ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-TUPRB040

DEVELOPMENT OF COHERENT TERAHERTZ WAVE SOURCES AND TRANSPORT SYSTEMS AT LEBRA LINAC

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Abstract

Development of a 125 MeV S-band electron linac for the generation of Free Electron Laser (FEL), Parametric X-ray Radiation (PXR) and coherent terahertz waves (THz waves) has been underway at LEBRA of Nihon University as a joint research with KEK and National Institute of Advanced Industrial Science and Technology (AIST). The high power coherent transition radiation (CTR), coherent edge radiation (CER) and the coherent synchrotron radiation (CSR) wave sources development has been carried out since 2011 at LEBRA. The transport systems of the each THz wave were installed in the vacuum chamber on the downstream side of the 45 degrees bending magnet of the PXR and FEL beam-line. In particular, a CER of the generated the FEL beam line can also be guided without disturbing the FEL oscillations. Additionally, a part of the mirror of the optical transport system is constructed using Indium Tin Oxide (ITO) mirror with the optimized for the transport of the CER. Since infrared light is transmitted through the ITO substrate, simultaneous transportation of the FEL beam and CER-THz is possible by setting it on the FEL line. In order to increase the CER-THz transport efficiency, the mirror of the transportation system were replaced from concave mirrors to toroidal surface mirrors. Transport testing and basic measurements will begin in late 2019. In this report, improvement of the CER-THz transport beam lines are discussed.

INTRODUCTION

Research and development of a 125 MeV electron linac for the generation of the infrared FEL, Parametric X-ray Radiation (PXR) and THz 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 (AIST) [1-3].

The THz wave sources development in the FEL Beam line has been carried out since 2011 [4]. Based on the development results of coherent synchrotron radiation (CSR) of the terahertz frequency range in the FEL beam line, higher power coherent transition radiation (CTR) and coherent edge radiation (CER) sources have been constructed in the PXR line since 2016. In addition to these, the new high power CER transportation line has been constructed between the downstream bending magnet in the FEL undulator section and the downstream optical cavity mirror from 2017 to 2018.

LEBRA 125 MEV ELECTRON LINAC

LEBRA-linac consists mainly of the -100 kV electron DC-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 with user's utilization purpose. The RF power sources has been powered by two S-band klystrons, the peak output power, the repetition rate and the pulse duration are 20 MW, 2 ~ 10 Hz, 5 ~ 20 μs, respectively. Saturated FEL lasing is also obtained in the 0.4 to 6 μm wavelength region by using nonlinear crystals [5]. The PXR generator covers the X-ray energies from 4 to 34 keV by using Si (111) and Si(220) planes as the target [6]. FEL, X-ray, THz are transported to the laboratory. Figure 1 shows an overview of LEBRA 125 MeV electron linac.

CER-THZ TRANSPORT LINE IN FEL BEAM LINE [7, 8]

The new high power CER-THz transportation line have been constructed between the downstream bending magnet in the FEL undulator section and the downstream optical cavity mirror. The main purpose of this mirror system are to monitoring of the electron beam bunch length, the control of the FEL lasing and using of high power CER.

The opening diameter of the new vacuum chamber in the bending magnet can correspond to a horizontal surface angle of about 38 mrad and vertical surface angle of about 23 mrad. The edge radiation from the bending magnet has an annular shape distribution. It is thus the CER-THz can be reflected and focused from the optical cavity of the FEL without a diffraction loss of the FEL beam by using a hole-coupled focusing mirror. The structure of the mirror holder is a gimbal type that can be adjusted from an atmospheric air side. The diameter of the two mirrors were 74 mm (effective diameter: about 68 mm) and the inner diameter of the hole-coupled mirror was 25 mm.

The average power of the CER-THz wave has been measured approximately 0.5 mJ/macro-pulse (by the total reflection mirror) at the frequency range of 0.1 - 2.5 THz. Additionally, inserting the hole-coupled concave mirror, the reflection efficiency was achieved about 70% as compared with the total reflection mirror. The simultaneous measurement of the CER-THz and the FEL oscillation are possible by the CER-THz transport system.

IMPROVEMENT OF CER-THZ TRANSPORT LINE

The CER-THz transport system was improved based on the basic measurement results of the CER-THz in the

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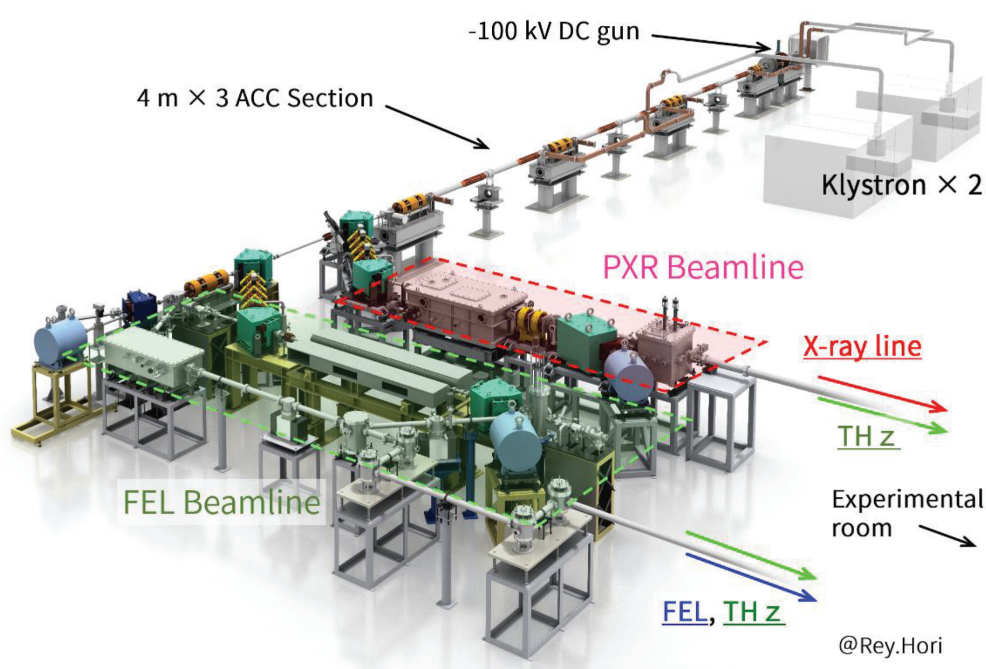

Figure 1: Layout of the 125MeV electron linac at LEBRA in Nihon University. LEBRA-linac consists mainly of the -100 kV electron DC-gun, the pre-buncher, the buncher and the three 4 m long traveling wave accelerating tubes. The main purpose of LEBRA-linac is the generation of FEL, PXR and THz.

accelerator room. Figure 2 shows a schematic diagram of the improved CER-THz transport system. A sapphire substrate with a thickness of 0.5 mm sputtered with 400 nm of indium tin oxide (ITO) [9] was placed in the FEL line. In the measurement before installation, it has been confirmed that this substrate can reflect THz waves with a frequency of 1 THz by 80% or more. Since infrared light is transmitted through the ITO substrate, simultaneous transportation of the FEL beam and CER-THz is possible by setting it on the FEL line. Additionally, highly precise measurement near the source point can be performed by placing the ITO mirror in the retracted position.

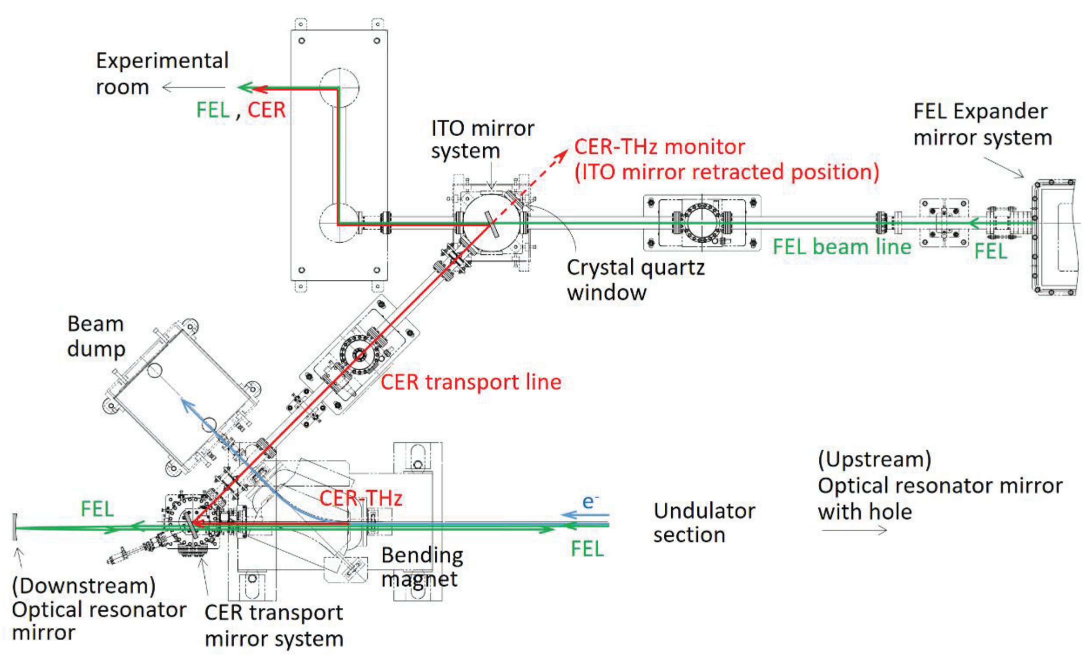

Figure 2: Schematic diagram of the improved CER-THz transport system. A sapphire substrate with a thickness of 0.5 mm sputtered with 400 nm of ITO was placed. ITO substrate can reflect THz waves with a frequency of 1 THz by 80% or more. The crystal quartz vacuum window of the extraction viewport is attached to reduce THz transmission attenuation. The mirrors of the CER transport mirror system were replaced from concave mirrors to toroidal surface mirrors.

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The crystal quartz vacuum window [10] of the extraction viewport is attached to reduce THz transmission attenuation. In order to increase the CER-THz transport efficiency, the mirrors of the CER transport mirror system were replaced from concave mirrors to toroidal surface mirrors. The new CER transport testing and basic measurements will begin in late 2019.

CONCLUSION

The CER-THz transport system of the FEL line was improved. A sapphire substrate (thickness of 0.5 mm) with sputtered with ITO (400 nm) was placed in the FEL line. In the measurement before installation, it has been confirmed that this substrate can reflect THz waves with a frequency of around 1 THz by 80% or more. The crystal quartz window of the extraction viewport is attached to reduce THz transmission attenuation. In order to increase the CER-THz transport efficiency, the mirrors of the CER transport mirror system were replaced from concave mirrors to toroidal surface mirrors. The new CER transport testing and measurements of the CER-THz spectrum will begin in late 2019.

ACKNOWLEDGEMENTS

This work was supported by JSPS KAKENHI Grant Number JP16K17539, JP16H03912 and JP19H04406.

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