THz wavefront measurement using 2D electro-optic imaging combined with Hartmann sensor principle

Institute of Technology and Science Tokushima Univ. [1]**, LOMA Bordeaux Univ.** [2]**;**
°Harsono CAHYADI[1]**, Jérôme DEGERT**[2]**, Eric FREYSZ**[2]**, Takeshi YASUI**[1]**, Emmanuel ABRAHAM**[2]

E-mail: harsono@femto.me.tokushima-u.ac.jp; Website: http://femto.me.tokushima-u.ac.jp/

Characterization of terahertz (THz) wavefront still remains challenging due to the limitation of suitable THz camera. The measurement based on 2D electro-optic (EO) sampling provides a powerful solution for frequency-resolved analysis of THz wavefront that compensates the requirement of area scanning to obtain cross-section of THz beam [1, 2]. In visible region, Hartmann sensor is a powerful technique for wavefront characterization. Since its invention around a century ago, Hartmann sensor has been applied to various applications of optical metrology systems including adaptive optics and ophthalmology [3]. Some detectors with Hartmann sensor have been available commercially for determination and measurement of the optical aberrations (e.g.: astigmatism, coma, tilt, defocusing, etc). In this communication, we propose a new method that combined the 2D EO imaging and Hartmann sensor for fast characterization of THz pulse wavefront.

Optical rectification of amplified femtosecond laser pulses (800 nm, 1 mJ, 150 fs) in ZnTe crystal provides the THz pulses in our detection system (Figure 1) based on collinear 2D EO sampling [4]. The expanded, collimated THz beam is then sent to another ZnTe crystal and probe by small part of the femtosecond laser pulse with varied time delay. There, the distribution of broadband THz beam is converted into optical intensities recorded by a CMOS camera [5]. By applying a phase sensitive detection, namely dynamic subtraction technique, one enables a high signal-to-noise ratio and video rate imaging [6]. The temporal evolution of electric field of THz pulse in the crystal can be mapped due to the changing of time delay between both pulses. The Fourier transformation of the temporal data provides the THz beam profile in frequency domain [7].

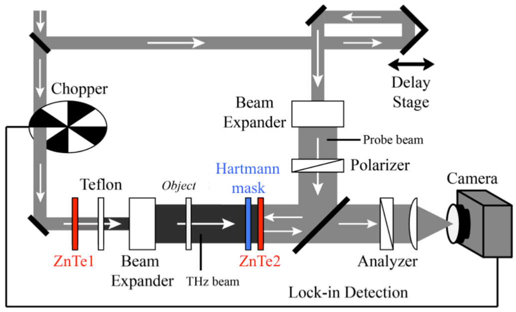

Fig. 1. Experimental setup of the THz wavefront sensor

The following experiment due to the Hartmann sensor implementation reveals the reconstruction of the THz beam wavefront and its distortion analysis. First, the reference image is recorded pointing out the locations of mask holes without any presence of optical component on THz beam pathway between the beam expander and Hartmann mask. Then, a plan-convex Teflon lens with focal length of 100 mm is introduced to change the plane THz wavefront into the spherical one and induced the centroid displacements of the holes. The integration of the displacements is used for the wavefront reconstruction of THz beam (Fig. 2a). We decide to apply modal reconstruction method by employing linear combinations of the Zernike polynomials. The coefficients of the Zernike polynomials denote the qualitative and quantitative analyses of the aberration occurred in the detected wavefront (Fig. 2b), which is dominated by defocusing as the main indicator of spherical wavefront. In summary, this system is applicable for THz pulse wavefront reconstructions and analyses from various sources, and further discussion on its limitation is required for the improvement. The analyses results of the reconstruction may lead to potential development of a compensation system for the aberrated THz wavefront in the future.

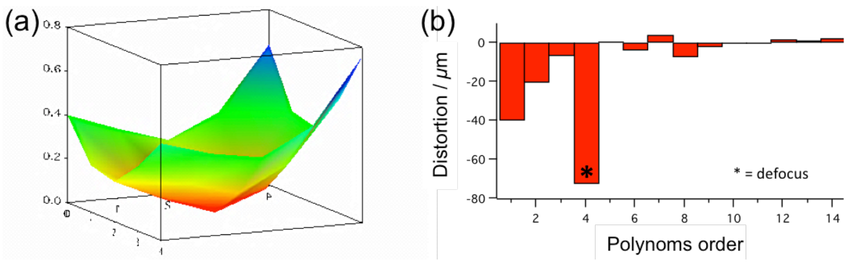

Fig. 2. (a) Reconstructed THz wavefront in the plane of the ZnTe crystal and in the presence of the converging lens, (b) Corresponding amplitudes of the Zernike coefficients.

[1] A. Bitzer et al., *IEEE JQE* **14**, 476 (2008).
[2] J.F. Molloy et al., *IEEE JQE* **19**, 8401508 (2013).
[3] J. Hartmann, *Z. Instrumentenkd.* **20,** 47 (1900).
[4] Q. Wu et al., *Appl. Phys. Lett.* **69**, 1026 (1996).
[5] T. Yasuda et al., *Opt. Commun.* **267**, 128 (2006).
[6] Z. Jiang et al., *Appl. Opt.* **39**, 2982 (2000).
[7] H. Cahyadi et al., *75th JSAP Fall*, , 03-385 (2014).