New Generating Schemes of Tunable Narrowband Terahertz Radiation in Plasmas by Femtosecond Laser Pulses

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In recent decades, the creation of powerful and tunable sources of terahertz radiation has become the field of active research in both laser and accelerator communities. The most significant progress has been achieved in generating high-field (up to 100 MV/cm) wide-band (single-cycle) THz pulses. The creation of high-power sources of tunable THz radiation with a narrow spectral line and high values of electric field is also highly demanded today, since it opens the way to different new problems in physics, chemistry, biomedicine and spectroscopy.

In this work, via the analytical theory and particle-in-cell simulations, we discuss several new compact schemes for the generation of tunable narrow-band THz radiation in a plasma by two counterpropagating femtosecond laser pulses. Our proposal is based on the following effect: superposition of laser-induced wakefields traveling in opposite directions along the coordinate x generates the nonlinear electric current which oscillates with the doubled plasma frequency and does not depend on the longitudinal coordinate. This current density does not vanish and can produce transversely propagating EM radiation if the transverse structure of the first plasma wave differs from the similar structure of the second wave ($E_1(y) \neq E_2(y)$). In experiments, this effect can be implemented either by using counterpropagating laser pulses focused into a gas (in a jet either in a glass tube) or by reflecting a single laser pulse from a plasma mirror.

The first theoretical estimates, in good agreement with simulation results, show that the joule-scale laser beams with the wavelength 800 nm are able to generate gigawatt terahertz pulses (20-30 THz) with the energy 1 mJ, electric field >10 MV/cm and the narrow linewidth (~1%). If the role of the driver is played by the 100 TW CO_2 laser, the power and energy of generated narrow-band THz pulses, according to this theory, can reach the level of 1 GW and 20 mJ even in the low-frequency range 1-5 THz.

Produced radiation is concentrated near the doubled plasma frequency and can freely escape from the plasma. Moreover, by changing the plasma density n_0, one can easily vary the radiation frequency in a wide range. The successful implementation of such schemes will allow to exceed the maximal energy of THz pulses achieved in the most powerful free electron laser by more than tenfold.