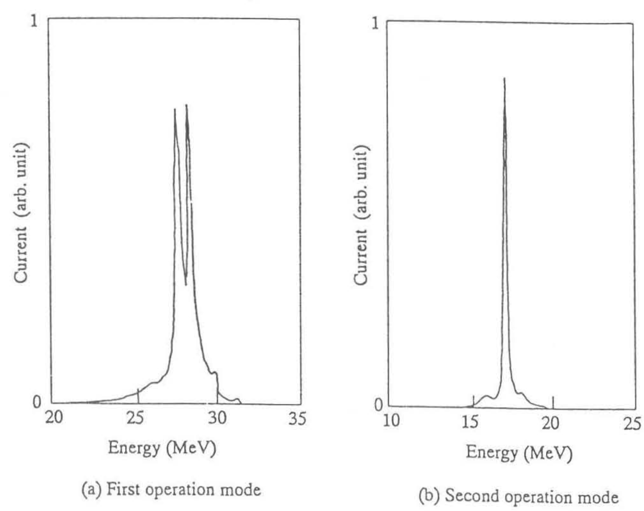

Fig. 5 The energy spectrum of the two-bunch beam in (a) the first mode and (b) the second mode.

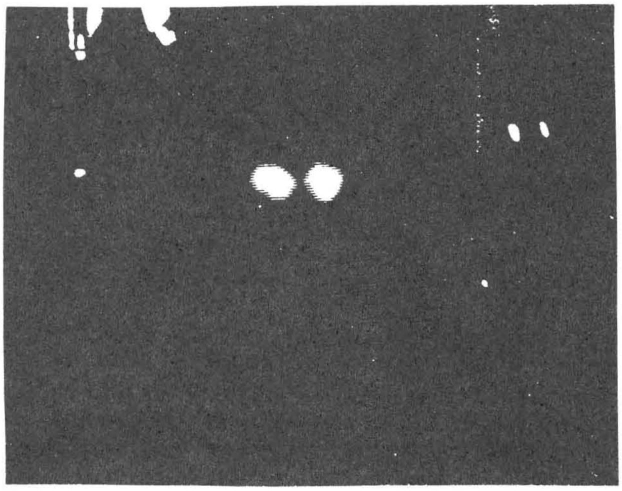

Fig. 6 The beam profile of the two bunches seperated with a bending magnet at a distance of 15 mm.

filling time of the accelerating waveguide. The energy spectrum of the two-bunch beam thus obtained is shown in Fig. 5(b). The optimum timing of injection on the rf pulse is determined by the charge of electrons and the time interval between the two bunches. The adjustment of the parameters of rf components of the accelerator system should be very fine. This procedure has been made by monitoring the waveform of the energy-analyzed two-bunch beam.

The shapes of the bunches of an accelerated beam in the first mode have been measured with a streak camera. In this measurement the Cherenkov radiation emitted from the beam passing in air has been observed. The charges of the satellite bunches have been negligible. The length of the bunch is about 45 ps in FWHM. From the results for the single-bunch beam it is anticipated that the bunch length would be compressed to 20-40 ps, by optimizing the buncher parameters. For the further compression of the bunch length a bunch compressor [5] and a bending magnet are available.

In the two modes the high-intensity two-bunch beams have been successfully accelerated. The time interval between the two bunch is 37 ns in the present experiments. This interval corresponds to an optical path length of 11 m. When in the first mode the first bunch is converted to Chrenkov light in the pulse-radiolysis method, the timing between the light pulse and the second bunch can be widely changed. The two-bunch beam in the second mode is being applied to the amplification of spontaneous emission at extremely high FEL gain [4].

Summary

High-intensity two-bunch beams have been successfully generated at charges of electrons in a bunch of 19 nC in the two beam-modes. The time interval between the two bunches is changeable and has been made 37 ns. In the first mode the difference between the energies of the two bunches has been 0.6 MeV at energies of about 27 MeV, which has made the seperation of the two bunches possible with a bending magnet. The energies of the two bunches have agreed in the second mode.

References

[1] S. Takeda, K. Tsumori, N. Kimura, T. Yamamoto, T. Hori, T. Sawai, J. Ohkuma, S. Takamuku, T. Okada, K. Hayashi and M. Kawanishi, IEEE Trans. Nucl. Sci. NS-32 (1985) 3219.

[2] H. Kobayashi and Y. Tabata, Nucl. Instr. and Meth. B10/11 (1985) 1004.

[3] S. Okuda, J. Ohkuma, N. Kimura, Y. Honda, T. Okada, S. Takamuku, T. Yamamoto and K. Tsumori, Nucl. Instr. and Meth. A331 (1993) 76-78.

[4] S. Okuda, J. Ohkuma, S. Suemine, S. Ishida, T. Yamamoto, T. Okada and S. Takeda, Nucl. Instr. and Meth. A341 (1994) 59-62.

[5] S. Takeda, T. Hori, K. Tsumori, N. Kimura, T. Yamamoto, T. Sawai, J. Ohkuma and T. Okada, IEEE Trans. Nucl. Sci. NS-34 (1987) 772.