# ELECTRON LINAC BASED COHERENT RADIATION LIGHT SOURCE PROJECT 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. The purpose of the present work is to establish a new light source of the coherent synchrotron and transition radiation from the electron beams of a 18 MeV S-band linac at Osaka Prefecture University (OPU). The pulse shape of the radiation has been evaluated from the electron bunch shape. 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 coherent radiation.

## INTRODUCTION

The coherent radiation from a short electron bunch of a 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 peak intensity of the coherent radiation is extremely high compared with those of the other 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 from the electron beams of the L-band electron linac under relatively simple configurations has been established at Kyoto University Research Reactor Institute [5], and has been generally used for experiments.

As well as the applications as probes the high peak intensity and the short pulse shape of the radiation are expected to be used for excitation of matters and time-resolved experiments. Such applications are not performed so far.

The present work has been performed to establish the new coherent radiation light source applied to the excitation of matters and the pump-probe experiments.

## COHERENT RADIATION LIGHT SOURCE

Synchrotron and transition radiation from short electron bunches of a 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 of the radiation is determined by the length and the shape of the electron bunch. In general cases the wavelengths correspond to the terahertz and the lower frequencies of light. The peak intensity of the coherent radiation is extremely high compared with those of the other 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 coherent radiation spectra the bunch shape of an linac beam has been found to be approximated as triangular [6]. The light pulse has a short length corresponding to the bunch length, typically within a few picosecond in the case of the electron bunch of an S-band linac. It might be possible to use the coherent transition radiation for obtaining the similar pulsed light as well as the coherent synchrotron radiation.

The coherent radiation induces intense pulsed electric field in a matter and results in the excitation of it. In the case of the coherent radiation the electric field induced in a matter is expected to be more than 10 MV/cm.

## LIGHT SOURCE SYSTEM

The new light source for the excitation of matters and the pump-probe experiments by using a 18 MeV S-band electron linac at OPU has been investigated.

### *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, pulse lengths, the maximum pulse repetition rate of the beam are 18 MeV, 5 ns-5 μs and 500 pulses/s, respectively. The accelerated beam is bent to an underground irradiation room, where the energy spectrum of the beam is measured. In this

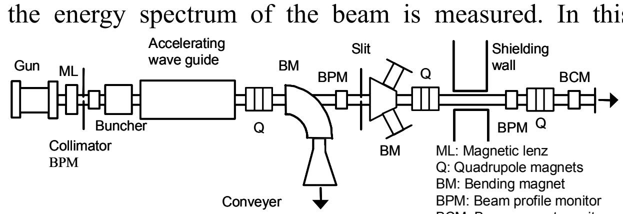


Figure 1: Schematic diagram of the OPU electron linac system.

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room a beam scanner for the irradiation over a relatively large area of samples is installed.

The beams transported to the straight direction through a hole in 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. The present system for the new 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 at 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 previously investigated [7]. 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 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.

### *Evaluation of the Coherent Radiation*

In the usual cases the radiation is suppressed in the relatively long wavelength range because of the limited space of the vacuum chamber made of conductor [8]. The absorption of the light in the path of transportation possibly causes the deformation of the pulse shape. In order to establish a new light source the characteristics of the radiation has been evaluated. The pulse shape of the electric filed of the coherent radiation obtained by calculation for the triangular electron bunch at a FWHM length of 1 ps is shown in Fig. 2. The complete suppression of radiation at wavelengths longer than a cutoff wavelength has been assumed in the calculation. As shown in this figure the peak electric field decreases with the cutoff wavelength. From these results it has been found that the cutoff of radiation at wavelengths shorter than 5 mm should be avoided in order to obtain sufficient peak field intensities of radiation.

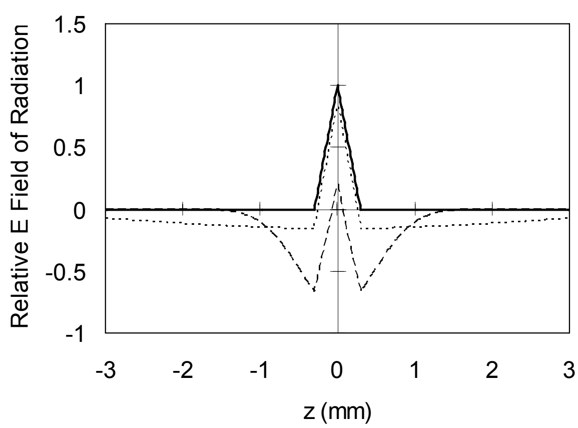


Figure 2: Pulse shape of the electric filed of the coherent synchrotron radiation obtained by calculation for the isosceles triangular electron bunch at a FWHM length of 1 ps. No suppression (solid line) and suppression of radiation at wavelengths longer than a cutoff wavelength of 1 (dashed line) and 5 (dotted line) mm have been assumed.

The electric field induced in matters by the coherent radiation has been estimated to be higher than 1 MV/cm.

### *Setup for Pump-Probe Experiments*

The important applications of the coherent radiation light source are pump-probe experiments, where matters are excited with the electron beams or the pulsed coherent radiation in a short period which corresponds to the bunch length and is typically within a few picosecond in the case of S-band linac. In the light source project at OPU the system schematically shown in Fig. 3 is established. In this system the coherent synchrotron and transition radiation is used as light sources. The sample is excited by pulsed electrons used for the source of light or by the pulsed radiation. A part of the radiation synchronized with the pumping beam is used as a probe to perform the time-resolved absorption spectroscopy after the excitation. On the path of light a delay line is installed.

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

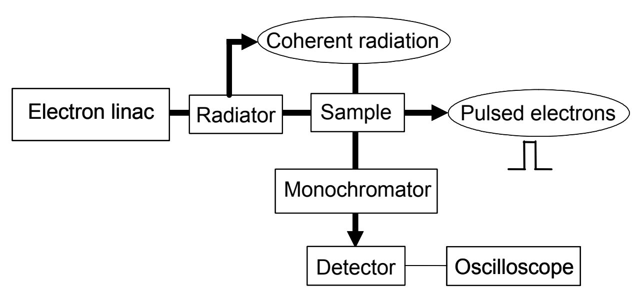


Figure 3: Schematic diagram of the pump-probe experimental setup.

## CONCLUSIONS

Study has been made to establish a new light source of the coherent synchrotron and transition radiation from the electron beams of a 18 MeV S-band linac at OPU. The pulse shape of the radiation has been evaluated from the electron bunch shape. 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 coherent radiation.

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