NEW PUMP-PROBE SYSTEM USING THE COHERENT RADIATION FROM A LINAC ELECTRON BEAM AT OPU*

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Abstract

The coherent radiation from an electron bunch of a linear accelerator (linac) has continuous spectrum in a submillimeter to millimeter wavelength range and has an intense pulsed electric field. In this work a new pump-probe system has been developed by using the electron beams of an 18 MeV S-band electron linac at Osaka Prefecture University (OPU) in order to investigate the transient phenomena induced by the pulsed coherent radiation. For this purpose the OPU pulse-radiolysis system has been improved. The intensity of radiation has been evaluated from the electron bunch shape. The light source will be applied to exciting and probing various kinds of matters using the electron beam and the coherent radiation.

INTRODUCTION

The coherent radiation (CR) from a shortly bunched electron beam of a linear accelerator (linac) has continuous spectrum in a submillimeter to millimeter wavelength range.

The peak intensity of the CR is extremely high compared with those of the other conventional terahertz light sources. The coherent synchrotron and transition radiation light sources have been applied to absorption spectroscopy for various kinds of matters [1-4], especially for matters with relatively strong light absorbance. Recently, the absorption spectroscopy system using the coherent transition radiation has been established at Kyoto University [5]. In the experiments using this light source the change of the transmission spectra with the intensity of the CR has been observed for several kinds of matters. These results suggest that some change might be induced in the matters by the pulsed CR.

The high peak intensity and the short-pulse radiation are expected to be applied to pumping matters and time-resolved measurements. Transient phenomena induced by pulsed electron beams have been investigated with a pulse-radiolysis system [6] with a 18 MeV S-band electron linac at Osaka Prefecture University (OPU).

In the present work a new pump-probe system has been developed to investigate the transient phenomena induced by the pulsed CR by improving the OPU pulse-radiolysis system. In this system the pulsed CR at high peak intensity is applied to time-resolved measurements in pump-probe experiments.

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OPU ELECTRON LINAC

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 beams are supplied to many users for various kinds of basic experiments. It has a multipurpose irradiation system. The accelerated beam is bent in the direction to an underground irradiation room. 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 with broad beams.

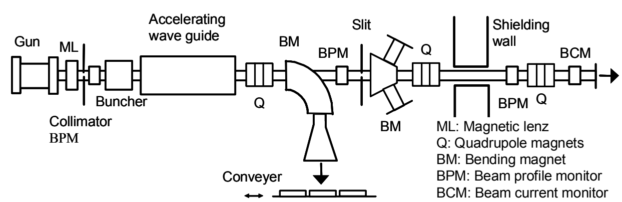

Figure 1: Schematic diagram of the OPU electron linac system.

For the applications of narrow beams and pulse-radiolysis experiments the beams are transported in the straight direction to the other irradiation room through a hole in a concrete shielding wall. Recently ultra-low intensity electron beams have been developed, where the minimum charge of electrons in a pulsed beam is several aC. This beam will be applied to investigating the characteristics of the highly sensitive radiation dosimeters such as thermoluminescence dosimeters and imaging plates, the method of advanced radiation measurements, biological effects of β radiation, etc. The present system using CR is located in the end part 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 enhancement of the radiation intensity by two or three orders of magnitude. Such conditions have been investigated previously [7]. While the energy spectrum of the electron beam slightly expands in these operational conditions, this does not affect the beam transportation in the straight beam line to the light source, as shown in Fig. 1.

Fig. 2 shows the schematic diagram of the pulse structure of the electron beams of the OPU linac. According to the emission process the CR from the electron beam would have the same pulse structure.

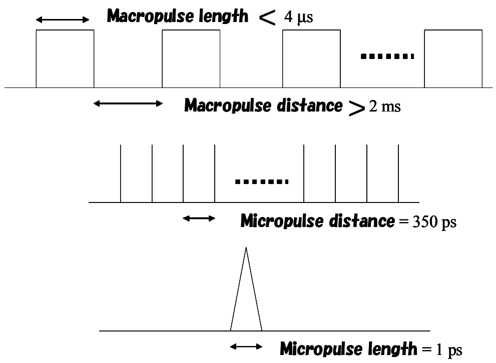

Figure 2: Schematic diagram showing the pulse structure of the electron beam from the OPU linac.

In order to perform the time-resolved experiments the grid pulser of the electron gun of the linac has been developed 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 in the pulse-radiolysis experiments has been improved for the new pump-probe experiments.

CHARACTERISTICS OF THE CR

The wavelength range of the CR is determined by the pulse shape of the electron bunch. In general cases the wavelengths in a submillimeter to millimeter wavelength range of CR correspond to the terahertz and the lower light frequencies. The peak intensity of the CR is extremely high compared with those of the other conventional terahertz light sources.

The coherent synchrotron radiation is emitted as a linearly polarized, unipolar and pulsed electric field. The pulse shape of the electric filed is determined by the electron bunch shape. In our previous work investigating the electron bunch form factors from the CR spectra the bunch shape of a linac beam has been found to be approximated as triangular [8]. The length of the CR light pulse corresponds to the bunch length, typically within a few picosecond in the case of the S-band linac.

The CR can produce the intense pulsed electric field in a matter irradiated and would cause the excitation of it. In the case of the electron bunch from the OPU linac the electric field in a matter is expected to be more than 1 MV/cm.

The pulse shapes of the CR correspond to those of electron beams. The CR has the same pulse structure as shown in Fig. 2. This structure shows the time resolution for investigating the transient phenomena in the range over several picoseconds.

PUMP-PROBE SYSTEM

The new light source for the excitation of matters and the pump-probe experiments by using the OPU linac has been developed. Fig. 3 shows schematically the components of the system. For this system the pulse-radiolysis system has been improved, where the samples

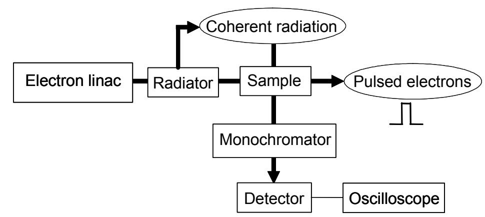

Figure 3: Schematic diagram of the pump-probe experimental setup.

are excited with the electron beams or the pulsed coherent radiation in a short period. The coherent synchrotron and transition radiation is used as light sources. Fig. 4 shows the configurations of the coherent transition radiation pump-probe system. The sample is pumped by pulsed CR. A part of the radiation synchronized with the

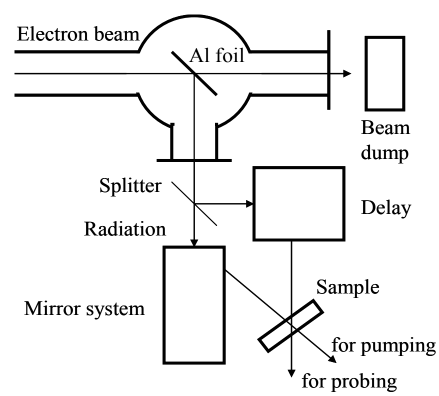

Figure 4: Schematic diagram showing the configurations of the coherent transition radiation pump-probe system.

pumping light is used as a probe to perform the time-resolved absorption spectroscopy after the pumping. On the path of the light a delay line is installed.

This system will be applied to investigating the transient phenomena induced by the intense pulsed CR or electron beams by using CR as probe.

CONCLUSIONS

A new pump-probe experimental system using the coherent synchrotron and transition radiation from the electron beams of a 18 MeV S-band linac was developed at OPU. The system of the light source has been optimized. The light source will be applied to the excitation of various kinds of matters and to the pump-probe experiments using the electron beam and the pulsed CR.

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