Dynamics of laser-ablation plumes of multicomponent materials: Effects of ambipolar field and non-congruent vaporization

N. M. Bulgakova and A. V. Bulgakov

HiLASE Centre, Institute of Physics ASCR, Za Radnicí 828, 25241 Dolní Břežany, Czech Republic
bulgakova@fzu.cz, bulgakov@fzu.cz

Short and ultrashort pulse laser ablation of solids is a complicated phenomenon which involves a wealth of processes triggered by laser light in the condensed matter as well as in the vapor phase if pulse duration is long enough to induce material vaporization already during irradiation. Analyses of laser plume expansion by time-of-flight diagnostic techniques and high temporal resolution imaging give valuable information on the conditions produced by laser irradiation in the irradiated material. However, many of laser-triggered processes are strongly interdependent that make difficult to separate influences of different processes and hence to understand the physics of particular effects.

In this seminar, we will focus on two processes, which considerably affect the expansion dynamics of multicomponent plume species, development of an ambipolar field in the plume and non-congruent laser-induced vaporization. Although both processes play significant roles in the development of the velocity distributions of the plume components, their importance is not well understood and is often disregarded. We will outline the physics of these processes, their manifestations at different irradiation conditions, and dependence on material properties. Ambipolar field effects will be demonstrated on the case of single-component materials such as silicon and carbon. It will be shown that often ion acceleration in the ambipolar field, which is rather a universal phenomenon of laser ablation, is confused with so-called Coulomb explosion, which can take place in some materials under specific irradiation conditions. Effects of non-congruent vaporization will be illustrated by the examples of ablation of binary semiconductors (CdTe, ZnO, InP) and Ag-Au alloy. It will be demonstrated that this ablation regime strongly modifies the particle time-of-flight distributions and even a small difference in volatilities (or a small delay in vaporization of different components) can affect dramatically the plume component velocities.