ISBN: 978-3-95450-194-6 ISSN: 2226-0366 doi:10.18429/JACoW-LINAC2018-MOPO024

DEVELOPMENT OF HIGH POWER COHERENT TERAHERTZ WAVE SOURCES AT LEBRA 125MeV LINAC IN NIHON UNIVERSITY*

T. Sakai†, T. Tanaka, Y. Hayakawa, Y. Sumitomo, K. Hayakawa, Y. Takahashi, K. Nogami, LEBRA, Nihon University, Funabashi, Japan
N. Sei, H. Ogawa, AIST, Tsukuba, Japan

Abstract

Development of a high performance electron linac for the generation of FEL, Parametric X-ray Radiation (PXR) and THz waves has been continued at the Laboratory for Electron Beam Research and Application (LEBRA) of Nihon University as a joint research with KEK and National Institute of Advanced Industrial Science and Technology. The transport systems of the THz wave were installed in the vacuum chamber on the downstream side of the bending magnet of the PXR and FEL beam-line. The CER and the CSR are generated by the bending magnet each of the beam line. In addition, the CTR using thin metal foil is also generated. The average power of the CTR wave was measured approximately 1 mJ/macro-pulse (pulse width 4.5 μs) near the CTR wave beam source point in the frequency range of 0.1 - 2.5 THz. In addition, the energy of the CER as high as 0.5 mJ/macro-pulse were achieved with the experimental room. Furthermore, CER of the generated the FEL beam line can also be guided from the bending magnet on the downstream side of the undulator without disturbing the FEL oscillations. THz transport beam-lines and the characteristics of the THz waves are discussed in this report.

INTRODUCTION

Research and development of a high performance electron linac for the generation of the infrared Free Electron Laser (FEL), Parametric X-ray Radiation (PXR) and THz waves has been continued at the Laboratory for Electron Beam Research and Application (LEBRA) of Nihon University as a joint research with the High Energy Accelerator Research Organization (KEK) and National Institute of Advanced Industrial Science and Technology (AIST) [1-3].

The LEBRA linac consists mainly of the -100 kV DC electron gun, the pre-buncher, the buncher and the three 4 m long traveling wave accelerating tubes. The electron-beam energy is freely adjustable from 40 to 100 MeV according to the purpose of use. The RF power sources has been powered by two S-band klystrons (Mitsubishi Electric Corporation, PV-3030A1, the peak output power of 20 MW, the repetition rate of 2 ~ 12.5 Hz and the pulse duration of 5 ~ 20 μs).

The saturated FEL lasing has been obtained in the wavelength region of 0.4 ~ 6 μm [4]. The PXR generator covers the X-ray energies from 4 to 34 keV by using Si(111) and Si(220) planes as the target and the second crystals [5]. CSR-THz wave source development in the FEL Beam line has been carried out since 2011 [6]. Based on the results of the CSR-THz wave source development in the FEL line, higher power CTR-THz and CER-THz wave sources line has been constructed in the PXR line since 2016. In addition to these, the new high power CER-THz wave transportation line have been constructed between the downstream bending magnet in the FEL undulator section and the downstream optical cavity mirror since 2017.

CER-THZ WAVE SOURCE OF FEL BEAM LINE

Measurements of the spectrum of coherent radiation generated by the electron bunch are well suited for monitoring the condition of the electron beam. Therefore, based on the results of the CSR-THz wave source

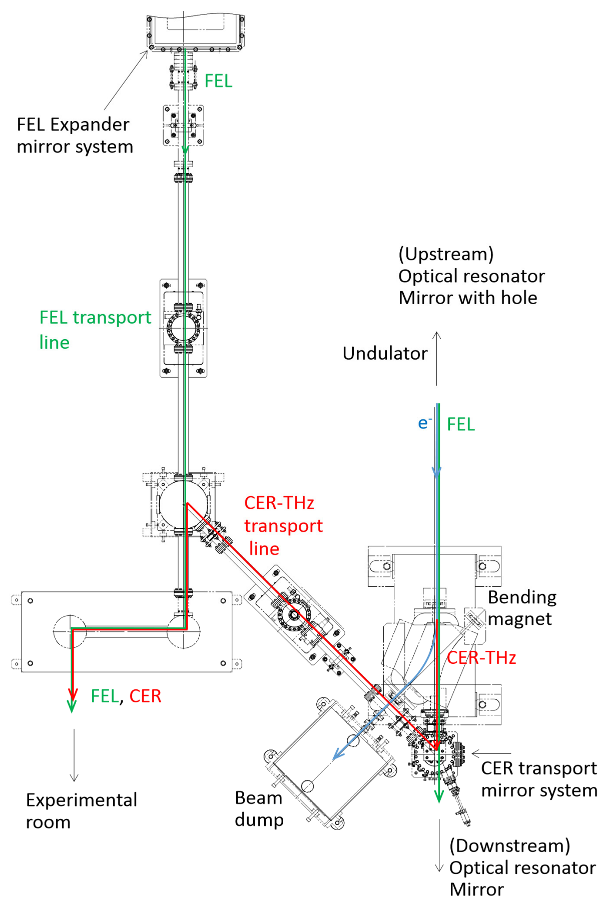

Figure 1: FEL beam line, CER-THz transport line and CER-THz wave transport concave mirrors system.

* This work was supported by JSPS KAKENHI (Grant-in-Aid for Young Scientists (B)) Grant Number JP16K17539.
† sakai@lebra.nihon-u.ac.jp

ISBN: 978-3-95450-194-6 ISSN: 2226-0366 doi:10.18429/JACoW-LINAC2018-MOPO024

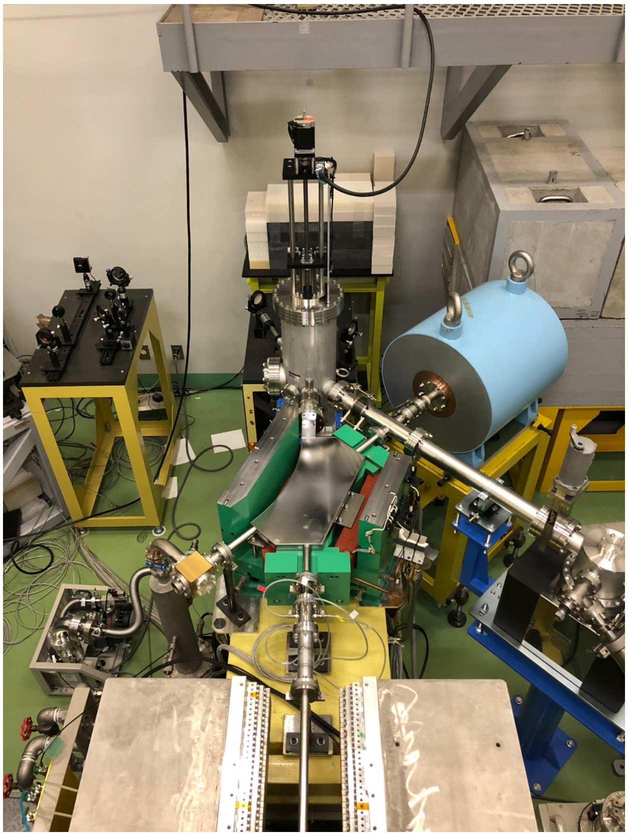

Figure 2: CER-THz transportation line as viewed from the upstream side after installation of the mirror system.

development in the FEL line, the new high power CER-THz wave transportation line have been constructed between the downstream bending magnet in the FEL undulator section and the downstream optical cavity mirror (see Figs. 1 and 2). The opening diameter of the vacuum chamber in the bending magnet can correspond to a horizontal surface of 30 mrad.

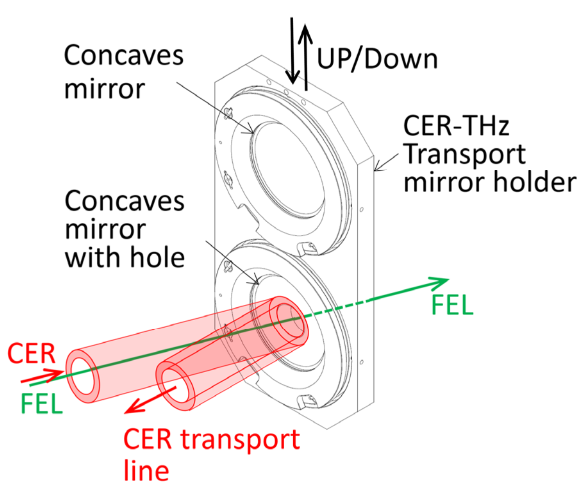

Figure 3: Transport mirrors system consists of the total reflection concave mirror and the concave mirror with a hole.

The main purpose of this mirror system is the monitoring of the electron beam bunch length and the control of FEL lasing. The edge radiation from the bending magnet has an annular shape distribution. In this case, by using a hole-coupled concave mirror, the CER-THz can be reflected and focused from the optical cavity of the FEL without a diffraction loss of the FEL beam (see Fig. 3). The diameter of the mirrors were 74 mm (effective diameter: about 68 mm) and the inner diameter of the hole was 25 mm. As a result, the simultaneous measurement of the FEL and the CER-THz wave are achieved. In addition, this mirror system can switch total reflection mirror and hole-coupled mirror in tens of seconds by remote control.

MEASUREMENTS OF CER-THz

Figure 4 shows the spectrum of the CER-THz wave at the accelerator room. The electron beam states were the electron-beam energy of 57 MeV, the macropulse duration of about 18 us and the macropulse repetition of 2 Hz. The wavelength of the FEL was 5.4 µm. The following instruments were used for the measuring. The energy measurement of the CTR-THz was carried out using a power sensor (Ophir 3A-P-THz [7]) with calibration for terahertz wavelengths. In addition, the spectrum was carried out using an interferometer (pyroelectric detector: THZ10 [8]). The average power of the CER-THz wave was measured approximately 0.5 mJ/macro-pulse (by the total reflection mirror) at the accelerator room the frequency range of 0.1 - 2.5 THz. Additionally, inserting the hole-coupled concave mirror, the reflection efficiency was about 70% as compared with the total reflection mirror. Confirmation of operation of the CER-THz transport system was achieved. Furthermore, simultaneous measurement of the CER-THz and the FEL oscillation succeeded.

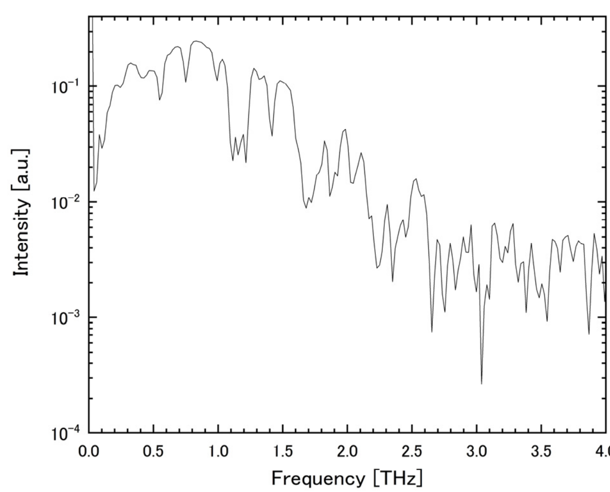

Figure 4: Spectrum of CER-THz measured using an interferometer.

ISBN: 978-3-95450-194-6 ISSN: 2226-0366 doi:10.18429/JACoW-LINAC2018-MOPO024

SUMMARY

On the basis of the CSR-THz wave source development in the FEL line, the CER-THz wave transportation line have been constructed between the downstream bending magnet in the FEL undulator section and the downstream optical cavity mirror.

Simultaneous measurement of the CER-THz and the FEL oscillation succeeded beam by using the hole-coupled concave mirror without a diffraction loss of the FEL. The average power of the CER-THz wave was measured approximately 0.5 mJ/macro-pulse (by the total reflection mirror) the frequency range of 0.1 - 2.5 THz. The reflection efficiency was about 70% as compared with the total reflection mirror.

The monitoring of the electron beam bunch length and the control of FEL lasing are possible from the use of this CER-THz transport system.

REFERENCES

[1] K. Hayakawa *et al*., "Operation of Near-infrared FEL at Nihon University", in *Proc. FEL'07*, Novosibirsk, Russia, Aug. 2017, pp. 114-117.

[2] Y. Hayakawa *et al*., "Dependence of PXR beam performance on the operation of the pulsed electron linac", *Nucl. Instr. Method. B*, vol.. 266, no.17, pp. 3758-3769, 2008.

[3] N. Sei *et al*., "Observation of intense terahertz-wave coherent synchrotron radiation at LEBRA", *J. Phys. D*, vol. 46, p. 045104, 2013.

[4] Y. Hayakawa *et al*., "First lasing of LEBRA FEL at Nihon University at a wavelength of 1.5 µm", *Nucl. Instr.. Meth. Phys. Res. Sec. A,* vol. 483, pp. 29-33, 2002.

[5] Y. Hayakawa *et al*., "X-ray imaging using a tunable coherent X-ray source based on parametric X-ray radiation", *JINST*, vol. 8, p. C08001,Aug. 2013. doi:10.1088/1748-0221/8/08/C08001.

[6] N. Sei *et al*., "Characteristics of Transported Terahertz-wave Coherent Synchrotron Radiation at LEBRA", in *Proc. FEL'14*, Basel, Switzerland, Aug. 2014, pp. 541-544.

[7] Ophir Optronics Solutions Ltd., http://www.ophiropt.com/laser--measurement/laser-power-energy-meters/products/Laser-Thermal-Power-Sensors/High-Sensitivity-Thermal-Laser-Sensors/3A-P-THz

[8] https://www.pyrosensor.de/Standard-924644.html