Simple and distortion free optical sampling of THz pulses near zero optical transmission point

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***Abstract* — A simple and distortion free method to sample THz pulse in zinc-blende crystal is proposed and experimentally demonstrated in a <110> cut ZnTe. A comparison of its performances with other techniques is given.**

I. INTRODUCTION

Electro-optic sampling, hereafter reported as conventional E-O, is a widely used technique for the measurement of the electric field E_{THz} of a THz pulse with subpicosecond time resolution [1]. Different alternatives to this technique have been proposed but they suffer from some detection nonlinearities [2,3]. Very recently, new methods based on a technique commonly used in optically heterodyne detected optical Kerr effect spectroscopy has been introduced [4]. These distortion-free techniques are based on two measurements at opposite optical biases near the zero transmission point in a crossed polarizers detection geometry. Hereafter, we propose a novel and simple scheme, based on three-waves mixing interaction which makes it possible to perform a distortion-free sampling of THz pulse within a single measurement.

II. EXPERIMENTAL SETUP

The experimental setup is presented on figure. 1.

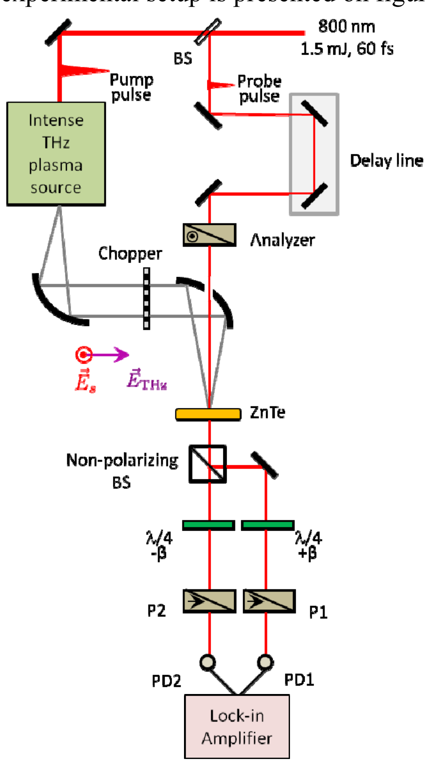

Fig. 1: Experimental setup: the intense THz pulses are generated through a plasma induced by a two-color femtosecond laser field, focused in the air. The letters P stand for Polarizer, BS for beam-splitter and PD for photodiode.

An amplified Ti:Sapphire regenerative amplifier yields at 1 kHz repetition rate, 1.5 mJ pulses centered at 800 nm with a 60 fs duration. The laser beam is split into pump and probe pulse respectively. The pump pulse generates an intense, linearly polarized THz pulse, emitted from air ionized by a two-color laser field. This THz field is then collimated and focused onto a 300 µm thick, <110> cut ZnTe crystal by two off-axis paraboloidal mirrors. The probe and THz pulses propagate collinearly and are polarized along the <001> and <-110> axis, respectively. The optical pulse transmitted by the crystal is then split by a 50/50 non-polarizing beamsplitter (BS).

Both pulses are sent through a λ/4 waveplate and a Glan-polarizer and recorded by photodiodes. The axes of the polarizers are set perpendicularly to the probe so that it is blocked in the absence of THz. However, when the probe and THz pulses temporally overlap in the crystal, their interactions within the crystal generates a weak optical signal E_s, polarized perpendicularly and phase shifted by $\pi/2$ with respect to the probe field. The latter is therefore transmitted by the polarizers. The THz beam is chopped and the intensities difference, measured by the two photodiodes versus the time delay τ between the probe and THz, is recorded by a lock-in amplifier.

III. RESULTS

Figure 2 presents the evolution of the signal S_1 recorded by a single photodiode versus τ, as well as E_{THz}^2, recorded by conventional E-O sampling. The inset also shows that the amplitude of S_1 is quadratic with respect to the amplitude of the THz field.

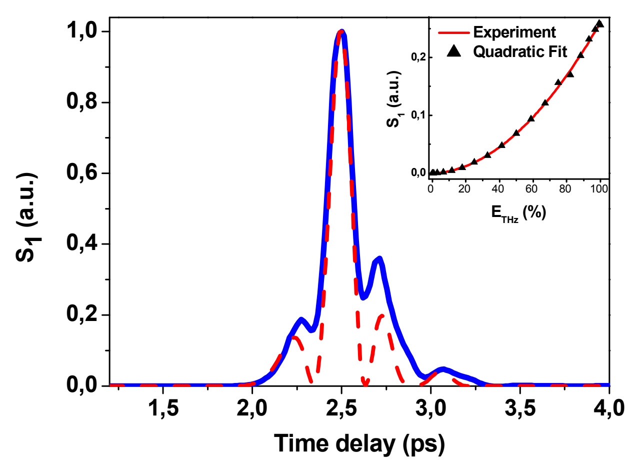

Fig. 2: Signal recorded by a single photodiode.

Figure 3 displays the intensity difference between the two photodiodes recorded versus τ, when the $\lambda/4$ waveplate in front of the photodiode PD_1 (PD_2) is respectively rotated around its fast axis by an angle $\theta=11°$ ($-\theta$). It can be shown that the difference of the signal produced by the two photodiodes is $S_1-S_2 \propto 2.\theta.E_{THz}$.

An excellent agreement is experimentally shown for both the temporal waveforms and spectra, obtained by conventional E-O sampling and this new setup.

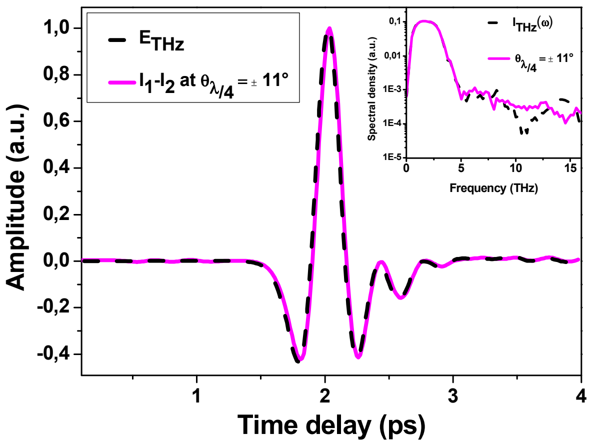

Fig. 3: Comparison of the THz field measurement with the ellipsometric EO sampling technique or our experimental set-up.

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