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THz pulse generation and single shot detection in a single ZnTe Crystal

IRMMW- THz 2022

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Abstract: Single-cycle THz signal of few picoseconds duration, have been simultaneously generated via optical rectification and detected by electro-optic effect in the same ZnTe crystal. An unbalanced seemingly single shot detection scheme was performed to characterize the signal. The added simplicity of this scheme aided the independent analysis of the horizontal and vertical polarization arm of the chirped probe beam to explain the associated nonlinearities in the detected THz signal.

INTRODUCTION

THz generation has been appreciably reported in several non-linear second order crystals owing to their non-linear coefficient value and wide transparency in the optical and THz domains. Optical rectification (OR) is a second order nonlinear process which has been used to explain the mechanism by which THz are generated in these nonlinear crystals such as ZnTe. The passage of an ultra-short pulse through a non-linear crystal, gives rise to polarization term, within the crystal whose extent of polarization is dependent on the intensity of the incident pulse. The second order susceptibility term is mostly relevant for OR in which the difference frequency mixing within the spectral bandwidth of the laser pulse generates low frequency signal within the THz region. Although most of the work have been achieved with ultrashort pump pulse, a growing interesting is also on the use of longer chirped pulse in order to scale up the energy in the THz range¹.

Though the spectral width of the THz signal are narrow-ranged, their signal amplitude can be optimized for detection. Usually, a similarly thinner crystal is utilized in the Electro optic Sampling (EOS) technique for the detection of the THz signal. Only a few THz related papers have explored the option of detecting the signal in the same crystal deployed for generation, of which the THz is sampled by a short probe beam in a multi-shot pattern^{2, 3}. To the best of our knowledge, the single-shot detection scheme has not been incorporated in the single-layout configuration. In the single-shot geometry, the THz pulse which is generated in the leading part of the crystal by the incident pump beam, becomes superimposed on a chirped probe beam that passes through the crystal the cost effectiveness and less cumbersomeness of this scheme prompted the quest of our research. In this work, we study the generation and

detection of THz signal in the single-crystal configuration with respect to a seemingly single shot

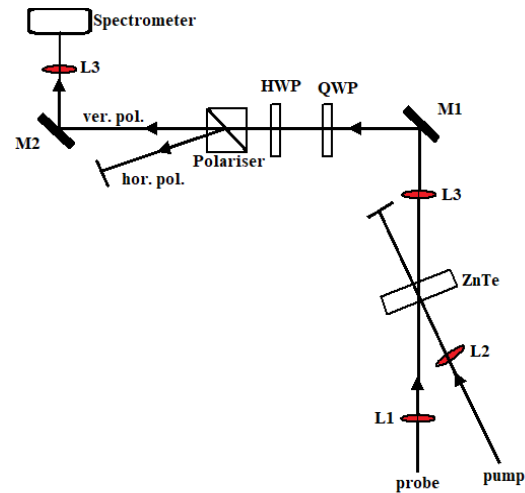


Fig.1.0 Sketch of the experimental set-up

measurement, pump-probe power ratio effect and comparison of the vertical and horizontal polarized THz signal arm.

A pre-chirped Ti-sapphire laser beam with center wavelength of 800 nm , 1 kHz repetition rate and $\sim 1\text{ mJ}$ of energy was split by a beam splitter into two arms that forms the pump and probe beam. The probe beam was temporally stretched more by repeated passage through sets of dispersion blocks. The experimental set up as illustrated in Fig. 1.0 consist of the 3.6 ps FWHM stretched pump beam focused onto the 0.6 mm ZnTe crystal with few tens of μJ . A 5.2 ps FWHM chirped probe overlaps temporally and spatially with the pump beam on the crystal at a crossing angle of $\sim 12^\circ$. The beam diameter of the probe and pump beam at the crystal position were $570\text{ }\mu\text{m}$ and $125\text{ }\mu\text{m}$ respectively. At the cross point of the two beams, the THz pulse generated via optical rectification by the intense pump beam overlaps with the propagating chirped probe. This probe-THz beam is collimated and subsequently circularly polarized of which the vertical and horizontal polarized component diverges upon exiting the polarizer. A half wave plate placed between the quarter wave plate and polarizer is used to switch the beam path of the two polarization, such that the same spectrometer detects the different polarization. The simplicity of this configuration does not only

guaranty its affordability but also provide an avenue to independently analyze the signals of the different polarization with the aim to quantify the induced nonlinearities from the probe beam intensity. The effect of two photon absorption was minimized by rotating the polarization of the pump beam following the suggestion of [3].

RESULTS

The spectrum of the chirped probe was captured both in the absence and presence of the pump beam. The consistency in the spectrum profile was confirmed by recording hundred shots of the spectrum. An average recorded spectrum in the presence/absence of the pump is displayed in Fig. 2.0. The THz pulse shape is then retrieved according to the standard normalization⁴. The average of one of the difference signal is shown in Fig. 3.0 (a). The linear relationship between time and frequency was obtained from the autocorrelation of the probe pulse although a FROG measurement will be performed in the near future to account for some nonlinear behavior.

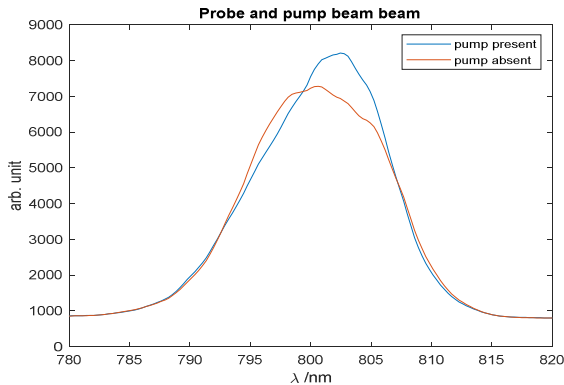


Fig 2.0. An averaged single shot probe signal recorded by the spectrometer in the presence or absence of the pump beam.

While keeping the chirped probe intensity fixed, the pump beam intensity was varied, in which case both the THz horizontal and vertical signal maintain similar profile. At much higher intensity of the chirped probe, the form of the THz signal changed (see Fig.3.0 (a), blue). These changes might be related to the contribution of the OR from the probe or higher order susceptibility phenomena such as Kerr effects and self-focusing. Numerical simulations are in progress to validate these assumptions.

The corresponding spectrum obtained by the Fourier transform the THz signal is illustrated in Fig. 3.0(b). The narrow spectral width, which extended from few GHz to 500 GHz, is due to the long pulse duration.

SUMMARY

We have discussed THz generation and its EOS detection in a single ZnTe by using picosecond pulses in both cases, and we highlighted the distortion in the THz field to be due to nonlinear contributions of the probe beam. Our findings implies that single shot THz time domain spectrometer can be used for the analysis of fast physical processes with high sensitivity and stability. The ultrashort acquisition time can allow the recording without averaging with a picosecond lasers.

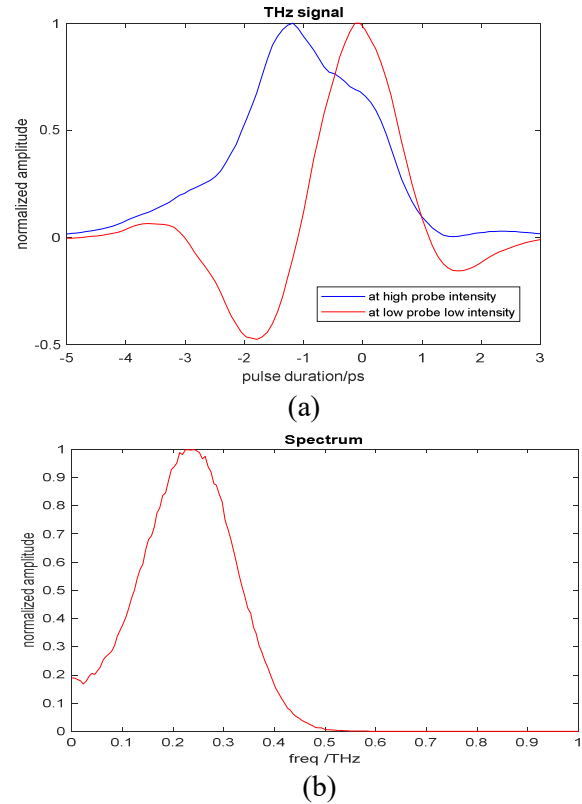


Fig. 3.0. a). THz time domain signal in the presence of weak (red) and strong (blue) probe. b). corresponding THz spectrum in the presence of the weak probe.

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