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(I) Plasma persistence, absorption and scattering: what physics governs burst-mode ultrafast laser-materials interaction?

Tuesday 20 June 2023 13:15 (30 minutes)

Burst-mode ultrafast laser-materials treatments use high-repetition-rate (>MHz) delivery of femtosecond laser pulses. This takes advantage of characteristically tiny residual heat left in a substrate through individual femtosecond-laser-matter interaction. At the same time, the approach opens the door to manipulating the accumulation of that same tiny heat from rapid repetition. This mode of fluence-delivery can, for instance, transition brittle materials like glasses to ductile states, then cut aggressively while ductile and not susceptible to fracture, before the material naturally returns to its brittle state.
In solid dielectrics, isolated sub-picosecond laser pulses first create a limited plasma from nonlinear ionization, then they increase that plasma through collisional ionization. Used in burst-mode, the hypothesis is that some residual ionization persists for a few nanoseconds, meaning that subsequent pulses need not re-initiate dielectric breakdown. Instead, they see linear absorption in a state comparable to a metal or semiconductor. In effect, the plasma is 'simmered'continuously throughout a burst, controlling the mode and amount of absorption.
We report studies of the persistence of the plasma state in fused silica within a burst of ˜60 pulses, each of 300 fs duration, arriving with an intra-burst repetition rate of 200 MHz (5ns separation). We measure – pulse-by-pulse during the burst – the partition of energy into specular scattering, diffuse scattering, transmission through the sample, and absorption of laser energy. With this, we determine the decay of the plasma created by one pulse, until the arrival of the next pulse 5 ns later, and we characterize the subsequent re-growth of the plasma.
In this picture, the absorption of any given pulse depends on the recent history of irradiation. The material response is therefore non-local in time, which we can then frame as a material susceptibility that depends on the frequency of the intra-burst repetition rate.

Keyword-1

burst-mode

Keyword-2

laser-matter interaction

Keyword-3

materials processing

Author: MARJORIBANKS, Robin S.

Co-authors: Mr GHARABAGHI, N. (University of Waterloo); Mr VEEVERS, C. (University of Toronto); Ms KING, A. (University of Toronto); Mr TANG, J. (University of Toronto); Mr COULTER, L. (University of Toronto); Dr KALAYCIOGLU, H. (Bilkent University); Dr YAVAS, S. (Lumos Laser Inc.); Ms GORKEM, S. (Lumos Laser Inc.); Prof. ILDAY, F.O. (Bilkent University)

Presenter: MARJORIBANKS, Robin S.

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