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Ablation-cooled material removal with ultrafast bursts of pulses

F. MER ILDAY, Department of Electrical and Electronics Engineering, Bilkent University, Ankara, Turkey, C. KERSE, H. KALAYCIOGLU, P. ELAHI, Department of Physics, Bilkent University, Turkey, S. YAVAS, FiberLAST, Inc., Ankara, Turkey, D. KESIM, . AKAALAN, Department of EEE, Bilkent University, Turkey, B. ETIN, Department of Mechanical Engineering, Bilkent University, Turkey, B. KTEM, Department of Physics, Bilkent University, Turkey, M. ASIK, Nanotechnology and Nanomedicine Department, Hacettepe University, Turkey, H. HOOGLAND, R. HOLZWARTH, Department of Physics, University of Erlangen-Nuremberg, Germany — Use of femtosecond pulses allows precise and thermal-damage-free material removal with broad applications. However, its potential is limited by low material removal speeds and complexity of the required lasers. The laser complexity arises from the high pulse energy threshold for ablation. Physics of the laser-material interaction precludes a straightforward scaling up of the removal rate by using more powerful lasers due to shielding and collateral damage from heat accumulation. Here, we exploit ablation cooling, a technique used in aerospace engineering since 1950s, to circumvent this limitation. We apply rapid successions of pulses from specially developed lasers to ablate the target material before the residual heat deposited by previous pulses diffuse away from the interaction region. This constitutes a new physical regime of laser-material interactions, where heat removal due to ablation is comparable to conduction. Proof-of-principle experiments demonstrate reduction of required pulse energies by 1000x, while simultaneously increasing efficiency and speed by 10x.

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