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THz and far-infrared radiation from ionizing multi-color pulses

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Research on intense terahertz (THz) electromagnetic sources has received an increasing attention owing to numerous applications, for example, in time-domain spectroscopy, biomedical imaging or security screening [1]. Among the various techniques employed to generate THz radiation, focusing intense two-color femtosecond pulses in air or noble gases provides interesting features like absence of material damage, large generated bandwidth (up to ~ 100 THz) and high amplitudes of the emitted THz pulses (> 100 MV/m) [2]. First reported by Cook *et al.* [3], THz emission from intense two-color pulses was initially attributed to optical rectification via third-order nonlinearity. However, it was shown later that the plasma built-up by tunneling photoionization is necessary to explain the high amplitudes of the THz field [4, 5, 6], and a quasi-dc plasma current generated by the temporally asymmetric two-color field is responsible for THz emission [7, 8].

Here, THz emission in gases via ionizing multi-color femtosecond pulses is analyzed by means of semi-analytical models and finite-difference-time-domain simulations in 1D and 2D geometries. We find the emission in backward direction having a much smaller spectral bandwidth than in forward direction and explain this by interference effects. Forward THz radiation is generated predominantly at the ionization front and thus almost not affected by the opacity of the plasma, in excellent agreement with results obtained from a unidirectional pulse propagation model [9]. Moreover, we show that produced THz signals interact with free electron trajectories and thus influence significantly further THz generation upon propagation, i.e., make the process inherently nonlocal. This self-action plays a key role in the observed strong spectral broadening of the generated THz field in forward direction. Diffraction limits the achievable THz bandwidth by efficiently depleting the low frequency amplitudes in the propagating field.

References

- [1] M. Tonouchi. Cutting-edge terahertz technology. *Nature Photon.*, 1:97, 2007.
- [2] Ki-Yong Kim, James H. Glowina, Antoinette J. Taylor, and George Rodriguez. High-Power Broadband Terahertz Generation via Two-Color Photoionization in Gases. *IEEE J. Quant. Electron.*, 48:797, 2012.
- [3] D. J. Cook and R. M. Hochstrasser. Intense terahertz pulses by four-wave rectification in air. *Opt. Lett.*, 25:1210, 2000.
- [4] Markus Kress, Torsten Löffler, Susanne Eden, Mark Thomson, and Hartmut G. Roskos. Terahertz-pulse generation by photoionization of air with laser pulses composed of both fundamental and second-harmonic waves. *Opt. Lett.*, 29:1120, 2004.
- [5] H.G. Roskos, M.D. Thomson, M. Kre, and T. Löffler. Broadband thz emission from gas plasmas induced by femtosecond optical pulses: From fundamentals to applications. *Laser Photon. & Rev.*, 1:349, 2007.
- [6] K. Y. Kim, A. J. Taylor, J. H. Glowina, and G. Rodriguez. Coherent control of terahertz supercontinuum generation in ultrafast laser-gas interactions. *Nature Photon.*, 2:605, 2008.
- [7] L. Bergé, S. Skupin, C. Köhler, I. Babushkin, and J. Herrmann. 3D numerical simulations of THz generation by two-color laser filaments. *Phys. Rev. Lett.*, 110:073901, 2013.
- [8] A. V. Borodin, N. A. Panov, O. G. Kosareva, V. A. Andreeva, M. N. Esaulkov, V. A. Makarov, A. P. Shkurinov, S. L. Chin, and X.-C. Zhang. Transformation of terahertz spectra emitted from dual-frequency femtosecond pulse interaction in gases. *Opt. Lett.*, 38:1906, 2013.
- [9] C. Koehler E. Cabrera-Granado, I. Babushkin, L. Bergé, J. Herrmann, and S. Skupin. Directionality of terahertz emission from photoionized gas plasmas. *Opt. Lett.*, 36:3166, 2011.