Proposal for a bright single-cycle terahertz source based on gas cells irradiated by two-color laser pulses

S V Popruzhenko[1] *, T V Liseykina[2]

[1] Prokhorov General Physics Institute of the Russian Academy of Sciences, Moscow, 119991, Russia
[2] Institute of Physics, University of Rostock, 18051, Rostock, Germany

Synopsis We propose a scheme for efficient generation of ultrashort intense terahertz waves from a gas irradiated by two-color laser pulses. The scheme is based on the use of small gas-filled cells comparable in size to the terahertz wavelength. A superposition of the first and the second circularly polarized harmonic of intense infrared laser radiation excites coherent dipole oscillations of the ionization-prepared plasma in the cell. Strong radiative damping of these oscillations results in the emission of an intense single-cycle terahertz pulse.

A new method for the generation of intense few-cycle electromagnetic pulses in the terahertz (THz) frequency domain, based on ionization of gases by high-power bichromatic laser fields has been recently suggested and experimentally explored [1, 2, 3]. Coherent two-color laser pulses induce asymmetric ionization of a gas medium resulting in the excitation of strong photocurrents which emit broadband THz radiation. Within this method, using a superposition of the fundamental and the second harmonic of infrared (IR) lasers, record values of quasi-static electric fields with amplitudes up to 10MV/cm have been achieved [3]. Further increase of the IR-to-THz conversion efficiency is of demand for a number of applied and fundamental research.

Recently it has been shown in experiment [4] and theoretically [5] that application of circularly polarized (CP) fundamental and second harmonic may lead to a few-fold increase in the emitted THz energy, compared to conventional schemes with linear polarization. Ionization by CP pulses leads to a much larger value of the photoelectron drift momentum, so that even a small symmetry violation introduced by the second harmonic results in the excitation of a strong net photocurrent [5].

In order to find conditions maximizing the IR-to-THz conversion efficiency, we investigate the dynamics and radiation of electron ionization-created plasma within a simple analytic model and using 3D particle-in-cell (PIC) simulations with the ionization step included. We propose a setup which employs a small gas volume with size close to that of the emitted THz wavelength. We show that, in combination to CP radiation, this leads to the excitation of a highly coherent electron motion in the gas cell, so that all electrons of the target emit almost as a single particle of a high charge. For such system, the IR-to-THz energy conversion efficiency can be considerably enhanced up to values close to 10^{-3}, in contrast to 10^{-5} typical for the case when THz radiation is generated in ambient air or in a gas-filled chamber in the regime of filamentation. The highly coherent election motion leads to a very fast radiation damping of the plasma oscillations and therefore restricts the duration of a THz pulse almost by that of the driving bichromatic femtosecond laser pulse. As a result, extremely short single-cycle pulses with a broad spectrum located in the domain $0.1 \div 10$THz can be generated. Using a system of gas cells irradiated by a loosely focused CP mid-infrared bichromatic laser pulse, a high-brightness source of THz radiation of an ultrashort pulse duration can be constructed.

References

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*E-mail: sergey.popruzhenko@gmail.com