Generation of Terahertz and Infrared Relativistic Half-Cycle Pulses in Laser Pulse Interaction with Nanodimensional Targets

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Abstract—A method for generation of intense infrared and terahertz radiation during interaction of powerful laser pulses with nano-dimensional targets (nanofilms, nanowires, and nanoclusters) was proposed and studied. It was shown that the temporal profile of radiation strongly depends on laser pulse amplitude and duration, electron density of the target and its geometry. Particularly, half-cycle infrared or terahertz pulses can be generated. The parameters of radiation were derived such as polarization, frequency, amplitude, etc. It was shown that the amplitude of the radiation can be on relativistic level for modern petawatt laser systems.

Keywords—petawatt lasers, intense terahertz and infrared radiation, nano-dimensional targets

The idea for synchronous acceleration of electrons from nanofilms with a superintense nonadiabatic laser pulse was proposed for the first time in [1]. Then, characteristics of relativistic electron bunches were studied in [2]. A nonadiabatic laser pulse of relativistic amplitude incident normally at a nanofilm can induce a simultaneous motion of all electrons from the nanofilm in the longitudinal direction (along the laser beam axis) due to the light pressure force. This force accelerates electrons to relativistic velocities. As a result, a relativistic electron bunch with diameter of several micrometers and thickness of several nanometers and less can be formed and its electron density can be about solid target density. For relativistic electron bunch formation, the laser pulse amplitude should be larger than some threshold, which is determined by material and thickness of the nanofilm. This scheme has the following properties: only one electron bunch is formed; the charge of the bunch can be very large about tens of nanocoulombs; and the parameters of the bunch can be controlled easily by changing the parameters of laser pulse and nanofilm.

During interaction, ions of the target cannot move considerably from their initial position because of great inertia. Due to strong Coulomb field, relativistic electron bunch exists as a whole only during some interval of time which depends on system parameters. After that time, some electrons turn back and return to their initial position [1,2]. Because of gained velocity, they oscillate around the ions. However, for a nanofilm target with infinite transverse dimensions, radiation of an electromagnetic pulse during these oscillations is not effective.

In the paper, fast and strongly non-stationary processes are studied, which are characterized by considerable charge separation arising from interaction of superintense laser pulses with nano-dimensional targets such as mass-limited nanofilms, nanowires, and nanoclusters. In this case, radiated pulse can contain from a half-cycle to several cycles of oscillations and its frequency depends on the system parameters and can belong to the terahertz or infrared bands. The characteristics of infrared and terahertz radiation generated during these processes are studied. It is shown that the temporal profile of radiation strongly depends on laser pulse amplitude and duration, electron density of the target and its geometry. The parameters of radiation are derived such as polarization, frequency, amplitude, etc. It is shown that the amplitude of the radiation can be on relativistic level for modern petawatt laser systems.

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