Self-induced nonlinearity modulates the THz waveform generated by the two-color laser filament

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1. Introduction

Pulsed laser-induced filaments by focused infrared (IR) fundamental wave (ω) and its second harmonic (2ω) is one of the most powerful benchtop sources of terahertz (THz) pulsed radiation. Since this method has no damage threshold to the emitter, and is capable of achieving strong electric fields of MV/cm level and broadband over 100 THz, this promising tool has stimulated a series of studies in both basic and application aspects. The asymmetric transient current model proposed by Kim et al. [1] successfully explains the theoretical principles of the two-color excitation scheme. In this model, the bounded electrons of gas-phase atoms or molecules undergo rapid photoionization, and thus the electrons freed from atoms or molecules by the combined laser field can form a directional transverse net current.

However, the nonlinear effects in the filament associated with changes of the refractive index when the pulse propagates through optical media [2], which leads to the changes of phase, amplitude and frequency, have not been considered.

2. Experimental results

In the experiment, we used a Ti:sapphire laser amplification system with a pulse width of 100fs as the IR laser source. The pulses are focused in air with their second harmonics (SH) generated from a 100-μm β-BBO crystal after the parabolic mirror with an effective focal length of 150 mm. Air biased coherent detection (ABCD) method is employed to detect the filament emitted THz waveform as shown in Figure 1(a). We observe that the positive half of the waveform gradually increases and the negative half decreases as the incident pulse energy increases. The raised part behind the main peak also gradually flattens out. Figure 1(b) shows the change in the spectrum with a gradual increase in the cutoff frequency but little change in the center frequency.

An acceptable explanation is the free carriers induced self-phase modulation (SPM) which leads to the temporal reshaping of the IR laser pulse, known as self-steepening [2]. And this additional phase also affects the group velocity of the two-color pulses, leading to the shaping of the temporal transient currents in the filament, thus modulating the THz spectrum. With this in mind, we need to re-understand the physical mechanism of pulse propagation in a filament and study the THz modulation due to nonlinearity in depth.

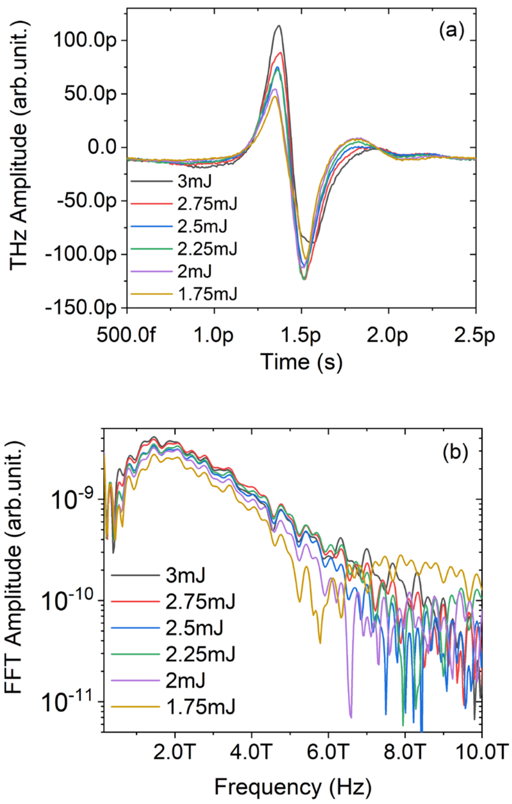

Fig. 1 The THz waveform (a) and frequency spectrum (b) of laser filaments under different pulse energy focusing.

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References

[1] K. Y. Kim, *Phys. Plasmas* **16** 056706 (2009)
[2] C. Gong et al., *Sci. Rep.* in press (2021) DOI: 10.1038/s41598-020-80105-7
[3] N. Aközbek et al., *Opt. Commun.* **191** 353–362 (2001)