CHARACTERISTICS OF THE ELECTRON LINAC BASED COHERENT RADIATION LIGHT SOURCE AT OPU*

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Abstract

The coherent radiation from the bunched electron beams of an RF linear accelerator has continuous spectra in a submillimeter to millimeter wavelength range at relatively high peak-intensity. In the present work the coherent transition radiation light source has been developed by using the electron beams of an 18 MeV S-band electron linac at Osaka Prefecture University. From the thermionic triode electron gun with a cathode-grid assembly pulsed electron beams are injected at pulse lengths of 5 ns-4 μs at a pulse repetition rate of 500 pulses/s in maximum. The light source will be applied to the absorption spectroscopy and also to the pump-probe experiments using the pulsed electron beam or the pulsed coherent radiation for pumping, and the coherent radiation for probing. The transient properties of the matters after pumping will be investigated. The characteristics of the light source are reported.

INTRODUCTION

The coherent radiation (CR) from a shortly bunched electron beam of an RF linear accelerator (linac) has continuous spectrum in a submillimeter to millimeter wavelength range at a relatively high peak-intensity. After the first observation of the coherence effect in synchrotron radiation the radiation processes have been investigated.

The CR light hav been applied to absorption spectroscopy for various kinds of matters [1-4], especially for relatively strong light absorbance. Recently, the authors have carried out the absorption spectroscopy experiments using the coherent transition radiation light source developed with the L-band electron linac at Kyoto University Research Reactor Institute [5].

In the present work a coherent transition radiation light source with an 18 MeV S-band electron linac at Osaka Prefecture University (OPU) has been developed. This light source will be applied to absorption spectroscopy for variety of matters. In this system the pulsed CR at high peak intensity is also applied to time-resolved measurements in pump-probe experiments.

COHERENT RADIATION AND ITS APPLICATIONS

Synchrotron and transition radiation from short electron bunches of an RF linac becomes coherent and highly intense at wavelengths longer than the bunch length. It has a continuous spectrum in a submillimeter to millimeter wavelength range. The wavelength range and the spectrum of the radiation are determined by the radiation process and by the length and the shape of the electron bunch. In general cases such wavelengths correspond to the terahertz and the lower light frequencies. The peak intensity of the CR is extremely high compared with that of the other terahertz light sources. In order to obtain high average power several accelerator-based CR light sources are under construction.

OPU ELECTRON LINAC AND ITS OPERATIONAL CONDITIONS

The accelerator system of the OPU S-band linac is schematically shown in Fig. 1. Pulsed electron beams are injected from a thermionic triode gun with a cathode-grid assembly. The maximum energy, the pulse lengths and the maximum pulse repetition rate of the beam are 18 MeV, 5 ns-4 μs and 500 pulses/s, respectively. The accelerated beam is bent in the direction to an underground irradiation room in order to measure the energy spectrum of the beam. In this room a beam scanner is installed for the irradiation over a relatively large area, and accordingly, over many samples at the same time.

The beams are transported in the straight direction to the other irradiation room through a hole in a concrete shielding wall for the applications of narrow beams and pulse radiolysis experiments. Recently ultra-low intensity electron beams have been developed, where the minimum charge of electrons in a pulsed beam of several aC has been achieved. This beam will be applied to investigating the characteristics of the highly sensitive radiation dosimeters such as thermoluminescence dosimeters and imaging plates, biological effects of β radiation, etc. The present system of the new CR light source is located in the end of the straight beam line.

The operational conditions of the linac components such as waveguides and the beam steering magnets are optimized to obtain the highest intensity of radiation measured with the light detector. In this process relatively strong bunch compression in accelerator waveguides results in the increase of the radiation intensity by two or three orders of magnitude. Such conditions have been investigated previously [6]. While the energy spectrum of the electron beam slightly spreads in the operational conditions, this does not affect the straight beam transportation to the light source as shown in Fig. 1.

In order to perform the time-resolved experiments the grid pulser of the electron gun of the linac has been

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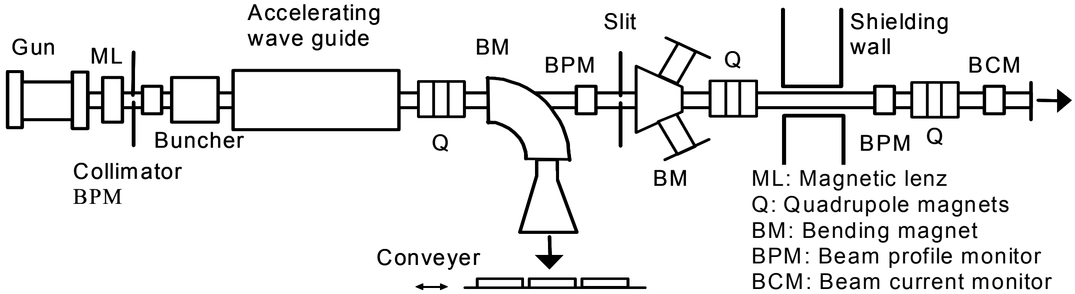

Figure 1: Schematic diagram of the OPU electron linac system.

improved for generating short-pulse electron beams at a length of 5 ns. It will be improved to be shorter to obtain a single-bunch beam. The trigger system for the pump-probe experiments has already been established for the pulse-radiolysis experiments.

CHARACTERISTICS OF THE CR LIGHT SOURCE

The characteristics of the CR light source have been evaluated. In our previous work investigating the electron bunch form factors obtained from the CR spectra the bunch shape of a linac beam has been found to be approximated as triangular [7]. The pulse length of the light corresponds to the bunch length, which is typically within a few picosecond in the case of the electron bunch of an S-band linac. The spectrum of the coherent transition radiation obtained by calculation for the triangular electron bunch at an FWHM length of 1 ps is shown in Fig. 2. In this case the energy of the electron

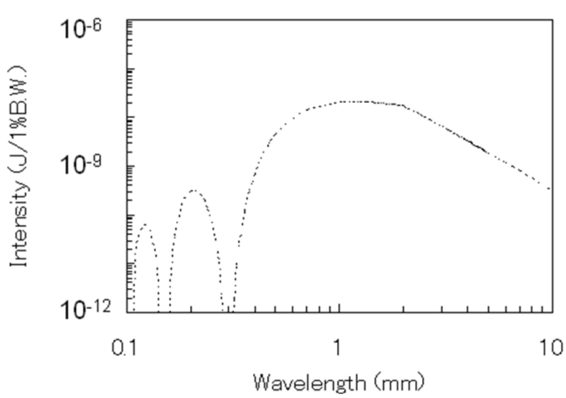

Figure 2: Spectrum of the coherent transition radiation obtained by calculation for the electron bunch of the OPU linac beam in the typical conditions.

beams is 10 MeV and the charge of electrons in a bunch is 0.3 nC. The typical configurations of the transition radiation source have been assumed in the calculation. Those are the same as described in ref. 8. In this figure the characteristic shape of the spectrum in a relatively short wavelength range comes from that of the electron bunch form factor. The FWHM electron bunch length corresponds to 0.3 mm in this case. The peak intensity of the CR is about 2 J/1%B.W. at wavelengths about 1 mm. At the shorter wavelengths the intensity of radiation decreases as the wavelength as shown in this figure.

The another important application of the CR light source is pump-probe experiment, where matters are pumped with the pulsed electron beams or the pulsed CR in a short period corresponding to the bunch length, typically within a few picosecond in the case of S-band linac. In the authors project the system schematically shown in Fig. 3 has been established. In this system the

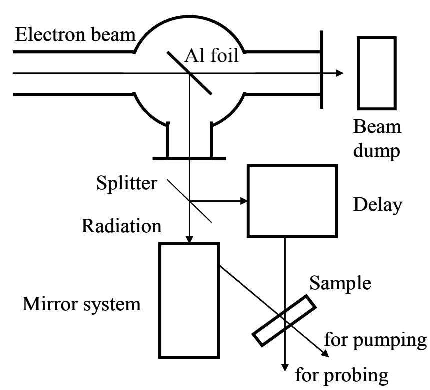

Figure 3: Schematic diagram of the setup for pump-probe experiment using the coherent transition radiation.

coherent transition radiation emitted from an aluminium foil in the backward direction is used as source light. The sample is pumped by the pulsed electron beam used to generate the CR or by the pulsed CR. A part of the radiation synchronized with the pumping beam is used for probing to perform the time-resolved absorption spectroscopy after pumping. On the path of the light a delay line is installed.

In our recent experiments for absorption spectroscopy performed at Kyoto University, the light intensity dependence has been observed for several matters. It is expected that the pump-probe experiments will give us the important information to understand this phenomenon.

The coherent synchrotron radiation light source is under construction.

The grid pulser of the electron gun of the linac will be improved for generating single-bunch electron beams in the near future.

CONCLUSIONS

Study has been made to investigate the characteristics of the coherent transition radiation from the electron beams of an 18 MeV S-band linac at OPU. The spectrum of the CR has been evaluated from the electron bunch shape. The light source will be applied to absorption spectroscopy for various kinds of matters and to the pump-probe experiments using the electron beam and the pulsed CR.

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