Spectrum-Modulated Terahertz Emission from Ultrafast Laser Pulses with Controlled Wavefront

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Abstract—Terahertz wave with modulated spectrum is always desirable in the remote detection, which is one of the most potential values of terahertz emission from plasma. We demonstrate a method to modulate the terahertz spectrum by controlling the wavefront of femtosecond laser pulses, in which the terahertz waves emit form the air induced plasma. The characteristic parameters of the plasma have been changed with the controlled wavefront of the laser pulses, which emitting variable terahertz wave in amplitude and peak-frequency shift. The experimental results are simulated and discussed.

I. INTRODUCTION

RECENTLY, terahertz (THz) wave generated from laser-induced plasma have been given more attention. In this optics-to-THz conversion method, THz wave has been replaced by femtosecond laser pulse to propagate, which avoids the water absorption in the long path and can be potential used in the THz remote detection. To make this potential application practicable, more works have been performed on the power and efficiency of the emitted THz wave, some schemes have been proposed, such as two-color pulses pumping, external electric field, optical pulses shaping and so on[1-3]. All these undergoing methods have greatly improved the power or efficiency of the emitted THz wave, which make the THz wave more powerful in the distance. However, as a relative fixed spectrum radiated from the ionized plasma, its role in remote detection has been ignored, and the THz wave with modulated spectrum is deemed to be desirable in the remote detection and recognition. In this paper, we demonstrate a method to modulate the terahertz spectrum by controlling the wavefront of femtosecond laser pulses, in which the terahertz waves emit form the air induced plasma.

II. RESULTS

A deformable mirror (DM) reflecting the femtosecond laser pulses is used to change the wavefront of laser beam. The laser pulses with modulated wavefront are focused with a lens to induce the air plasma, the focal length of the convex lens is 150mm. A CCD put aside the filament is used to capture the fluorescence of the plasma column, which can be used to detect and analyze the distribution of electric field strength of the laser pulse in the foucus. With this wavefront control technology, the expected profiles of a single filament, including the initial position, length and diameter have been obtained. To compare with the experimental results, the electric fields of the laser pulses after the lens have been simulated with the Fresnel diffraction effect. For clarity, two lines are abstracted from the experimental and simulated results respectively, shown in Fig.1.

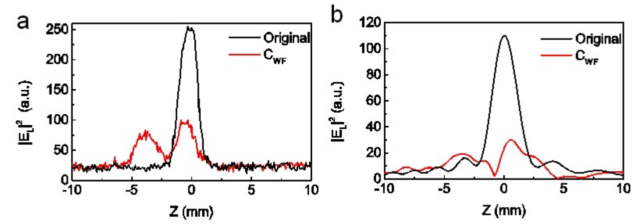

Fig. 1. The $\left|E_L\right|^2$ curves of plasma induced by laser pulses with the original and modulated wavefronts along laser propagation direction, (a) for the experimental results and (b) for the simulated results.

The laser-induced plasma emits THz waves, which are collected and detected by a conversional THz time domain spectroscopy system (TDS). The detected THz signals are Fourier-transformed to get the spectrums. With the controlled wavefront of the femtosecond laser pulses, the modulated spectrums in amplitude and peak-frequency-shift have been obtained. The THz spectrums induced from the modulated wavefront of the laser pulses are simulated with a Cherenkov-like model. The experimental and simulated results are shown in Fig.2. It shows that the simulated result accords with experimental ones well.

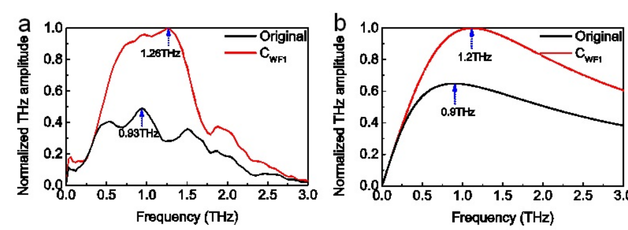

Fig. 2. Terahertz spectrums obtained from the laser pulses with the original and modulated wavefronts, (a) for the experimental results and (b) for the simulated results.

III. SUMMARY

In conclusion, we demonstrate a method to modulate THz spectrum in amplitude and peak-frequency shift by controlling the wavefront of the laser pulse. It can provide a potential application for the THz remote detection.

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