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Controllable broadband terahertz radiations from laser driven air plasmas

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Plasmas driven by two-color femtosecond laser pulses in air are known to be able to emit broadband strong terahertz waves with reasonable efficiency suitable for many applications such as material sciences, medical and biological diagnostics, near-field communications and public securities. Such applications lead to an urgent requirement of the flexible control method of the terahertz radiation including the peak intensity, waveforms, distributions and polarizations.

Firstly, we demonstrate an effective control on the carrier-envelope phase and angular distribution as well as the peak intensity of a nearly single-cycle terahertz pulse emitted from a plasma filament formed by two-color laser pulses propagating in air. Experimentally, such control has been performed by varying the filament length and the initial phase difference between the two-color laser components. A linear-dipole-array model, including the descriptions of both the generation (via laser field ionization) and propagation of the emitted terahertz pulse, is proposed to present a quantitative interpretation of the observations. Our results contribute to the understanding of terahertz generation in a femtosecond laser filament.

Secondly based upon theoretical and experimental studies, we show that the two-color laser scheme in gas plasma can provide effective control of elliptically polarized terahertz waves, including their ellipticity, azimuthal angle, and chirality. This is achieved with a circularly-polarized laser at the fundamental frequency and its linearly polarized second harmonic, a controlled phase difference between these two laser components, as well as a suitable length of the laser plasma filament. A flexible control of their ellipticity and azimuthal angle is demonstrated with our theory model and systematic experiments. This offers a unique and flexible technique on the polarization control of broadband terahertz radiation suitable for wide applications.

References

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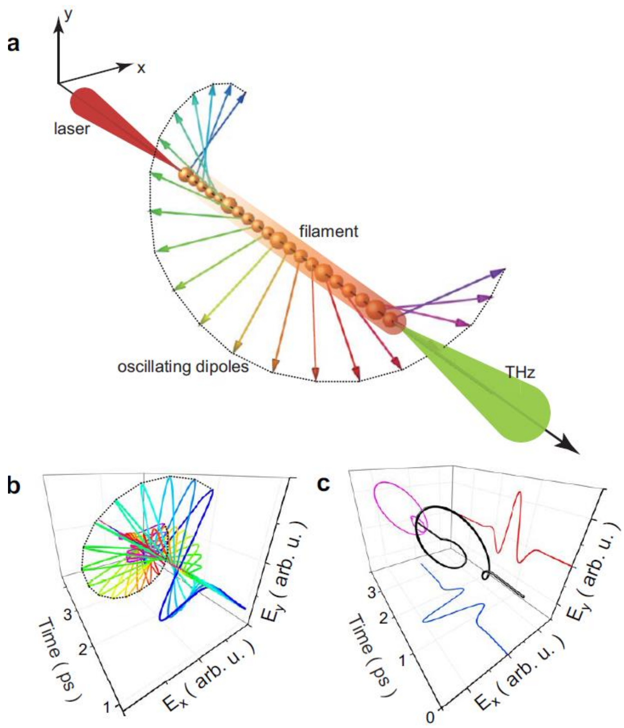

Figure 1. The diagrams interpreting the generation process of far-field terahertz radiation from a plasma filament. (a) A schematic of a plasma filament consists of a linear array of oscillating dipoles located along the filament (z-axis). The oscillating direction of each dipole is marked as a colored arrow. These dipole oscillations are equivalent to those distributed along a long filament. (b) Far-field terahertz waves emitted from an array of dipoles located along the filament. Each waveform corresponds to a terahertz electric field $[E_x(t);E_y(t)]$ emitted from one dipole of the filament. (c) The polarization of the far-field terahertz pulse emitted from a long filament obtained by coherent superposition of linearly polarized terahertz fields from each dipole located along the filament shown in (b) in two orthogonal directions.