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Ultra-short double pulse laser ablation: basic mechanisms and nanoparticle formation

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Laser ablation is the process of material removal from a target surface by intense Laser radiation. The technique is used for the production of nanoparticles (NPs) and associated thin films, micromachining of surfaces, and Laser-induced breakdown spectroscopy (LIBS) for material analysis. The amount of ablated material, sample heating, plasma properties (density, temperature, and luminosity) and properties of the generated NPs (size distribution, shape, crystallinity, and magnetic order) depend on material, Laser fluence, and Laser pulse shape. Using numerical simulations, we study the influence of the delay of ultra-short double Laser pulses on the ablation process elucidating the underlying mechanisms and identifying promising conditions for applications. This work focuses on aluminum as a generic example and a widely investigated material in Laser ablation.

The wide range of time and length scales involved in Laser ablation is challenging for both experiment and simulation. We follow a hybrid two-temperature model (TTM) and embedded atom method (EAM)-based molecular dynamics (MD) approach, which offers a simple but realistic description of metallic interactions and electronic properties for systems containing several million atoms over nanosecond timescales. The TTM is based on the heat equation for electrons with the Laser as a source term. The energy of hot electrons is then transferred to the MD subsystem via an electron-phonon coupling term.

The effect of double pulse delays in the range of 1-200 ps on the mechanisms active during the different stages of ablation is revealed using thermodynamic pathways analysis. Furthermore, the NP size distribution is monitored as a function of pulse delay. This study contributes to an explanation of the trends observed in double pulse ablation with respect to ablation efficiency and NP formation. Validation against available experimental results is also attempted.

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