Probabilistic Approach in the Theory of the Laser Pulses – Matter Interactions

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A universal analytical approach has been proposed and developed in the theory of interaction of laser pulses with matter, within the framework of which photoprocesses induced by laser pulses are described in terms of probability for the entire duration of the pulses [1] or probability at the current moment in time [2]. This approach allows one to easily take into account the internal dynamics of the target and the characteristics of laser pulses (duration, carrier frequency, envelope and phase of the carrier envelope).

This method is used to describe various photoprocesses in the field of laser pulses of arbitrary duration, including ultrashort ones, namely photoexcitation, photoionization of various targets, as well as various types of radiation scattering (Rayleigh, Thomson, Compton, Raman and transition).

Simple analytical expressions are obtained that describe the probability of resonance photoprocesses for laser pulses with different envelopes and for different spectral resonance profiles of targets [3].

A number of characteristic features of photoprocesses in the field of ultrashort pulses have been established. In particular, it has been shown that the dependence of probability on pulse duration under certain conditions is nonlinear with extremes even in the case of a linear interaction mode in terms of radiation intensity. The developed method was used to determine the rate of the photoprocess under the action of a laser pulse, which was used to describe the kinetics of populations of atoms and ions in plasma [4]. It was shown that the traditionally used kinetic approaches based on the Einstein coefficients and the spectral cross section of photoexcitation, generally speaking, do not describe photoexcitation correctly, but are limiting cases of our universal approach in the ultrashort and quasi-monochromatic limits, respectively. The probabilistic approach was also used to describe the excitation of a quantum oscillator by laser pulses using the Schwinger formula [5] adapted for this case [6]. The oscillator damping was taken into account using a model approach in the spirit of Husimi's consideration [7]. The probability of photoexcitation of a quantum oscillator by laser pulses of various types was analytically and numerically investigated. In particular, the presence of two excitation modes, weak and strong, was established, for which characteristic features of the process were revealed [8].

We have shown that our expression for the probability of excitation of a microtarget by laser pulses transforms into a well-known formula for the energy dissipation of a non-monochromatic electromagnetic field in a dispersive medium [9]. In our approach, we have described the energy transfer from a laser pulse to a medium in terms of the total absorption coefficient and analyzed the dependences of this quantity on the pulse parameters and the characteristics of the medium [10].

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