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Filament characterization via absorption of terahertz wave

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Nowadays, air-plasma prepared by symmetry-broken dual-color laser fields is extensively served as a convenient and low-cost light source for terahertz wave generation. In the picture of strong field dynamics, electron formed drifting current contributes to the emission of THz wave. However, less attention has been paid on the propagation of the THz wave within the plasma since its generation. Simple questions, such as what inherently happens during the THz wave propagating though the plasma, are still not well answered. To give a more comprehensive picture of the generation process, the lacking knowledge on THz propagation within the gas plasma should be added. Meanwhile, the diagnostics of plasma are mainly based on the optical properties, because the dispersion relationship is closely associating to the plasma frequency. Different diagnostic source are limited to its spectral region of the detector, because if the frequency of the probing light is far from the plasma frequency, the phase shift of the detecting pulse may be too small to be observed, introducing a bad dynamic range of detection. Therefore, THz-based plasma diagnostics should be performed to reveal more physics locating at THz frequency range, offering both the intensity damping and the phase information.

The experimental setup consists of a 800 nm, 100 fs, 4.2 mJ, 1 kHz Ti:sapphire laser (Coherent). The light path is sketched in Fig. 1. Filament is prepared by Pulse 1. In Pulse 2, THz wave is generated by the parallel-polarization fundamental pulse and its second harmonic, which are temporal and spatial overlapped. After generation, THz wave is reflected by two parabolic mirrors and refocused to pass though the filament. Pulse 3 is to track the THz waveform by a 1 mm thick (110)-cut electro-optic ZnTe crystal. DL1 in Fig. 1 is to vary the relative time delay τ between plasma-generated beam (Pulse 1) and the THz-probe pulse (Pulse 2). DL2 is to vary the time delay t between the THz-probe pulse (Pulse 2) and the THz-sampling pulse (Pulse 3).

By continuously varying the time delay τ, the THz waveform and the DS can be traced through electro-optics sampling. In Fig. 2(a), the transmitted THz waveforms (every horizon line) at different time delays τ are compared. It is obvious that the peak position of the transmitted THz waveform is shifting, and when the whole THz-probe pulse is delayed after the plasma generation (τ ≥ 1.5 ps), the waveforms maintain the same. In Fig. 2(b), DS at different τ is traced by placing the chopper at the plasma-generated arm. The gray dashed line indicates the general shape of the time difference between the plasma-generated pulse and the THz pulse. To give an intuitive view, the transmitted THz waveform and the DS at three different time delays τ are shown in Fig. 2(c) and 2(d), respectively.

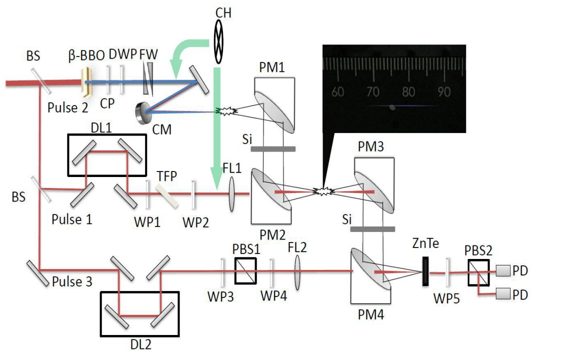

Fig. 1. Schematic of experimental setup. BS: beam splitter. β-BBO: β-BaB2O4 crystal. CP: calcite plate. DWP: dual wavelength wave plate. FW: fused silica wedges. CM: concave mirror. WP1-4: 1/2 λ wave plates. DL1, 2: delay lines. TFP: thin film polarizer. FL: focusing lens. PM1-4: parabolic mirrors. PBS1, 2: polarizer beam splitter. WP5: 1/4 λ wave plate. PD: photodiode detector. Si: silicon plate. CH: chopper. The green arrows point out the positions to place the chopper for different measurements. The top-right inset shows the filament formed in laboratory.

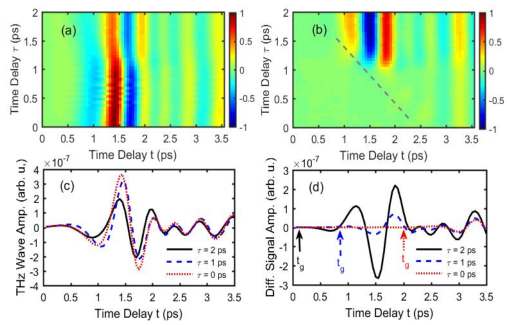

Fig. 2. Experiment results of THz waveform and the difference signal (DS) at different time delays τ between the plasma-generated pulse and the THz-probe pulse. (a) and (b) show the normalized THz transmitted waveform and DS, respectively. The gray dashed line in (b) indicates the variations of the time difference between the plasma-generated pulse and the THz-probe pulse. (c) and (d) depict three horizon lines from (a) and (b), indicating the plasma effect on THz wave at different time delays τ, respectively. The plasma generation time tg are pointed out by arrows for different τ in (d) (same color and line style as the DS curve). The power of the plasma-generated beam is 0.7 W and the length of filament is about 2.15 cm.

References

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