Early motion of matter observed by ultrafast transient studies of reflectivity and absorption

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ABSTRACT

Ultrashort pulsed lasers offer a high potential for precise and efficient material processing. A deep understanding of the fundamental laser-material interaction aspects is of great importance to optimize laser processes for industry. The transient pulse reflectivity in conjunction with the transient absorption decisively influences the laser-material interaction. We present a unique pump-probe ellipsometry measurements allowing the determination of the transient complex refractive index of laser irradiated materials. Measurements were performed on industrial relevant metals (Al, Cu, stainless steel and Molybdenum) at laser fluences near the ablation threshold. A simulation including an accurate description of optical, thermal and thermomechanical properties is predicting the measured refractive index n and extinction coefficient k on copper. A comparison between measured time-resolved optical properties and results of the simulation reveals underlying physical mechanisms in the first 20 ps. The overall transient behavior shows that the mechanical motion of the material is starting already in the first picosecond after the pump pulse, when the electron temperature and thus the heating rate of the lattice are at their maximum. This early motion of matter could be responsible for the main contribution of the ablation efficiency decrease with increasing pulse duration or double pulse delay, which many research groups had previously observed. The here presented results provide a deeper understanding of laser ablation. This knowledge is inevitable for further improving laser ablation efficiency and quality for bulk materials and thin films.