OPERATION OF THE ISIR L-BAND ELECTRON LINAC IN VARIOUS MODES

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Abstract

High-intensity electron beams of the 38 MeV L-band linac are being generated in various pulse modes and irradiation doses for applications to experimental researches. Single-bunch and multibunch beams are generated under the different operational conditions of the gun and the subharmonic prebunchers at macropulse lengths below 2 μs. For the irradiation experiments with the single-bunch beams the irradiation doses are in a remarkably wide range of 0.05-91 nC/bunch or 30 fC-10 nC/mm^2/bunch. The applicability of the beams to experimental researches are discussed.

1 INTRODUCTION

High-intensity single-bunch and multibunch electron beams are generated with a 38 MeV L-band (1300 MHz) linac [1,2] at the Institute of Scientific and Industrial Research (ISIR) in Osaka University. The beams are being applied to basic experimental researches for analyzing ultra-fast phenomena induced in matters irradiated with the beam. High-intensity far-infrared light sources using free-electron lasers [3] and the coherent synchrotron or transition radiation [4] from the beams have been developed. In these experiments the electron beams having various pulse modes at macropulse lengths below 2 μs have been used.

Recently, high-current thermionic triode electron gun has been developed [5]. By the improvement of the pulse characteristics of the beams injected from the gun the electron charge in the single-bunch beams has increased to 91 nC/bunch. Irradiation experiments in a remarkably wide dose range are being performed after the development of the method for monitoring a low electron dose using radiation dosimeters.

2 LINAC COMPONENTS

The components of the ISIR linac are schematically shown in Fig. 1. In the electron gun a cathode-grid assembly YU-156 (EIMAC) is installed. The maximum peak current of the beam from the gun measured with a test facility is 30.1 A at an anode voltage of 100 kV [5].

The pulsed electron beam injected from the gun is compressed longitudinally with three subharmonic prebunchers (SHPBs) (two at an rf frequency of 108 MHz and one at 216 MHz). The SHPB has a coaxial single-gap cavity. Pulsed rf generated with a 20 kW rf amplifier at a pulse length of 20 μs is supplied to each SHPB. This system has been optimised to generate the high-intensity single-bunch beams. In this case the pulse length of the beam from the gun is 5 ns FWHM.

Two bunchers are driven by a 5 MW L-band klystron. An accelerating waveguide 3 m long is driven by a 20 MW L-band klystron. The pulse lengths of the rf on the flattop are 3.2 and 3.9 μs, respectively. The maximum

Table 1: Beam pulse modes

Beam modes	Micropulse spacing	Macropulse length	Beam charge (nC/bunch)
Single-bunch			91 (max.)
Two-bunch	9.2 x N ns		20
Multi-bunch 1	770 ps	5 ns - 2 μs	0.2
Multi-bunch 2	9.2 ns	2 μs (max.)	2

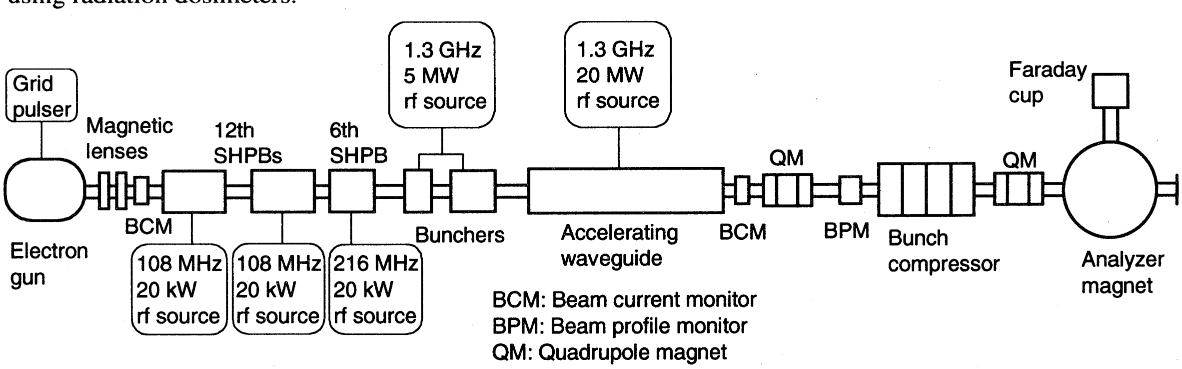

Figure 1: Schematic diagram of the components of the L-band linac at ISIR.

repetition rate of the pulsed rf is 360/s. The operational conditions of the rf components are described in ref. 2.

Electron beam current monitors and beam profile monitors are placed in the beam transport system, some of them being shown in Fig. 1. The energy spectrum of the beam is measured with a bending magnet and a Faraday cup.

Under the various operational modes for the linac components single-bunch and multibunch beams as indicated in Table 1 are generated. Two-bunch beams are generated by injecting two pulsed beams succeedingly from the gun [6]. The micropulse spacing of the multibunch beams depends on the operational conditions of the SHPB system, and can be changed by selecting the natural number *N*. The beams are transported to irradiation rooms and are being applied to various kinds of experiments.

3 CHARACTERISTICS OF THE SINGLE-BUNCH BEAM

The characteristics of the single-bunch beam have been measured at an energy of 27 MeV, which is a common energy in usual experiments. The electron charge of the single-bunch beam increases with the peak current of a pulsed electron beam injected from the gun. At a peak injection current of 28 A the electron charge has the maximum value, 91 nC/bunch. The width of the energy spectrum is 0.8-1 % FWHM at charges below 45 nC, and at the higher charges it increases with the charge.

The single-bunch beam of the ISIR linac generally has a triangular bunch shape and the bunch length is 20-30 ps FWHM. In the previous work the bunch shape of the beam has been investigated by analyzing the longitudinal bunch form factor given from the spectrum of the coherent transition radiation emitted from the beam [7].

The beam emittance has been measured with the method using a quadrupole magnet and a beam profile monitor. Figure 2 shows the electron charge dependence of the normalized rms beam emittance measured at charges of 9-63 nC/bunch. The averaged value of emittance for vertical and horizontal directions is plotted and the error in the measurement is indicated. This figure shows that the emittance increases as the charge and is in a range of 65-160 πmm mrad. These values are below 20% of those of the linac at Argonne National Laboratory [8] in which an electron charge of 100 nC/bunch was obtained.

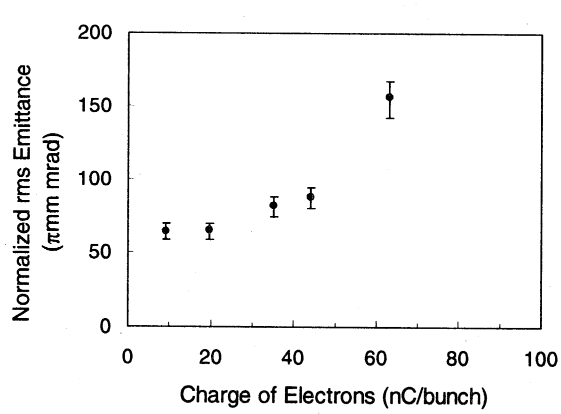

Figure 2: Electron charge dependence of the normalized rms emittance of the single-bunch beam, given by being averaged for vertical and horizontal directions.

4 IRRADIATION AT A WIDE RANGE OF DOSES

The irradiation dose of a beam in a certain volume of a target sample is determined mainly by the intensity and the quality of the beam. Assuming a bunch length of 25 ps the beam brightness are given from the electron charge of the single-bunch beam and the emittance, as shown in Fig. 3. The brightness has a peak at a charge of 40-50 nC/bunch. Assuming the irradiation area of 2x2 mm^2, the irradiation dose is about 10 nC/mm^2/bunch in maximum.

On the other hand, for the irradiation at relatively low doses it is important to monitor beam intensity and irradiation doses accurately. The experimental setup for monitoring relatively low irradiation doses is schematically shown in Fig. 4. By using the beam current monitor the bunch charge at 0.05 nC/bunch can be

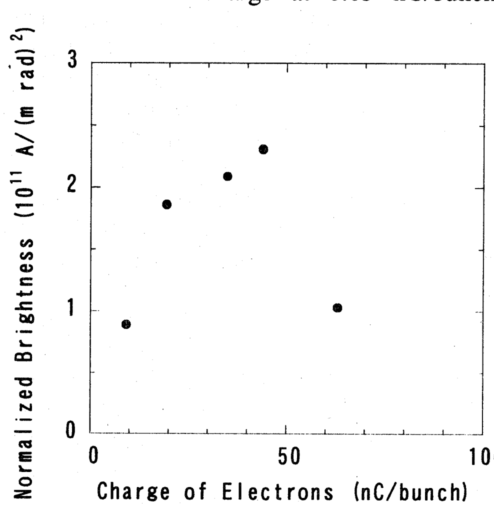

Figure 3: Electron charge dependence of the normalized brightness of the single-bunch beam, given by the results shown in Fig. 2.

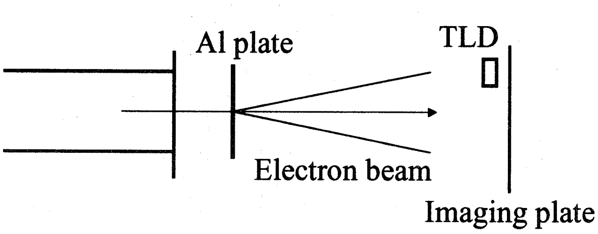

Figure 4: Schematic diagram of the experimental setup for monitoring relatively low irradiation doses.

monitored. The diameter of the electron beams is expanded by the vacuum window and an aluminium plate 2 mm thick used as a beam expander. The beam diameter thus obtained is 50 mmϕ at 450 mm from the plate. In this case the lowest irradiation dose corresponds to 30 fC/mm^2. The density distribution of the beam in the lateral direction has been measured by a wire-scanning method and with an imaging plate. The irradiation dose has also been measured with a thermoluminescence detector (TLD) used for personal dosimetry. The dose corresponds to 1 mSv. In the irradiation the effect of the grid emission from the gun is avoided. In this experiment irradiation doses have been expanded as 0.05-91 nC/bunch or 30 fC-10nC/mm^2/bunch.

The minimum irradiation dose is determined by the sensitivity of these dosimeters and can be decreased more by about two orders of magnitude.

5 BEAM APPLICATIONS

The brightness of the single-bunch beams of the ISIR linac is about two orders of magnitude lower than that of the linac using photocathode rf gun while the intensity of the former is one order of magnitude higher that the latter. For the self-amplified spontaneous emission free-electron laser experiments the brightness and the intensity of the beam are important factors. On the other hand, in the pulse radiolysis experiments using the beams in air atmosphere the beam intensity is the most important factor when the irradiation area is more than a few mm^2. For the experiment of the coherent radiation in a submillimeter to millimeter range the intense beams of the ISIR linac have good features.

The irradiation experiments at relatively low doses are being performed for characterizing highly sensitive dosimeters such as imaging plates and TLDs, and for imaging experiments with the imaging plates.

The various beam modes of the ISIR linac and the irradiation experiments at a wide range of irradiation doses will expand the research fields using the beams.

6 CONCLUSIONS

The single-bunch and the multibunch beams were generated with the ISIR linac in various pulse modes given by the various operational conditions of the gun and the SHPB system. The electron charge of the single-bunch beam is 91 nC/bunch in maximum. By using the beam the irradiation doses of 0.05-91 nC/bunch or 30 fC-10nC/mm^2/bunch were achieved. By these features in the beams of the ISIR linac the application research fields are expected to be widely expanded.

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