TERAHERTZ PHOTONICS: FROM CLASSICAL TO RELATIVISTIC LASER-PLASMA INTERACTION REGIMES

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1. Introduction

Terahertz (THz) radiation has many promising applications in security screening, cryptography, material sciences, medical imaging and remote detection. Because these applications often request to probe unknown materials over long distances, there is a need for more and more intense THz signals with spectra tunable to the desired application. For this purpose, the technique relying on frequency mixing in a plasma spot created by femtosecond light pulses is quite attractive, in particular for generating intense broadband fields [1]. With two colors that render the pulse profile asymmetric, transverse photocurrents appear as efficient emitters that can convey high THz power out of the plasma channel [2]. Besides this mechanism, longitudinal wakefield oscillations may also produce important THz fields inside the plasma.

2. PIC Simulations of laser-driven THz emission

Here, we consider laser intensities larger than 10^{19} Wcm^{-2}, capable of accelerating electrons to relativistic velocities. We address the impact of ponderomotively-driven wakefields on THz generation in gases, both numerically and theoretically. Figure 1(a) displays the results from a 1D particle-in-cell (PIC) simulation of a two-color 35-fs laser pulse of 2.2x10^{19} Wcm^{-2} intensity interacting with an underdense gas of helium. Terahertz electromagnetic fields as high as 8 GV/m are emitted from photocurrents in the laser region. In addition, new THz transverse emissions occur behind the laser pulse at harmonics of the relativistic plasma frequency (see thick solid red curve). These replicas coincide with periodic sharp peaks in the electron density, which are triggered by the plasma wakefield (thin dashed red curves), and they give rise to intense THz wavetrains extending over several relativistic plasma cycles. An analytic formula allows us to accurately describe this wakefield-modified THz emission (black solid curve).

These 1D predictions will also be compared to the results of 3D PIC simulations. While an overall agreement is found, some differences arise [Figure 1(b)]. In particular, the THz bursts associated with the wakefield appear amplified in 3D due to an increase in the electron density by transverse acceleration motions, which can open novel perspectives in THz field science.

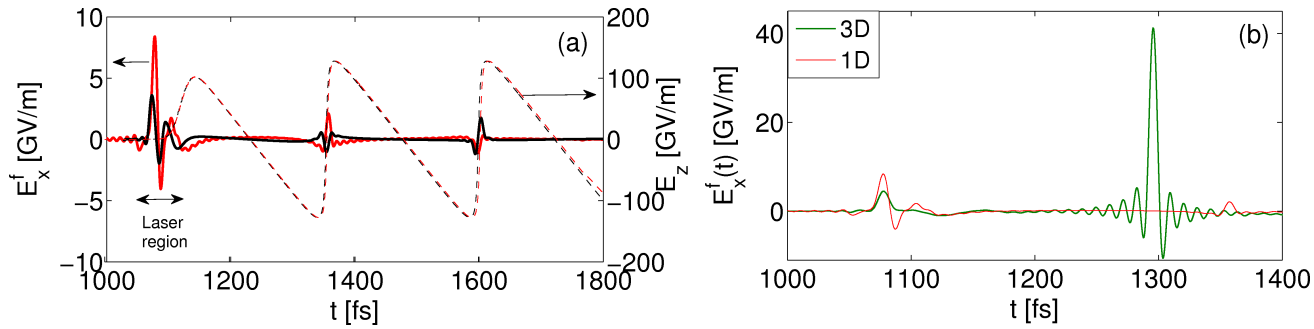

Figure 1. (a) Transverse THz fields (solid lines, left y-axis) and longitudinal fields (dashed lines, right y-axis) after laser propagation over 300 μm in helium, computed from an analytical solution (thick black curve) and 1D PIC simulations (thick red curve) for a two-color 35-fs laser pulse with 2.2x10^{19} Wcm^{-2} intensity. (b) Transverse THz field from 1D PIC (red curve) and on-axis 3D PIC simulations (green curve) in the same configuration as in (a).

3. References

[1] K. Y. Kim, A. J. Taylor, J. H. Glownia, and G. Rodriguez "Coherent control of terahertz supercontinuum generation in ultrafast laser-gas interactions," *Nat. Photon*. **2**, 605 (2008).
[2] P. González de Alaiza Martínez, X. Davoine, A. Debayle, L. Gremillet, and L. Bergé, " Terahertz radiation driven by two-color laser pulses at near-relativistic intensities: Competition between photoionization and wakefield effects," *Scientific Reports* **6**, 26743 (2016).