Externally Triggered Terahertz Imaging For Microbolometer Focal Plane Array

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***Abstract*—Both 640x480 and 320x240 terahertz (THz) imagers were developed whose sensitivity were improved in sub-THz region by a factor of 10. The imagers include functions such as external-trigger imaging, lock-in imaging, beam profiling and so forth. The function of the external-trigger imaging was verified, using the pulsed THz free electron laser developed by Osaka University.**

I. INTRODUCTION

REAL-TIME THz imaging equipment is demanded for application fields, such as non-destructive inspection (NDI) in industries, security, biomedicals and so forth. It relies on technology of THz imager which includes THz focal plane array (FPA) operating at TV frame rate.

Incorporation of user-friendly input/output (I/O) interfaces into THz imager is important to facilitate usage of THz imager for imaging system composed of THz source and THz imager. There are two kinds of I/O interfaces for imaging, one for external-trigger imaging and the other for lock-in imaging [1]. THz imager equipped with both functions can be more easily accepted for NDI system.

Both 640x480 and 320x240 THz-FPAs (pixel pitch: 23.5 μm) with the new pixel structure have been fabricated, whose sensitivities were made higher in sub-THz region by a factor of 10 than that of the current product (T0831) [2]. Based on this technology, both 640x480 and 320x240 THz imagers have been developed. Both THz imagers incorporate a function of an external-trigger imaging and an enhanced function of lock-in imaging as well as software for beam profiling.

II. EXTERNAL-TRIGGER THZ IMAGING

The external-trigger imaging makes use of slow thermal time constant of microbolometer in THz-FPA which is formed on microbridge structure. The thermal time constant (τ_{th}) of the THz-FPA used in this work is ca. 18 msec [3], which is shorter than the frame time of 33 msec. It is convenient to have two pulses for the external-trigger imaging, i.e., trigger pulse for THz imager and brightening pulse for THz source. Adjustment of the time interval between these two pulses can improve signal-to-noise ratio, considering characteristics of the exponential decay of the signal from the THz-FPA.

The function of the external-trigger imaging has been verified for both 640x480 THz imager (Fig.1.(a)) and 320x240 THz imager (Fig.1.(b). product model:T0832) in combination with the pulsed THz free electron laser (THz-FEL). The details of THz-FEL developed by Osaka University, are described by G. Isoyama et al.[4]. The wavelength of radiation emitted by the THz-FEL is tuned in a range of 25 to 150 μm. In our experiments, the THz-FEL is tuned to 86 μm in wavelength.

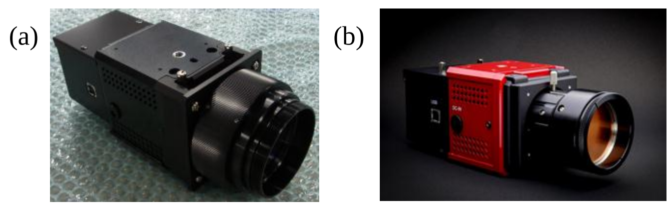

Fig.1. (a) 640x480 THz imager, (b) 320x240 THz imager (T0832)

Figure 2 shows a schematic experimental configuration. A brightening pulse is applied to the THz-FEL, while a trigger pulse is output by a pulse generator which shifts the brightening pulse by a certain amount of time interval (t_a shown in Fig.3), and is applied to the 640x480 THz imager. Figure 3 shows the relation of the trigger pulse for the THz imager to the brightening pulse for the THz-FEL. The repetition time interval of the brightening pulse (t_{rep}) is chosen out of 100, 200, 300 and 400 msec (the repetition rate: 10, 5, 3.3 and 2.5 pulses per second (pps)). The trigger pulse initiates electronic scan of the THz-FPA in the THz imager. After the electronic scan is over (frame time: t_{fr} =33 msec), one frame data is recorded and the THz-FPA returns to the waiting mode for the next trigger pulse coming in.

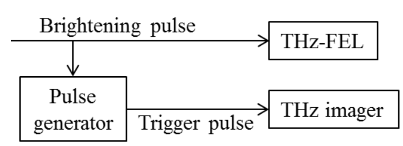

Fig.2. Schematic experimental configuration

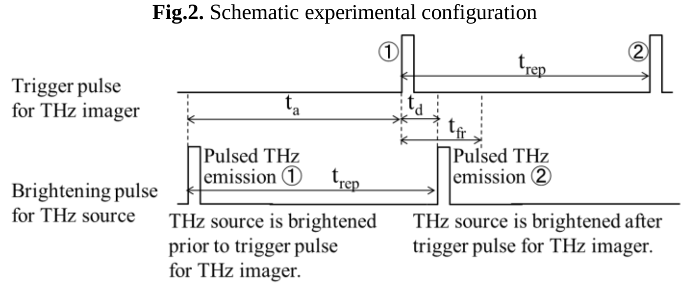

Fig.3. Relation of the trigger pulse for the 640x480 THz imager to the brightening pulse for the THz-FEL. t_{fr}: frame time (33 msec), $t_a + t_d = t_{rep}$

Let us assume that the trigger pulse ① initiates electronic scan of the THz-FPA in the imager (see Fig.3). In the case of $t_a << t_d$, the pulsed THz emission ① can be detected. In the case of $t_a >> \tau_{th}$ and $t_{fr} > t_d$, the signal of THz-FPA for the pulsed THz emission ① decays to nearly zero so that the pulsed THz emission ② is detected.

III. Experimental Results

Figure 4 shows a beam pattern of one pulse from the THz-FEL (3.3 pps, i.e., t_{rep}=300 msec) obtained with the 640x480 THz imager in the external-trigger imaging mode, where the parameters of t_d=1 msec and the pulse width of 1 μsec were set. A series of pulses (ca.100 pulses) were detected by the THz imager and frame data for each pulse was recorded. Figure 5 shows a variation of peak signals for a series of the THz pulses. Energies per pulse were measured with Joule meter for another series of ca. 100 pulses. The same experiments were also made at the repetition rates of 10, 5 and 2.5 pps. Table 1 summarizes the experimental results. The comparison of the THz imager data with the Joule meter data shows that the external-trigger imaging works well.

Figure 6 shows defocused beam patterns for t_a=0, 10, 20 and 30 msec, obtained at t_{rep}=100 msec (10 pps), which corresponds to the case of $t_a << t_d$. The peak signal decays, as the time interval (t_a) increases. The decay profile may be consistent with the thermal time constant of the THz-FPA.

Figure 7 shows defocused beam patterns for t_d=14, 15, 16 and 17 msec (t_a=86, 85, 84 and 83 msec), obtained at t_{rep}=100 msec, which corresponds to the case of $t_a >> \tau_{th}$ and $t_{fr} > t_d$. The truncated part of the beam is larger, as t_d increases. This is because electronic scan position in FPA is further advanced for larger t_d. It is, therefore, important to carefully set the parameters of t_{rep} and t_a, considering THz beam position in FPA and thermal time constant of FPA.

The same sets of experiments described above, but with different parameters, were successfully made for the 320x240 THz imager (product model: T0832). It is the difference that T0832 internally operates at frame rate of 60 Hz and frame data is transferred to computer at 30 Hz.

Fig.4. Beam pattern of one pulse from the THz-FEL (3.3 pps)

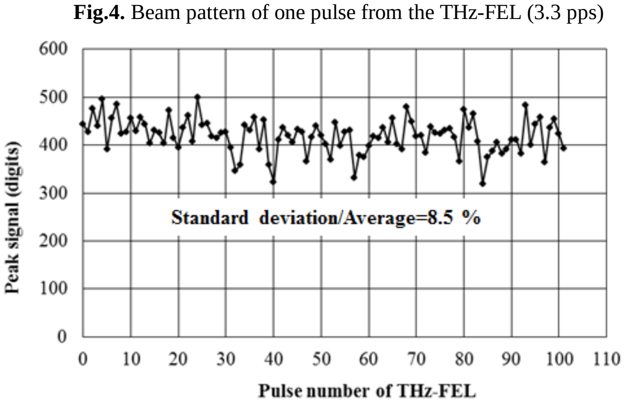

Fig.5. Time variation of peak signals for a series of ca. 100 pulses from THz-FEL (3.3 pps)

Table 1. The experimental results obtained with the THz imager and the Joule meter

Repetition rate	640x480 THz imager		Joule meter	
	Peak signal (Average±1σ)	1σ/Average	Signal (Average±1σ)	1σ/Average
2.5 pps	316±41 digits	13.0 %	326±31 μJ	9.4 %
3.3 pps	419±36 digits	8.5 %	353±41 μJ	11.7 %
5.0 pps	468±42 digits	8.9 %	493±42 μJ	8.5 %
10 pps	375±53 digits	14.3 %	352±40 μJ	11.4 %

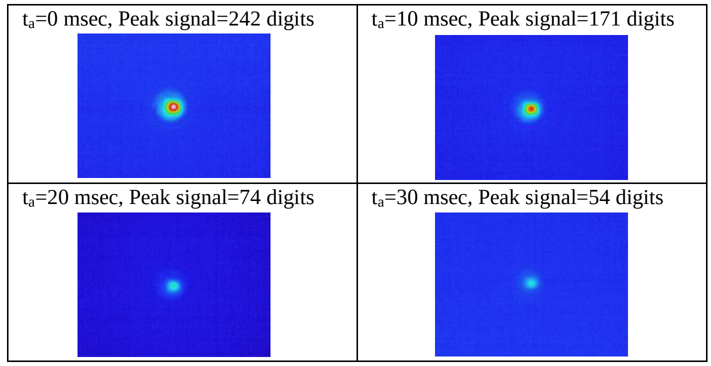

Fig.6. Defocused beam patterns for t_a=0, 10, 20 and 30 msec (t_{rep}=100 msec)

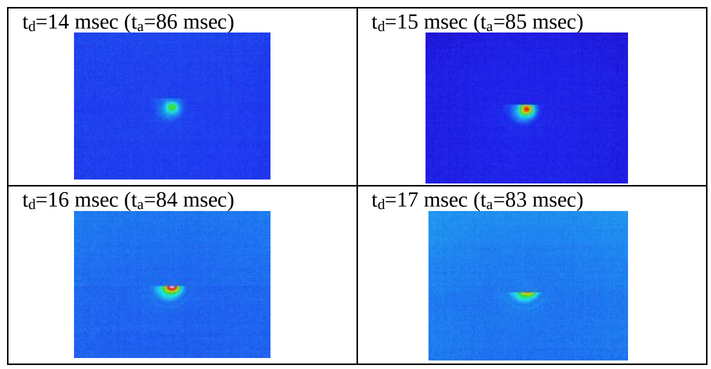

Fig.7. Defocused beam patterns for t_d=14, 15, 16 and 17 msec (t_{rep}=100 msec)

Thus, it is confirmed that the function of the external-trigger imaging works well for both 640x480 and 320x240 imagers.

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