Fyzikální ústav AV ČR, v. v. i.
Na Slovance 2
182 21 Praha 8
hilase@fzu.cz
www.hilase.cz

Oddělení diodově čerpaných laserů, sekce výkonových systémů,
a realizační tým projektu HiLASE
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Pulsed laser - matter interaction for material processing: Basic processes and perspectives

Prof. Nadezhda M. Bulgakova, PhD, Dr.Sci.

Institute of Thermophysics SB RAS, 1 Lavrentyev Ave., 630090 Novosibirsk, Russia
Optoelectronics Research Center, University of Southampton, SO17 1BJ, United Kingdom

Vaporization of solid materials by laser light (laser ablation) has proved to be an important technique for fundamental research and different industrial applications. When laser light couples a solid target, it is absorbed and, starting from a definite fluence threshold, it can melt material, modify it chemically, and vaporize that is already widely used in different technologies for surface cleaning, hardening, patterning, and hole drilling. In the cloud of the ablation products, expanding in vacuum or ambient gas, cluster formation takes place through the condensation process that is used for new nanomaterial production. Femtosecond laser pulses provide unique possibilities for high-precision material processing. Due to rapid energy delivery, heat-affected zones in the irradiated targets are strongly localized with minimal residual damage that allows generation of well-defined microstructures with high quality and reproducibility. Understanding of underlying physics and interrelations of the processes taking place in materials irradiated by laser pulses of different duration may facilitate optimization of experimental parameters in current applications and development of contemporary pulsed laser technologies.
In this talk, the complexity of the interrelated processes involved in laser-matter interaction will be analyzed and a number of theoretical models will be presented which have been successfully applied to describe response of different materials to short and ultrashort pulse laser irradiation. Potentials of the thermal model in its one- and two-temperature forms will be discussed with its development to the case of multi-component materials. A unified continuum model developed for studying laser excitation and charge-carrier transport in metals, semiconductors, and dielectrics

exposed to femtosecond laser radiation will be described with its advantages and limitations, time and length scales of its application, and its modifications for different classes of materials and to the other time scales. One of its extension is a two-dimensional model of surface layer breakdown in wide-band-gap dielectric materials which has made possible to uncover mechanisms that enable the spatial modulation of the surface structures induced by temporally modulated laser pulses. A combined thermal/elasto-plastic model will be presented which has allowed uncovering the mechanisms and dynamics of laser-induced microbump and nanojet formation on nanosized metal films. A novel modeling approach will be demonstrated which has been developed for studying the spatiotemporal dynamics of ultrashort-laser-induced modifications inside transparent materials. The approach is based on Maxwell's equations for describing laser light propagation through a dielectric sample and light absorption in the focal volume and on the equations of thermoelastoplasticity for simulating laser-induced material heating and expansion/compaction dynamics. The processes in the laser ablation products will be analyzed which govern gas-phase nanoparticle formation and pulsed laser deposition. A special attention will be given to the laser-induced chemistry whose role is now underestimated but which can control material modification upon laser irradiation of solids in chemically active environment and even in the bulk of transparent materials.

Finally, some possible experimental arrangements will be discussed which could be perspective for new laser applications.

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