Portable real-time terahertz imaging system

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Abstract—**The portability of a terahertz imaging system is crucial for practical applications because most of the measured objects are generally fixed and cannot be moved from their locations. We have developed a portable imaging system using a terahertz quantum cascade laser and a microbolometer focal plane array. We also obtained a direct image of the focused beam of the laser.**

I. Introduction and Background

A sensing/imaging system is one of most fascinating applications of terahertz (THz) technology, since the THz electromagnetic wave has two advantageous properties: characteristic absorption lines in the frequency range in most materials and a higher spatial resolution than the millimeter wave. For example, THz time-domain spectroscopy (TDS) was utilized to obtain two-dimensional (2D) images by scanning mechanical x-y stages attached to the samples under investigation[1]. However, the size of the conventional system hinders industrial applications. This is because most of the objects in which many people are interested are fixed and cannot be moved from their original locations. Furthermore, real-time image acquisition is also required in the THz imaging system.

In this work, we have developed a portable real-time THz imaging system that does not require a huge Ti:sapphire laser and a complicated 2D scanning system. In this imaging system, a THz quantum cascade laser (QCL) was used as the illuminating device and a focal-plane array (FPA) microbolometer camera was used to acquire the THz images.

II. Components for Imaging System

The THz QCL used here consists of an active region with the resonant-phonon-depopulation scheme and a semi-insulating surface plasmon waveguide[2]. The front and back facets are as-cleaved and HR-coated, respectively. The lasing frequency was observed to be ~3.1 THz at a low bias current; further, the THz QCL was found to operate up to 120 K in the pulsed mode. This means that our THz QCL can be driven at LN_2 temperature (~77 K). Therefore, we installed the THz QCL in a LN_2 reservoir cryostat integrated with a parabolic collimating mirror (Fig. 1).

Real-time images of the THz radiation from the THz QCL were obtained using a vanadium oxide (VO_x) FPA uncooled microbolometer camera (THz camera) whose format is 320x240 with a pitch of 23.5 μm (Fig. 2). In order to improve the performance in the THz regime, high-reflectivity silicon was used as a window for the vacuum package and the sheet resistance of the THz absorption layer was optimized in the present pixel structure[3]. As a result, a noise equivalent power (NEP) of as low as ~40 pW was attained.

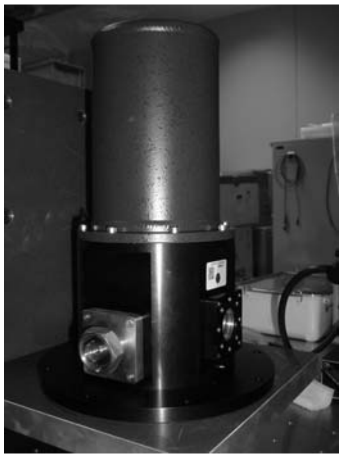

Fig. 1: Photograph of the THz QCL-installed LN2 reservoir cryostat integrated d with a parabolic collimating mirror. A collimated THz beam is directly obtained from the output window of the unit.

III. Image Acquisition

By assembling the light source unit (THz QCL), the imaging unit (THz camera), and some optical components, we constructed the portable THz imaging system. In order to investigate the performance of the system, we measured the focused direct beam from the THz QCL. Figure 3 shows the direct image obtained during the irradiation of the THz QCL.

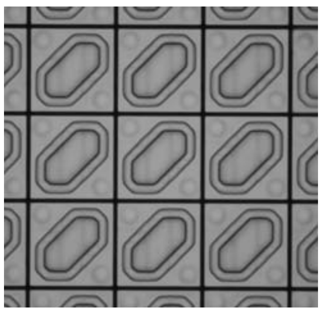

Fig. 2: Scanning microscope image of the vanadium oxide microbolometer array sensor for detecting the THz radiation. The array pitch is 23.5 μm.

The image was captured at a frame rate of 60 Hz. As seen in the

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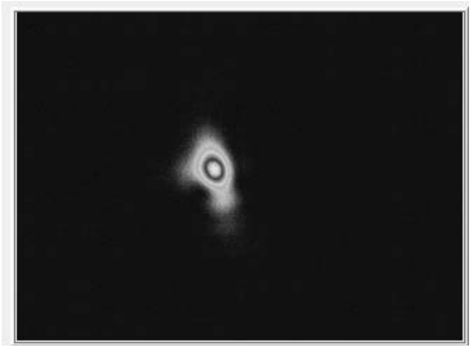
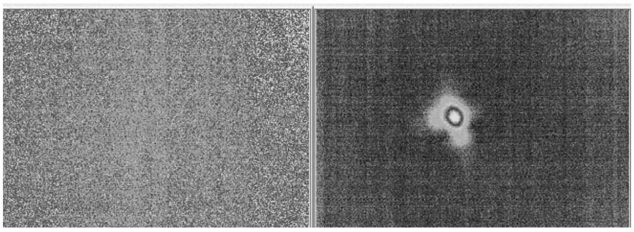


Fig. 3: Direct image of the focused beam emitted from the THz QCL, obtained using the FPA camera.

figure, a clear beam image was obtained and the signal-to-noise ratio was found to be 12.8 dB at the incident peak power of ~3 mW.

We have further measured the THz beam image transmitted through some pigments. Figure 4 shows the experimental results for the lead white (Fig. 4(a)) and the japanese kaolin (Fig. 4(b)). Colors of both pigments are apparently white in the visible range. In the THz regime, however, the lead white is opaque, while the Japanese kaolin is transparent at the frequency of ~3.1 THz. These results shown in Fig. 4 are consistent with the transmission spectra measured by the time-domain THz spectroscopy. This indicates that we can distinguish kinds of pigments which are the same in the visible range by the system.



(a) (b)

Fig. 4: THz beam image transmitted through the lead white (a) and the Japanese kaolin (b).

IV. Summary

We have developed a portable real-time THz imaging system. In this imaging system, a THz quantum cascade laser (QCL) was used as the illuminating device and a focal-plane array (FPA) microbolometer camera was used to acquire the THz images. We have confirmed that the THz beam emitted from the THz QCL was clearly imaged and, further, the transmission change induced by the materials which have the same color in the visible range was obtained. Using this system, THz transmission and reflection images can be measured in real time by applying suitable sample configurations.

Acknowledgement

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