Laser Terahertz Emission Microscope and Its Application

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***Abstract*—One can observe terahertz (THz) emission upon femtosecond (fs) optical pulse illumination from various materials. Scanning fs laser beam on the materials gives us an image to visualize its dynamic optical response to generate rapid generation of photocurrent. We named the system as laser THz emission microscope (LTEM). In the present work, recent progress of LTEM and its application will be reviewed.**

I. INTRODUCTION

TERAHERTZ (THz) imaging system is one of essential tools for THz application [1]. THz emission can be generated from various electronic materials by illumination of femtosecond optical pulses on electronic materials such as superconductors, ferroelectrics, manganites, etc. [2,3]. Since the emission properties reflect their ultrafast carrier dynamics, construction of THz emission imaging system by scanning fs laser beam realizes a unique microscope which visualizes ultrafast photocurrent generation [4,5]. We have proposed such imaging system as laser THz emission microscope (LTEM) and applied to quantitative evaluation of supercurrent density distribution, ferroelectric domain imaging, LSI defect analysis, solar cell evaluation, and so on [6-9]. In this paper, we review recent progress of the LTEM development and several application.

II. PRINCIPLES

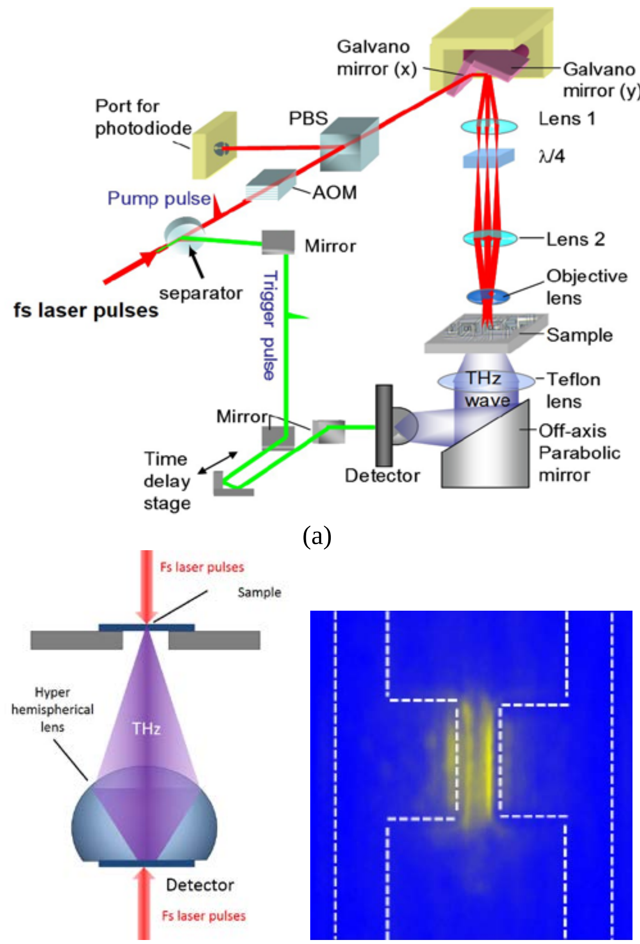
THz waves are emitted from materials upon femtosecond laser illumination by rapid photocurrent generation or nonlinear effect. LTEM visualizes amplitude distribution of THz electric field E_{THz} by the local photocurrent generation. E_{THz} is expressed as

$$E_{THz} \propto \frac{\partial J}{\partial t} \propto ev\frac{\partial n}{\partial t} + en\frac{\partial v}{\partial t} \qquad (1)$$

Where J, n, $\boldsymbol{v}$ are density of photocurrent, density of photocarriers, and their velocity, respectively. Thus images of LTEM provides the local information of excited carrier spatial behavior in a subpicosecond time domain, which differs from other microscope completely. One of merits of LTEM is that its resolution is limited by the fs laser wavelength rather than THz one.

III. RESULTS

We have developed several types of LTEM so far [10-12]. Typical LTEM and example of LTEM image are given in Fig.1. The image is taken near dipole antenna of LT-GaAs photoconductive switch. We will report, at the conference, recent extension of its functions to near field microscope(Fig.2), and pump and probe LTEM (DTEM) [13], as well as its application to the studies for solar cells, molecular sensing, and wide gap semiconductors [14,15].



(a)

(b) (c)

Fig. 1. Schematic drawing of (a) LTEM system, (b) enlarged around sample/detector part, and (c) an example of LTEM image of Photoconductive antenna (indicated dashed line) with a gap of 5 μm.

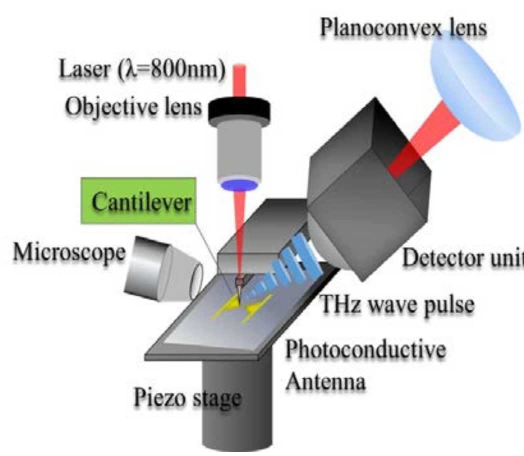


Fig. 2. Schematic drawing of Near-Field LTEM system [13].

Figure 3 shows an example of LTEM application to solar cell evaluation. The image is obtained from a polycrystalline Si solar cell. The angle of the incident laser pulses is 45° to the surface and the detector locates at 90° angle off from the incident beam. The LTEM image gives the THz amplitude distribution, which clearly coincides to the grain distribution of the Si crystal in the cell.

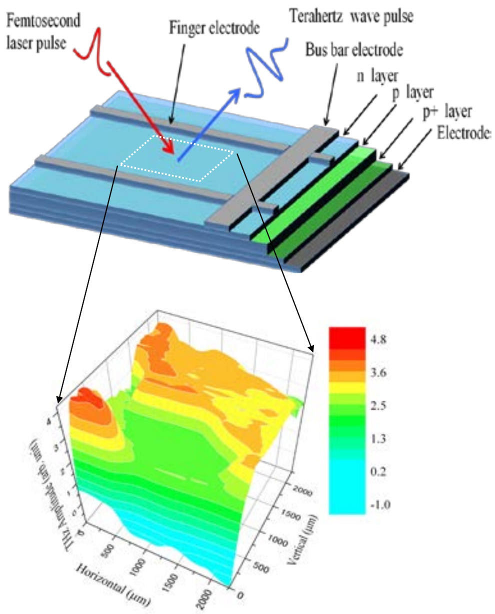


Fig. 3. Schematic drawing of Solar cell evaluation method and an example LTEM image obtained from the polycrystalline Si solar cell[9].

IV. Summary

In this talk, we review recent progress on LTEM and introduce a variety of its application.

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