Modelling of Laser Induce Optical Breakdown in Skin

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Beside scientific, focused femtosecond pulses are widely used in medical applications. At the same time, it is shown that this application can cause a significant danger for (to) the skin, eyes and other organs. Because of that it is important to mark all relevant mechanisms and parameters which influence it and, depending on the application form and for a given matter, optimize the conditions.

Interaction of laser with matter resulting in a variety of non-linear processes, such as photoionization (tunnel and multiphoton), photon absorption, as well as laser induced optical breakdown (LIOB). We consider the LIOB related to skin (nowadays, there is an increasing interest and demand for different laser applications in skin, ranging from tissue engineering to drug delivery) that occurs when a threshold density of ejected photoelectrons is reached, which leads to plasma generation by different mechanism of ionization, followed by explosive vaporization and mechanical expansion in the dermis.

Rate equation models for describing the electron's density evolution during laser matter interaction are mostly based on the Keldysh approach which showed that both, multiphoton and tunneling, photoionization processes could be described within the same framework. To improve existing model, we introduced new one and considered photoionization rate as a cumulative contribution of tunnel and multiphoton rate. To describe tunnel part we employed the Landau Dykhne approach which takes into account the initial and final conditions on the way that include numerous relevant processes and with intention to include as much as possible relevant conditions (depending on body location, skin type, body weight, hydration level, age, sex and ethnicity, skin properties, such as thickness, can vary considerably). We considered different processes, such as avalanche (cascade) ionization, recombination, recollision, thermal ionization and diffusion losses, what allow us to observe time evolution of free electron density, $d\rho_c/dt$ as a sum of each particular process, $d\rho_c/dt = \sum_i (d\rho_c/dt)_i$, $n = 0,1,2$.

Additionally, it is shown that different irradiation geometries significantly influence the whole interaction process, as well as, pulse duration. We analyzed these parameters in order to optimize them for laser's practical applications.

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