Direct measurement of terahertz wavefront pulses using 2D electro-optic imaging

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Wavefront characterization of terahertz (THz) pulses is essential to optimize far-field intensity distribution or spot focalization, as well as increase the peak power of intense terahertz sources. In the visible spectral region, Hartmann masks, invented a century ago, are used to perform optical metrology for a wide variety of applications [1]. However, in THz spectral range, it is well-known that spatiotemporal profiles of THz transient fields can also be directly determined through electro-optic (EO) sampling in a nonlinear crystal [2]. In this communication we will show that this latter technique is well adapted for the quantitative determination of the optical aberrations of THz pulses.
THz pulses are generated by optical rectification of amplified femtosecond laser pulses (800 nm, 1 mJ, 150 fs) in a ZnTe crystal. 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 (Fig. 1a). There, the spatial distribution of the broadband (0.1–3 THz) THz electric field is converted into optical intensities captured by a CMOS camera. By varying the time delay between the probe and THz pulses, EO sampling can record the spatial dependence of the full (amplitude and phase) THz electric field in the crystal plane. Then, after Fourier transformation of the temporal data, we can get for every frequency the amplitude and the phase of E_{THz} in this plane. From this phase mapping, it is possible to calculate the surface of equi-phase, which constitutes the definition of the wavefront.
To illustrate our method, we measured the optical aberrations of the THz beam presented in Fig. 1a, which is supposed to have a planar wavefront. The result is presented in Fig. 1b at 1 THz but can be perform at every other frequency within the broadband THz pulses. Clearly, this wavefront is not fully planar, some optical deformations are visible near the edge of the beam. This is clearer after the decomposition of the wavefront onto Zernike polynomials, where each polynomial represents a specific optical aberration. As shown in Fig. 1c, the THz wavefront presents some X and Y tilts associated with astigmatism that may be attributed to imperfect beam collimation or optical aberrations on the incident laser beam or the ZnTe nonlinear crystal. More generally, we believe that our THz wavefront sensor could provide a real advance for time-domain (imaging) spectrometers which require a perfect focalization of the THz beam or any other THz devices sensitive to wavefront distortions. Associated with deformable mirrors, it could open the route to THz adaptive optics.

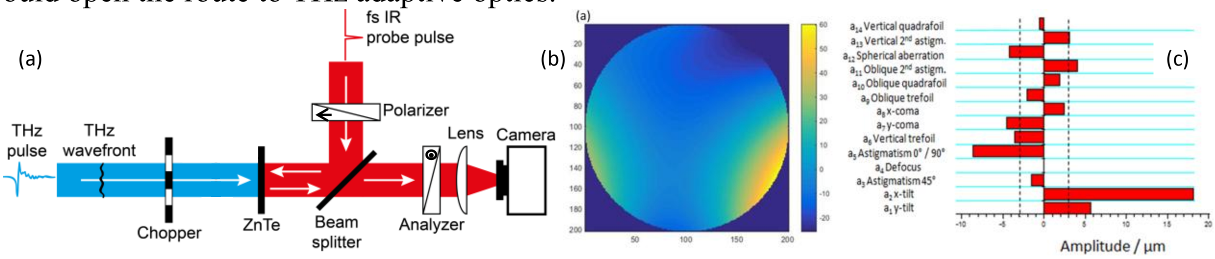

Fig.1. (a) Experimental setup. (b) Reconstructed THz wavefront at 1 THz. (c) Amplitude of the Zernike polynomials.

References
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