Quantum-Mechanical Description of Ionization-Induced Generation of Tunable Mid-Infrared Pulses

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We examine a new method for generation of the coherent few-cycle mid-infrared pulses. The method utilizes the gas ionization by ultrashort incommensurate two-color laser pulses, which contain the fields at two different frequencies. One of the frequencies is detuned from the doubled value of the other one. Such incommensurate pulses can be obtained with the use of the nonlinear crystal or with the use of the optical parametric amplifier [1,2]. In previous works the radiating low-frequency currents excited by such pulses were calculated analytically and numerically on the basis of semiclassical approach [1-3]. It was shown that excitation of radiating mid-infrared electron currents can be understood as the ionization-induced wavemixing caused by response of mobile free electrons. Therefore, the duration of excited low-frequency current is much less than the laser pulse duration, and the central frequency of current can be controlled by tuning the frequencies of the optical field components.

In this work we calculate the electron current excited by the two-color pulse in a gas through the use of the analytical and numerical solution of 3D time-dependent Schrödinger equation. Analytical model is based on the strong-field approximation [4,5] for ionization dynamics. We calculate the dependences of spectrum and amplitude of low-frequency current on the intensities of laser pulse components and frequency of laser pulse components. We show that in the tunneling regime of ionization the obtained analytical results agree with the corresponding formulas [3] given by the semiclassical approach based on hydrodynamic equation for current density. In the multiphoton regime of ionization the spectrum of low-frequency current can differ significantly from the results given by semiclassical approach. The full-dimensional simulations based the solution of the 3D time-dependent Schrödinger equation support the results obtained from analytical model and confirm the possibility of employing the phenomenon for creating the tunable source of coherent few-cycle mid-infrared pulses.

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References