Large-Area Transmission and Reflection Imaging with 640x480 Pixel Terahertz Camera

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***Abstract*— An active terahertz (THz) imaging system that can easily be switched between a transmission and a reflection mode is developed. The system consists of a compact THz source that operates at room temperature, optical system utilizing polarization and two 640x480 pixel uncooled THz cameras. In order to take an image of a large sample, a part of the imaging system is moved at a fixed distance and a series of images taken are combined to one elongated image. Concealed nonmetallic object detection in an envelope is demonstrated.**

I. INTRODUCTION

THZ camera has an advantage in imaging a large field of view (FOV) in real time [1], which is very attractive for non-destructive testing application [2][3]. A high-power THz source is required to observe a large sample at a time with a sufficient signal-to-noise ratio. However, FOV is generally limited within the size of around several centimeters when a compact THz source with a few-millwatt power, such as a quantum cascade laser and an amplifier/multiplier chain (AMC), is used. In this paper, a THz imaging system using a compact THz source which enables observation of a large area is designed and developed. The THz camera is moved at a fixed distance and takes a transmission or reflection image. A series of images are combined to one elongated image. By moving a quarter-wave plate, the system can operate in the both transmission and reflection modes.

II. DESIGN AND FABRICATION OF SYSTEM

Figure 1 shows a schematic diagram of the system. The system consists of the following three parts.

A. Optical system for illumination [4]

The AMC source made by Virginia Diodes, Inc. was used as a THz source. The frequency and the averaging power were about 480 GHz and 8 mW, respectively. A beam radiated from the source with a linear polarization was expanded and collimated by a high-resistivity silicon collimator lens. The beam diameter (a full width at half-maximum) was about 30 mm. The beam was wobbled by dual-axis galvano mirrors placed in front of the collimator lens in order to reduce interference pattern in an image. A frequency modulation function of the source also helps reduce interference. The position of the galvano mirrors affects utilization efficiency of light, so the distance between the source and the mirrors was carefully designed. A sample was illuminated along the direction normal to the sample surface, using a tilted wire-grid polarizer by an angle of 45° against the optical path. In the case of transmission observation, THz wave was transmitted through the sample and detected with a THz camera #1. In the case of reflection observation, a quarter-wave plate was put in the optical path.

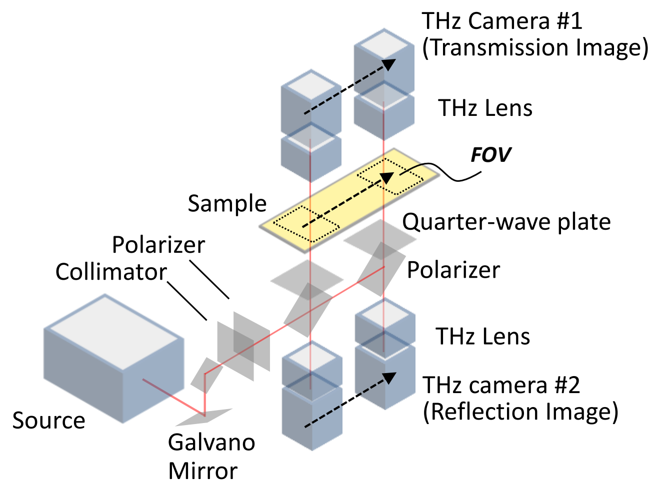

Fig. 1. Schematic diagram of the combined transmission and reflection imaging system using terahertz cameras.

The reflected THz wave passed through the polarizer and was detected with a THz camera #2.

B. THz camera and lens

THz camera contains a 23.5-μm pitch 640x480 microbolometer focal plane array (FPA) and operates at 30-Hz frame rate. The modified pixel structure was applied to the FPA, whose sensitivity was increased in sub-THz region [5]. The THz camera has a Gigabit Ethernet interface, so the two cameras are easily changed from the computer by selecting IP address of the camera. The THz lens has about 0.25x magnification, which corresponds to the FOV of about 60 mm x 45 mm.

C. Moving mechanism

The cameras with the THz lenses, the polarizers and the quarter-wave plate were moved by using a stepping motor. By moving the cameras with them, it is possible to acquire a large area THz image. The software controlled the sequence of taking pictures and the movement. The system is equipped with a visible camera so that an operator can know which part of the object is imaged, when the object is larger than FOV of the THz camera.

Table 1 shows specifications of the fabricated system. Figure 2 shows a photograph of the fabricated imaging system and a screen view of the control program.

Table 1. Specifications of fabricated system

Imaging frequency	480 GHz
Source power	8 mW
Lens magnification	c.a. 0.25
FOV	c.a. 60 mm x 45 mm
Scan length	210 mm (max)
Camera frame rate	30 Hz
Size (excluding control rack and computer display)	83 cm(W) x 60 cm(D) x 82 cm(H)

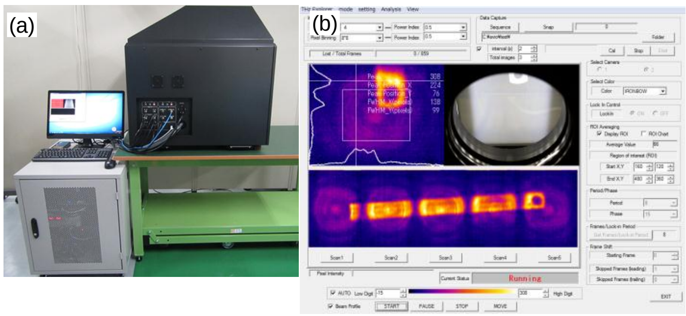

Fig. 2. (a) Photograph of the fabricated imaging system (right: main body of equipment, left: 19-inch control rack and computer display), (b) screen view of the control program (top left: THz image, top right: visible image, bottom: image in which five THz images are combined).

III. Results

Figure 3 shows transmission and reflection THz images of a ceramic knife in a cardboard envelope. The system can detect nonmetallic object such as ceramic material that metal detectors cannot detect. In transmission mode, the knife is displayed like a shadow because it is opaque to THz wave. In the reflection mode, the blade of knife has brighter contrast than that of the grip portion, which means low reflectivity of the grip material. Stripe-shape interference pattern is also observed at the blade. The reason might be interference between the blade and the envelope surface. At this stage it takes about 4 secons to acquire one THz image. Therefore, total image acquisition time is over 20 seconds. Figure 4 shows a reflection THz image of a razor blade. The narrow slit portion is clearly observed, so the spatial resolution of the system is much better than 3 mm in the reflection mode.

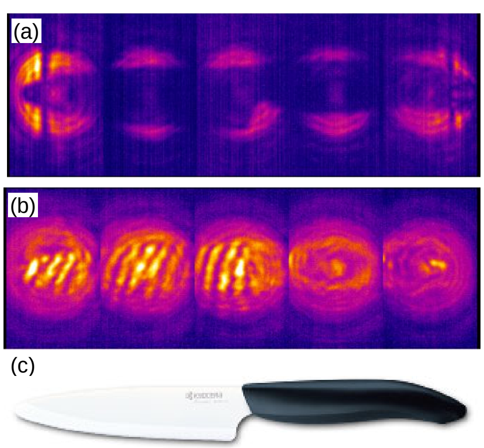

Fig. 3. (a) Transmission and (b) reflection THz images of a ceramic knife in a cardboard envelope. (Lock-in frequency: 3.75 Hz, frame integration: 16, pixel binning: 4x4) (c) Visible image of knife. The blade length is about 23 cm.

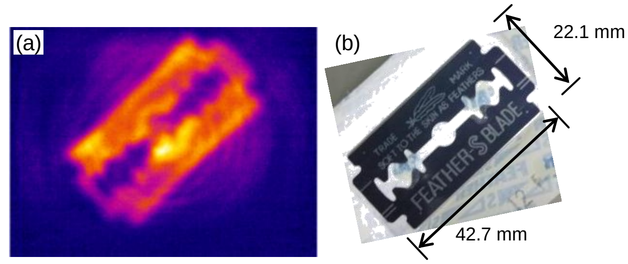

Fig. 4. (a) Reflection THz image of a razor blade (Lock-in frequency: 3.75 Hz, frame integration: 16, pixel binning: 4x4) and (b) visible image.

It is a future issue to shorten the image acquisition time. For example, illumination by a high-power source and lock-in imaging at a high frequency are expected.

IV. Summary

An imaging system using two 640x480 pixel THz cameras and a compact THz source has been developed. By moving a part of the imaging system, a large area observation is possible. Only by moving a quarter-wave plate, a transmission and reflection imaging are easily switched.

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