LOW INTENSITY ELECTRON BEAM MONITORING AND BEAM APPLICATIONS AT OPU LINAC

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Abstract

Low intensity beams are generated with a 18 MeV S-band electron linear accelerator at Osaka Prefecture University. The minimum charge of electrons in a pulsed beam is about several aC. Study has been made to establish the methods for measuring the intensity and the spatial profile of the beam at electron charges of a beam in aC to pC regions. In pC region a beam monitor using a charge-sensitive amplifier and a two dimensional monitor using a scintillator and a CCD camera have been developed. The characteristics of thermoluminescence dosimeters and two-dimensional radiation dosimeters as monitors in fC region have been investigated. From the results it has been found that these dosimeters can be applied to monitoring the low intensity electron beams. Possible beam application researches are discussed.

INTRODUCTION

High-energy electron beams from accelerators are widely used for irradiation in the various fields of basic researches, and industrial or medical applications. A beam micropulse of an ordinary microwave electron linear accelerator (linac) has about 10^{13} electrons. For the study on the response of highly sensitive radiation dosimeters such a beam is too intense, and β rays from radioisotopes are generally used. However, characteristics of electrons from accelerators such as to be monoenergetic, collimated and synchronized with the trigger signal of the accelerator are not obtained in the case of β-ray sources.

Recently, low intensity beams have been developed with the 18 MeV S-band electron linac at Osaka Prefecture University (OPU) [1]: low intensity means the total electron charge in a beam below roughly 1 pC. The minimum charge of electrons in a beam macropulse so far obtained is about several aC [2]. One of the key technologies for achieving such low intensity is to measure the intensity and the profile of the beam.

In the present work the methods for monitoring the low intensity beams have been investigated. From the results of the study possible application researches are discussed.

GENERATION AND MONITORING OF LOW INTENSITY BEAMS

In order to apply the low intensity electron beams from a linac to irradiation experiments technical developments in generating and monitoring the beams are required. Figure 1 shows such technologies in the region of beam intensity. The following methods are used for generating the low intensity beams.

1) Short pulse operation of an electron gun.
2) Low current operation of an electron gun with suppressed heater current.
3) Beam attenuation by using narrow beam slits.

In the beam monitoring the intensity and the spatial profile of the beams are measured. One beam monitor does not work over such wide range of beam intensity as shown in Fig. 1. Each monitor is available in the corresponding region. At electron charges of the beam

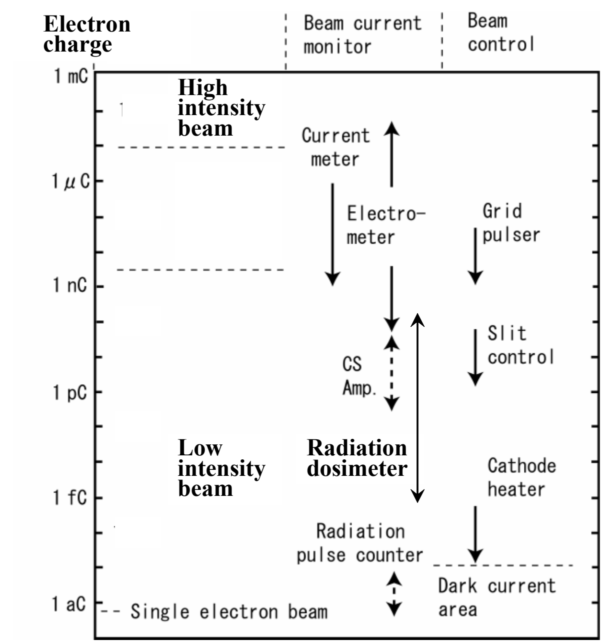

Figure 1: Technologies for generating and monitoring low intensity electron beams from a linac.

above 1 nC ordinary beam monitors can be used. At charges in pC region a charge sensitive and low noise detector has been developed in the present work. In fC region thermoluminescence dosimeters (TLD) and two-dimensional radiation dosimeters would be candidates. The characteristics of the dosimeters have been investigated by using the low intensity electron beams from the linac also in the present work. In aC region each electron can be detected by using a radiation detector without overlapping between the pulsed signals.

LINAC SYSTEM FOR LOW INTENSITY BEAM GENERATION

The accelerator system of OPU S-band linac is schematically shown in Fig. 2. Pulsed electron beams are injected from a thermionic triode gun with a cathode-grid assembly, Y-796 (EIMAC). The maximum energy, pulse

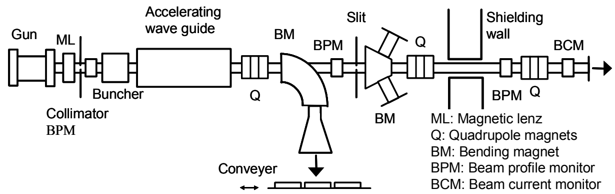

Figure 2: Schematic diagram of the accelerator system of the OPU electron linac.

lengths, the maximum pulse repetition rate of the beam are 18 MeV, 50 ns-5 μs and 500 pulse/s, respectively. The accelerated beam is bent to an underground irradiation room, where the energy spectrum of the beam is measured and a beam scanner for the irradiation over a relatively large area of samples is installed. The beams transported to the straight direction through a concrete shielding wall are used in the other irradiation room for various experiments such as irradiation experiments with narrow beams and pulse radiolysis experiments.

Figure 3 shows the processes to obtain low intensity beams in the accelerator system. The operational

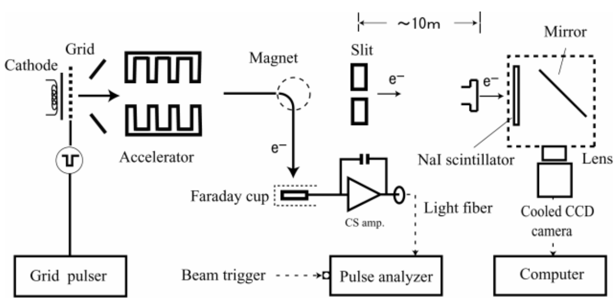

Figure 3: Schematic diagram showing the processes to obtain low intensity electron beams in the accelerator system.

conditions of the linac are basically the same as those for beams at an ordinary intensity. Monitoring the electron beam in the underground room the operational conditions of the linac are optimized to obtain the stable beam conditions and the peak beam energy is fixed. Also in this process the beam intensity is decreased with the emission current of the electron gun, changing the heater current at the cathode. After determining the operational conditions the intensity of the accelerated beam is decreased by using the water cooled beam slits, when the attenuation factor measured in a typical case is about 1/350.

BEAM MONITORING AT CHARGES IN PC REGION

In the region of electron charge of a low intensity beam about pC, a charge sensitive (CS) amplifier, commonly used as a pre-amplifier of a radiation detector measuring electric charge in pulsed signals, has been newly developed as a component of an electron beam charge monitor. Figure 4 (a) shows the circuit of the amplifier. The monitor consists of the CS amplifier, a pulse width stretcher and an optical link. The amount of the electron

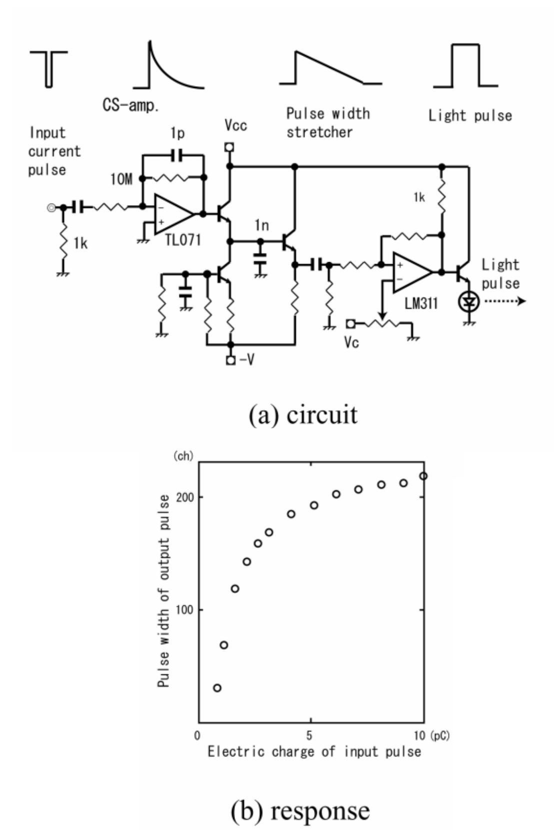

Figure 4: Circuit of the CS amplifier developed (a) and the relation between the input charges supplied from a standard pulse generator and the pulse width of the output signal of the CS amplifier monitor (b).

charge in a beam is converted to the width of an optical pulse. A CS amplifier is generally sensitive to electric noise. In order to avoid the relatively strong noise from the linac modulator the monitor is operated with a battery power supply and the output optical signal is transmitted through an optical fiber to the data acquisition system. This system is isolated electrically from other equipments around the linac. With the additional components for the circuit and the shielding a low-noise monitor has been established. Figure 4(b) shows the relation between the input charges supplied from a standard pulse generator and the pulse width of the output signal. Linear relation is shown in the region about 1pC. The lowest limit for detection is about 0.2pC.

A two-dimensional beam profile monitor for the low intensity beam has been developed by using a high sensitivity imaging system for radiation. The schematic diagram of the system is shown in Fig. 3. This consists of a cooled CCD camera and an NaI (Tl) scintillator of circular plate 1 mm thick with a diameter of 50 mmϕ, which is set in a dark box. The applicability of this system to beam profile monitoring in pC range has been confirmed.

BEAM MONITORING AT CHARGE IN FC REGION

In the region of electron charge about fC high sensitivity radiation dosimeters are candidates for monitoring the beams. In the present work TLD and two dimensional dosimeters have been investigated. The element of TLD (UD309-P, Matsushita Corp.) used for personal dosimeter in radiation protection has been normally irradiated with the low intensity electron beams. The element material is $Li_2B_4O_7$ doped with an impurity element added at small amount. This is probably the first experiment using a linac electron beam while the effect of γ rays is well known. The beam energy has been 10 MeV. The beam has been transmitted through a beam window with a diameter of about 10 mmϕ at the TLD element. The beam intensity has been sufficiently stable over many beam macropulses. The electron charge in a beam macropulse has been evaluated from the results for the measurement of the total charge of electron beams of many pulses with the CS amplifier monitor. Figure 5 shows the electron charge dependence of the TLD output signal. This has the linear response to the electron charge over the range of five orders of magnitude. The lowest detection limit of the TLD has been found to be about 10 fC. These results shows that the TLD can be used as a beam monitor in fC region.

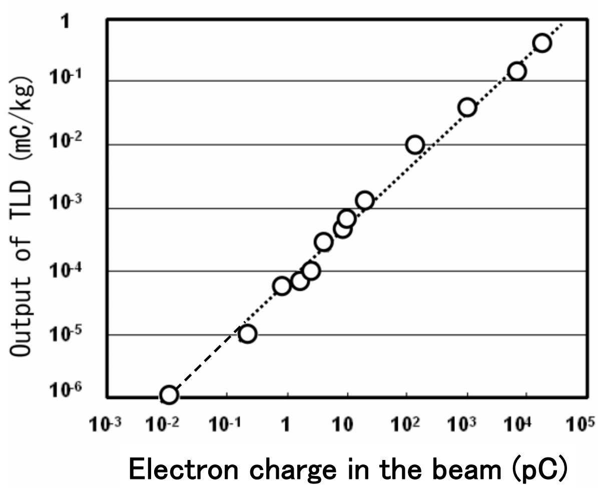

Figure 5: Experimental results for the electron charge dependence of the TLD output signal in the irradiation with electron beams at an energy of 10 MeV: the broken line shows a linear relation.

Two dimensional measurement of the beam profile has been performed by using an imaging plate (Fuji Corp.), which is generally used for radiography. The details of the results on the characteristics of the dosimeter will be shown elsewhere.

APPLICATIONS OF LOW INTENSITY ELECTRON BEAMS

In the present work the experimental system for irradiation with low intensity linac beams in aC-pC region has been established. By using the system irradiation experiments have been started for investigating the characteristics of high sensitivity dosimeters, and the energy spectra of bremsstrahlung X-rays without piling up of the pulsed signals of a radiation detector. A two dimensional dosimeter can be applied to electron radiography experiments. Investigation of the biological effects is important to know the effects in the electron beam therapy. In many experiments the comparison with the effects of γ rays would give ones new information.

Many kinds of irradiation experiments using the low intensity electron beams are prepared under the collaboration of researchers in various research fields.

CONCLUSIONS

The beam monitors were investigated to measure the charge and the spatial profile of the low intensity electron beam from OPU electron linac at an electron beam charge in aC-pC region. By these results the irradiation system using the beams was established. Several application researches were started by using the low intensity beams.

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