Accepted Manuscript

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PII: S1350-4495(18)30039-2
DOI: https://doi.org/10.1016/j.infrared.2018.06.013
Reference: INFPHY 2592

To appear in: *Infrared Physics & Technology*

Accepted Date: 8 June 2018

Please cite this article as: J. Saisut, N. Chaisueb, C. Thongbai, S. Rimjaem, Coherent Transition Radiation from Femtosecond Electron Bunches at the Accelerator-based THz Light Source in Thailand, *Infrared Physics & Technology* (2018), doi: https://doi.org/10.1016/j.infrared.2018.06.013

Coherent Transition Radiation from Femtosecond Electron Bunches at the Accelerator-based THz Light Source in Thailand

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Abstract

A THz radiation source based on electron linear accelerator (linac) has been built and commissioned at the Plasma and Beam Physics (PBP) Research Facility, Chiang Mai University (CMU) in Thailand since 2005. The accelerator system consists of a thermionic cathode RF electron gun, a magnetic bunch compressor in a form of an alpha-magnet, an S-band travelling-wave linac structure, beam steering and focusing magnets, beam and radiation diagnostic instruments, control system and other support components. Electron bunches with an average kinetic energy of about 8 MeV, a bunch charge of 100 pC, and a bunch length of 300 fs can be produced from the PBP-CMU electron linac system. Coherent THz radiation generated via transition radiation technique is used as a source of the THz spectroscopy and THz imaging applications. The measured power spectrum indicates that the radiation obtained from short electron bunches covers the frequency range of 0.15-1.80 THz or the wavenumber range of 5-60 cm^{-1}. Experimental results reveal that a peak radiation power as high as 0.2 MW per micropulse and an average radiation power of 2.5 mW can be obtained. Generation and characterization of the coherent THz transition radiation as well as some examples of experiments to achieve electron bunch length and radiation power spectrum are reported and discussed in this paper.

Keywords: THz radiation, coherent radiation, interferometer, THz spectroscopy

1. Introduction

Terahertz (THz) radiation is an electromagnetic wave with wavelengths in the range of 100-1000 μm (0.3-3 THz), which lies in a gap between microwave and infrared regimes. In the past, this gap was an unexplored region due to lack of powerful source and effective detector. Nowadays, THz sources and technologies have been developed rapidly [1–7]. Consequently, the THz radiation is presently utilized in many fields, especially for spectroscopy and imaging applications [2, 8–13]. One of the most efficient sources for the THz radiation is relativistic electron bunches generated from particle accelerators. The coherent radiation generated from short electron bunches of some hundred microns lies in the THz spectral range. An electron bunch can emit coherent radiation at wavelengths about or longer than its bunch length with intensity proportional to the number of electrons squared. Since a typical population in a bunch is around 10^8 – 10^{11} electrons, the coherent enhancement is expected to be the same factor over incoherent radiation.

Transition radiation emitted from short electron bunches and a conducting radiator is a convenient process to generate radiation pulses with the length equivalent to electron bunch length. Observation of coherent THz transition radiation from electron bunches was reported since 1989 [14–18]. The intensity from transition radiation is expected to be much more intense than other conventional light sources e.g. synchrotron or black body radiation. Furthermore, since the power spectrum of coherent transition radiation is related to the electron bunch structure, the radiation can then be used for electron bunch characterization [19]. Therefore, the transition radiation is of great interest as a potential high intensity THz source and for ultra short electron bunch length measurements with a Michelson interferometer using autocorrelation technique.

In this paper, we report the generation and characterization of electron bunches and coherent transition radiation (TR) from the accelerator-based THz radiation source at the Plasma and Beam Physics (PBP) Research Facility, Chiang Mai University (CMU), Thailand. The accelerator system was established at the PBP facility since 2003. Then, it was commissioned to produce short electron bunches and THz transition radiation in 2005-2006. This facility is the first and the only accelerator-based THz light source in Thailand and South East Asia. Figure 1 shows a layout of the PBP-CMU electron linac system used in this study. The main components of the system are an thermionic cathode radio-frequency electron gun (RF-gun) [20], an alpha-magnet (α-magnet) serving as a magnetic bunch compressor [21], a SLAC-type traveling-wave linac structure, steering and focusing magnets, beam diagnostic instruments and transition radiation experimental stations (TR1-TR2).

The RF gun has a 1.6-cell S-band standing-wave cavity. It

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