LINAC-BASED THZ IMAGING AT CHIANG MAI UNIVERSITY

J. Saisut#, P. Boonpornprasert, K. Kusoljariyakul, S. Rimjaem, C. Thongbai, Department of Physics and Materials Science, Chiang Mai University, Chiang Mai 50200, Thailand
M.W. Rhodes , P. Tamboon, STRI, Chiang Mai University, Chiangmai 50200, Thailand

Abstract

At the Plasma and Beam Physics Research Facility (PBP), Chiang Mai University, intense THz radiation is generated in a form of coherent transition radiation from femtosecond electron bunches. The THz radiation is used as a source of THz imaging system which was successfully setup and tested. The radiation is focused onto a sample which will be scanned using an xy-translation stage. The transmission or reflection at different points of the sample are recorded to construct a THz image. Details of the setup and the experimental results from the system will be presented. The THz imaging to accommodate a future IR-THz Free Electron Laser (FEL) will also be discussed.

INTRODUCTION

A THz facility based on femtosecond electron bunches has been established at the Plasma and Beam Physics Research Facility (PBP), Chiang Mai University. Femtosecond electron bunches are generated from a system consisting of an RF-gun with a thermionic cathode, an alpha-magnet as a magnetic bunch compressor and a linear accelerator as a post acceleration section. At the experimental station, the bunches are compressed to less than 1 ps. The experimental results reported in [1] show that electron bunches as short as σ_z =200 fs can be generated from the system. Typical operating parameters and electron beam characteristics of the facility are complied in Table 1.

The femtosecond electron bunches can be used to produce high intensity THz radiation in the form of coherent transition radiation by placing an aluminium foil (Al-foil) 45° in the electron path, representing a transition between vacuum and conductor [2]. The backward transition radiation is emitted perpendicular to the beam axis as shown in Fig. 1. The radiation is collimated by a 1-inch 90° parabolic mirror and transmits through a high density polyethylene (HDPE) window of 1.25-mm-thick and 32-mm diameter. The available THz radiation covers wavenumbers from 5 cm^{-1} to around 80 cm^{-1} which corresponding to a frequency range from 0.3 THz to 2.4 THz. This THz radiation is used as a source of the THz imaging system.

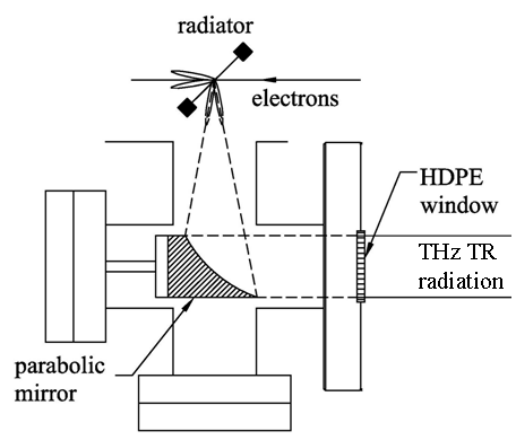

Figure 1: Setup to generate THz Transition radiation.

THZ IMAGING SYSTEM

A schematic diagram of the THz imaging system (transmission measurement) at the Plasma and Beam Physics Research Facility (PBP), Chiang Mai University is illustrated in Fig. 2 for transmission or reflection measurement. THz radiation is focused on a sample which will be scanned using an xy- translation stage

Table 1: Operating and beam parameters

Parameters	RF-gun	Linac
Maximum beam energy (MeV)	2.0-2.5	6 - 12
Macropulse peak current (mA)	700-1000	5-150
RF-pulse length (µs)	2.8	8
Repetition rate (Hz)	10	10
Beam-pulse length (µs)	2	0.8
Number of microbunches per macropulse	5700	2300
Number of electrons per microbunch	1.4×10^9	1.4×10^8

#jatuporn.saisut@cmu.ac.th

ISBN 978-3-95450-123-6

controlled by a computer. The transmission or reflection intensity will be detected by a room-temperature pyroelectric detector. Computer program will be employed to calculate and analyze intensity at difference points on the sample for THz image construction.

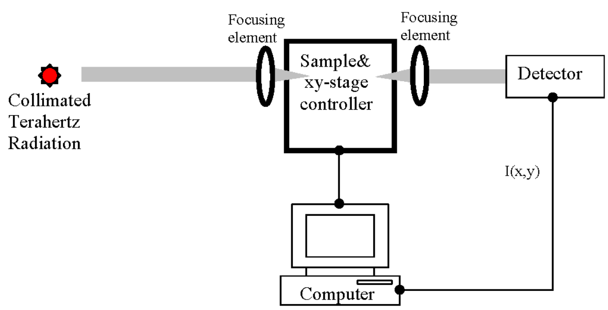

Figure 2: Schematic diagram of the THz imaging system at Chiang Mai University.

The Transmission Mode THz Imaging

The transmission mode THz imaging is suitable for materials which are transparent to THz radiation, e.g. non metallic and non polar materials. It is possible to construct contrast images from totally transmitted signals of various materials. Figure 3 shows the THz imaging system setup beside the electron beamline at the experimental station and this setup use Tsurupica lens as a focusing element.

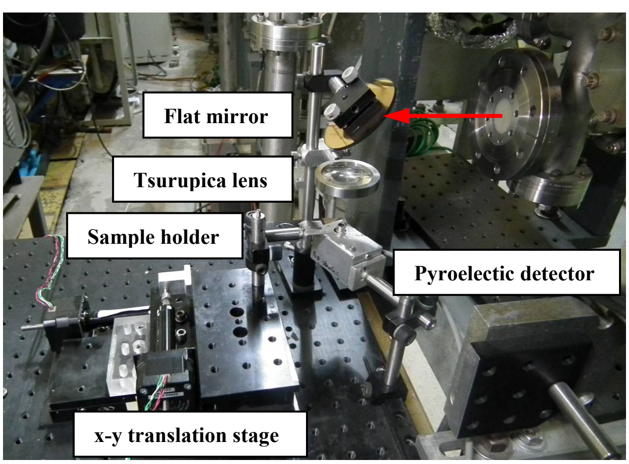

Figure 3: The THz imaging system setup at the experimental station.

By using a copper cone as a focusing element, the first THz image circular cuts of various sizes in an Al-foil [Fig. 4(a)] placed in an envelope is shown in Fig. 4(b). The holes diameter varies from 4 – 9 mm. Positions and spot sizes of the patterns from the THz image correspond well to those of the Al-foil sample.

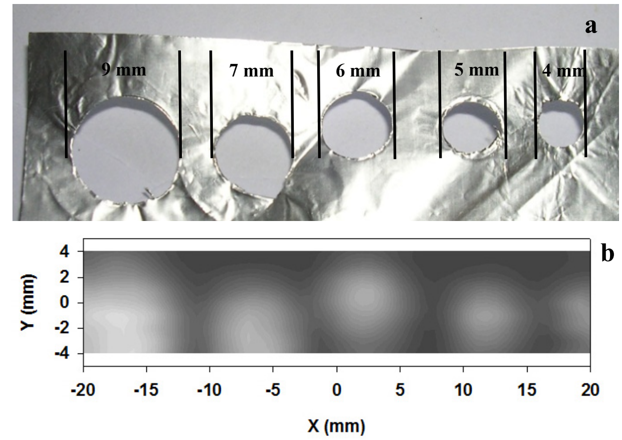

Figure 4: (a) Optical and (b) THz images of circular cuts of various sizes inan Al-foil.

Figure 5(a) is an Al-pattern and Fig. 5(b) is its THz image scanned using the Tsurupica lens as a focusing element. The THz image can demonstrate the rough feature of the sample but not its details especially at the big slot of the sample. Since our THz radiation source is board band, the focusing spot size of the THz radiation beam is about 3-4 mm. By using a copper mesh as a high pass THz filter [3, 4], the focusing spot size can be reduced to about 2 mm [4]. The copper mesh filter is placed in front of the focusing element in the imaging system. The image quality can be improved when the sample is scanned using mesh filter. Visually, more details of the sample can be seen as shown in Fig. 5(c).

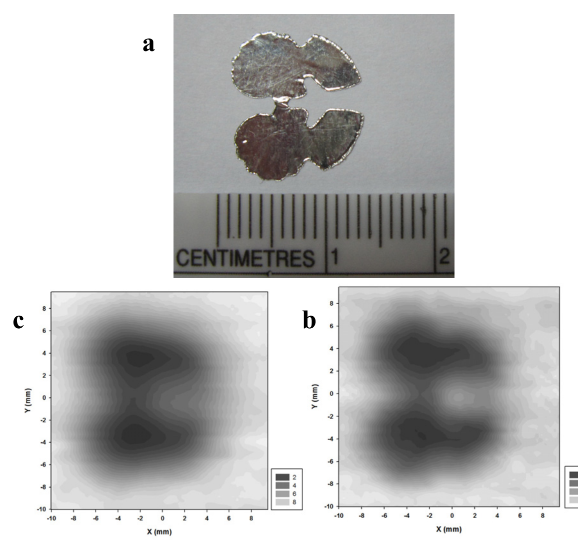

Figure 5: Cut pattern from Al-foil and its THz images; (a) Optical image of the sample, (b) its THz images achieved without mesh filter and (c) its THz image achieved with the mesh filter.

By using a transmission mode THz imaging, the THz image of a fresh leaf which contains water contents inside is successfully demonstrated. The THz image of a leaf sample [Fig. 6(a), (c)] placed in an envelope is shown in Fig. 6(b), (d). The low intensity area of THz image is

ISBN 978-3-95450-123-6

corresponding to the leaf. Obviously, it shows the shape of the leaf which corresponds to its optical image.

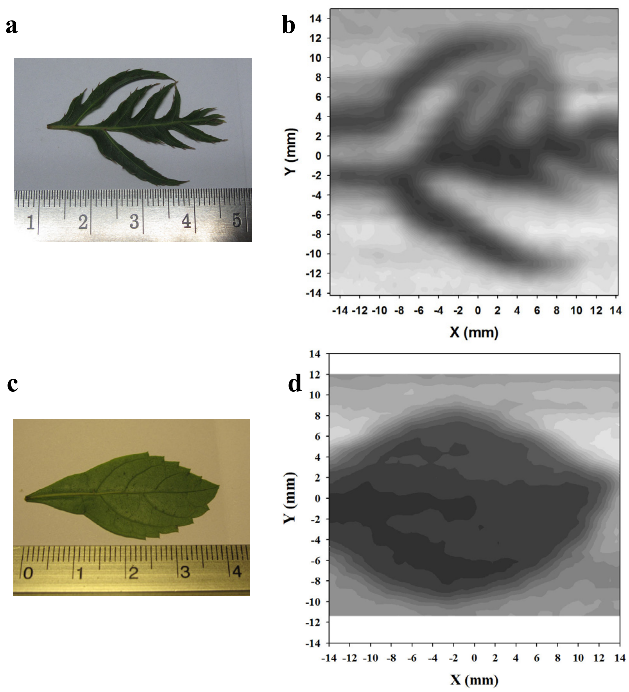

Figure 6: Leaf samples and its THz images; (a), (c) Optical images of the leaf which clearly shows the leaf structure and (b), (d) its THz images achieved with the mesh filter.

The Reflection Mode THz Imaging

The reflection mode THz imaging is suitable for materials which reflect THz radiation, e.g. metallic samples. The reflection mode THz imaging setup at PBP is shown in Fig. 7. A collimated THz beam is reflected off a gold-coated mirror to a THz lens of 6-cm focal-length. The beam is then focused onto a sample at approximately 30° incident angle. The reflected signal from the fuel cell is collected by another THz lens of 3-cm focal-length and continued to a pyroelectric detector. The sample under investigation is placed on top of the X–Y translational stages and scanned using computerized motion controllers.

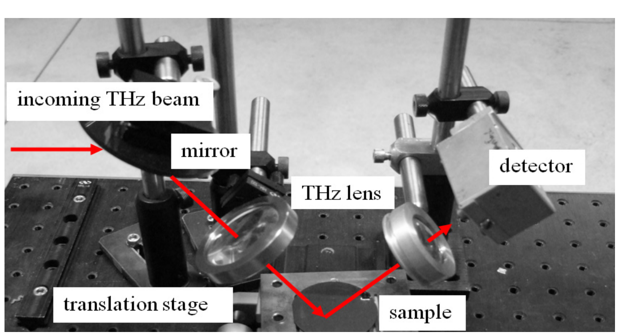

Figure 7: the reflection mode THz imaging setup.

Identification of Water in Flow Channels of PEM Fuel Cells using THz imaging [5] has been studied. A model cell of a PEM fuel cell shown in Fig.8(a) is machine-through-brass flow channel plate which sealed the bottom side of the plate tightly with a cloth tape. Then some channels were filled with water and the cell was covered by a Si window (see Fig. 8(b)) that allows THz access. The THz image in Fig. 8(c) shows a water filled channel and an unfilled channel indicated as air-filled in the figure. The darker area reveals absorptive region within the flow channels, with the darkest region lies in water-filled channel. In order to clearly distinguish the water-filled and the air-filled region, we perform a line-scan plot (along the dash-line shown in Fig. 9). It is evident that we are able to identify water presence in the flow field with THz imaging.

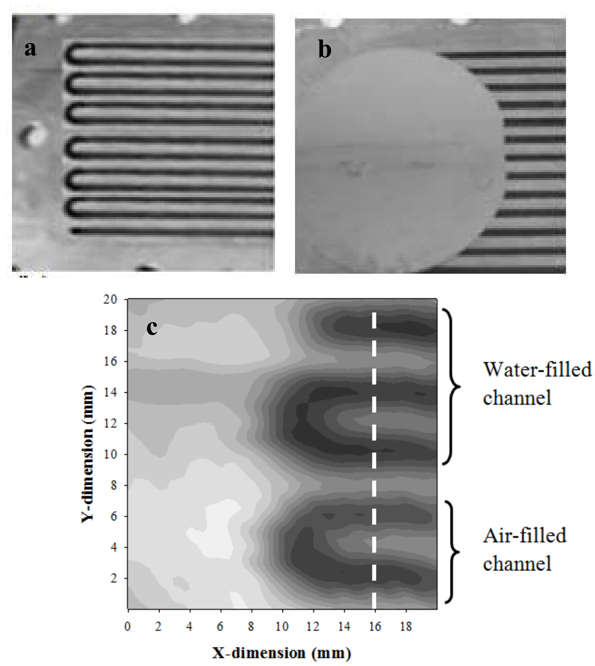

Figure 8: Photographs of a machine-through-brass flow channel plate (a) before and (b) after covering with Si window; (c) THz image of (b).

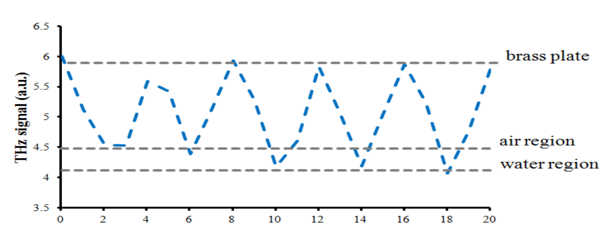

Figure 9: THz-signal line-scan along the dashed line in THz image.

CONCLUSION

At PBP, Chiang Mai University, the transmission mode and reflection mode THz imaging systems were successfully setup and tested. We successfully

ISBN 978-3-95450-123-6

demonstrate THz images of Al-foil patterns which reflect the THz radiation, THz images of water content samples which absorb the radiation and THz images of the model cell of a PEM fuel cell. The image resolution is limited by focusing spot size and it can be improved by scanning samples with mesh filter. To extend the ability of the imaging system based on the transition radiation source, the simple scanning system can be combined with the Michelson Interferometer to allow "Interferometric Imaging" [6]. This system is able to provide both information; typical THz imaging and the radiation power spectrum. The power spectrum, the Fourier Transform of the interferogram, from various positions on the sample will provide THz images of different frequencies. Both the transmission mode and reflection mode THz imaging experiments will be performed using a future IR-THz Free Electron Laser (FEL) which have wavelengths of 200µm to 50 µm as a source of the systems.

ACKNOWLEDGMENT

We would like to thank Mr. N. Kangrang and Mr. V. Jinamoon for their technical support. We would like to acknowledge the supports from the National Research Council of Thailand, the Thailand Research Fund, the (Thailand) Commission on Higher Education, the Thailand Center of Excellence in Physics and Chiang Mai University.

REFERENCES

[1] J. Saisut et al. Nucl. Instrum. Methods Phys. Res. A, 637(1) Supplement 1(2011) S99-S106.
[2] C. Thongbai, et al., Nucl. Instr. and Meth. A 587 (2008) 130
[3] R. Ulrich, Infrared Phys. **7**, 33 (1967)
[4] J. Saisut, Ph.D. thesis, Chiang Mai University, 2011.
[5] P. Buaphad, M.S. thesis, Chiang Mai University, 2012.
[6] W.L. Chan, J. Deibel and D.M. Mittleman, Rep. Prog. Phys. **70,** 1325(2007)

ISBN 978-3-95450-123-6