Control of THz wave emission by tuning relative phases between two color lasers

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***Abstract*—THz waves emitted from air filaments induced by elliptical polarized laser pulses are studied both theoretically and experimentally. The results show that not only the relative phase between the fundamental and its second harmonic laser fields but also the relative phases introduced by the elliptical polarized laser contribute to the THz generation.**

I. Introduction

TERAHERTZ (THz) waves generated by laser plasmas have been widely studied in recent decades. Since Cook etc. reported efficient THz wave generation by mixing the fundamental and its second harmonic laser fields in air [1], lots of work has been done in controlling THz waves with the two-color laser fields. Recently, Wang etc. showed that THz intensity can be tuned generally by changing the relative phases between the fundamental and its second harmonic laser fields through theoretical simulations [2]. However, the theoretical simulations assume that the two color laser fields are in the same linear polarization, which is usually hard to satisfy in experiments.

In this work, we study the THz waves emitted from air filaments which are induced by a femtosecond laser pulse and its second harmonic wave with an elliptical polarization. Both experimental and theoretical investigations have been carried out. In principle, one can derive any elliptical polarized laser field from the superposition of two orthogonal linearly-polarized laser fields with different relative phases, which is the key factor of the THz source control technique.

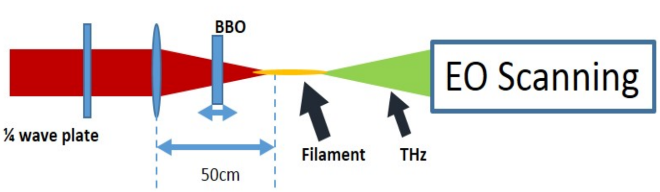

Fig. 1. Experimental setup. THz signal is detected by EO scanning system. By rotating the EO crystal, one can get THz waves with two orthogonal linear polarized direction.

In the experimental setup, a 1 kHz, 800nm, 40 fs laser pulse is used as the fundamental wave. The air plasma is generated by focusing the strong laser field through using a 50cm-focal-long plano-convex lens. The initial polarization of the laser is a linear polarization in p-direction. Tuned through a quarter wave plate (QW), its polarization state changes to an elliptical one. Before the generation of the filament, the second harmonic wave is introduced by use of a nonlinear crystal (type-I BBO), which is always linear polarized. The THz waves emitting from the filament is detected by the electro-optical (EO) sampling device. Through this we can study the change of the THz fields with the relative phases between the fundamental wave and its second harmonic wave (tuned by moving BBO) and those between the two orthogonal linear polarized fundamental laser pulses (tuned by rotating QW).

II. Results

The experimental results show that the THz signal emitted from the air filament driven by elliptical polarized laser pulses changes sensitively with those relative phases mentioned above. As is shown in Fig. 2, THz waves emitted from the air plasma with different relative phases between the fundamental wave and its second harmonic wave change differently.

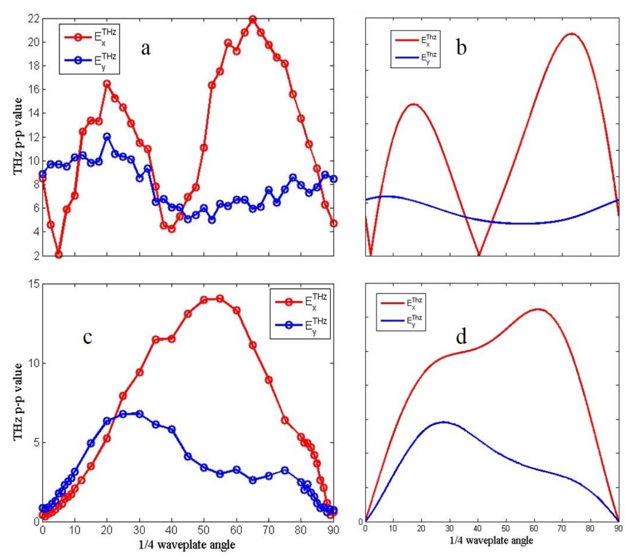

Fig. 2. Experimental results (a,c) and theoretical simulations (b,d) of the THz emission yields, where the x-axis is the rotating angle of the 1/4 wave plate, which indicates the change of the relative phases between the two orthogonal linearly-polarized fundamental laser pulses. The relative phases between the fundamental wave and its second harmonic wave is fixed at zero for (a,b) and $\pi/2$ for (c,d).

Not only the intensity but also the polarization of the THz wave can be tuned by simply changing either relative phases. The theoretical simulations show that the THz waves can be divided in several components induced by different polarized pump laser pulses.

The mechanism of the THz wave generation is considered as the nonlinear four wave mixing in air plasma. And the mathematical explanation of the THz wave can be written as

$$E_{THz} \propto \chi^{(3)} E_{2\omega} E_{\omega} E_{\omega} \cos\theta \quad (1).$$

The 3-order nonlinear coefficient in the plasma is determined by the states of the pumping laser, including the polarization states and the relative phases between the fundamental wave and its second harmonic wave. Notice that the relative phases between the two orthogonal linear polarized fundamental laser pulses can be changed by rotating the quarter wave plate, which also contributes to the parameter θ.

III. SUMMARY

THz waves emitted from air filaments induced by elliptical polarized laser pulses are studied both theoretically and experimentally. The relative phases between different polarized laser components play an important role in the THz generation.

IV. ACKNOWLEDGEMENT

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REFERENCES

[1]. D. J. Cook and R. M. Hochstrasser, "Intense terahertz pulses by four-wave rectification in air," *Opt. Lett.* 25, 1210-1212 (2000).

[2]. W.M. Wang, Y.T. Li, Z.M. Sheng, X. Lu and J. Zhang, "Terahertz radiation by two-color lasers due to the field ionization of gases," *Phys. Rev. E*, 87, 033108 (2013).