Wavefront Measurement of Terahertz Pulses using a Hartmann Sensor Combined with 2D Electro-Optic Imaging

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***Abstract*—We report on the wavefront analysis of THz pulses emitted by optical rectification of femtosecond laser pulses in ZnTe crystal. The system is based on a Hartmann sensor associated with a 2D electro-optic imaging system.**

I. Introduction

The Hartmann sensor was invented a century ago to perform optical metrology for a wide variety of applications including adaptive optics, ophthalmology and wavefront characterization [1]. In the visible spectral region, commercially available Hartmann sensors can be efficiently used to reveal optical aberrations such as astigmatism, coma, spherical aberration, etc. In the terahertz (THz) spectral domain, it is still challenging to fully measure the spatial profile and wavefront of a THz beam due to the lack of effective THz cameras. Moreover, contrary to optical beams, the wavelengths associated to the THz beams are not negligible compared to the size of the optical elements used in the experimental setup, leading to diffraction and a possible deviation from standard Gaussian beam propagation. In this communication, we propose a new 2D measurement system for frequency-resolved wavefront analysis of THz pulses which does not need to scan any aperture along the THz beam cross section, contrary to previous works [2,3].

II. Experimental Setup

THz pulses are generated by optical rectification of amplified femtosecond laser pulses (800 nm, 1 mJ, 150 fs) in a ZnTe crystal (Fig. 1). After beam expansion and collimation, the THz beam is sent into a second ZnTe crystal for electro-optic detection with a time-delayed laser probe pulse. There, the spatial distribution of the broadband (0.1 – 4 THz) THz electric field is converted into optical intensities captured by a CMOS camera. By changing the time delay between the THz and probe pulses, it is possible to record the temporal evolution of the THz electric field distribution in the crystal. The Hartmann mask consists of a metallic plate with an array of circular holes (1 mm diameter with 2 mm periodicity in the horizontal and vertical directions). The mask is placed 2.5 mm in front of the ZnTe crystal.

III. Results

We propose to measure the wavefront of a THz beam after passing through a 100 mm focal length plan-convex lens positioned 60 mm before the Hartmann mask (indicated by a dash line in Fig. 1). First, one has to record a reference image indicating the locations of the mask holes in the absence of any optical component on the THz beam pathway between the beam expander and the Hartmann mask. After FFT of the temporal data, the red arrows in the inset of Fig. 2b indicate, at 1.5 THz, the displacements of the centroids induced by the insertion of the lens. These arrows are directly related to the local slopes of the THz wavefront, which can be reconstructed by integration of the gradient measurements using a modal reconstruction method with Zernike polynoms.

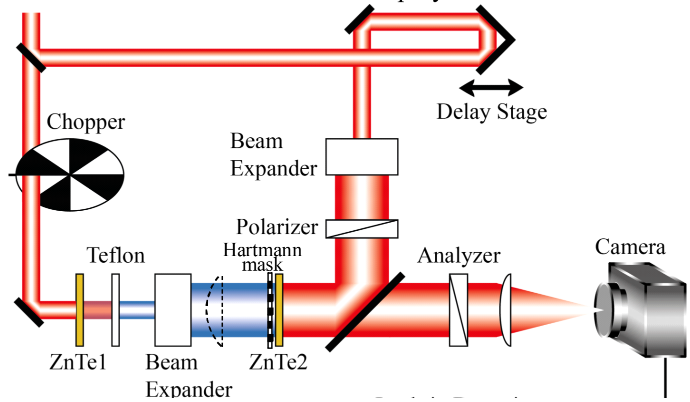

Fig. 1. Experimental setup of the THz wavefront sensor.

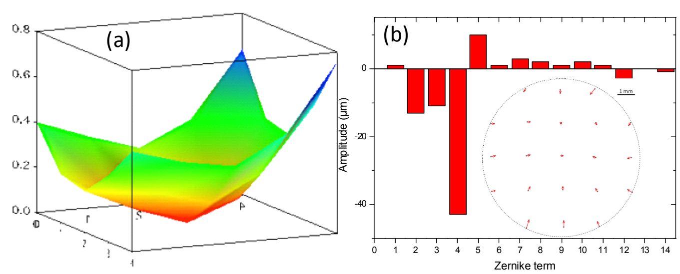

Fig. 2. (a) Reconstructed THz wavefront in the presence of the converging lens, (b) Amplitudes of the Zernike coefficients.

Fig. 2a represents the reconstructed THz wavefront at the position of the ZnTe crystal after passing through the converging lens. The analysis of Zernike coefficients indicates a dominant defocus (Zernike number 4) of -45 µm (i.e. $\lambda/4.4$) consistent with the curvature of the converging THz beam at that location (Fig. 2b). The communication will discuss the advantage of the system to limit distortions and aberrations of broadband THz waves in the arrangement of complex optical systems together with the limitations in terms of resolution and signal-to-noise ratio.

References

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