Importance of second laser pulse duration in transient and selective laser processing

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Femtosecond laser processing has attracted significant attention for glass micromachining. However, issues such as crack formation and low processing efficiency remain challenges. Recently, a novel transient and selective laser (TSL) processing has been developed, enabling crack-free, high-precision, and ultrafast material removal [1]. This method utilizes an ultrashort laser pulse to generate a transiently excited electronic region, followed by irradiation of a second laser pulse with a relatively longer pulse duration, selectively absorbed to achieve efficient processing. However, the influence of the pulse duration of the second laser pulse on the processing characteristics remains unclear. Therefore, this study aims to evaluate the importance of the second laser pulse duration.

In this study, a numerical simulation of TSL processing was developed, primarily focusing on thermal aspects. As initial conditions, the absorption coefficient and temperature distribution were estimated based on the electron density distribution measured by the pump-probe experiment. The simulation was based on the heat conduction equation, calculating thermal diffusion, reflectivity and temperature rise due to the absorption of the second laser pulse. The absorption coefficient was dynamically updated at each time step using theoretical temperature-dependent equation, allowing for an iterative progression of the simulation.

The simulation results are shown in Figure 1. The numerical simulation reveals that the pulse duration of the second laser pulse significantly affects absorption efficiency and processing performance. In the nanosecond range, the high reflectivity of the laser prevents sufficient energy absorption within the material, leading to low processing efficiency. When the pulse duration exceeds several hundred microseconds, the supplied energy is diffused, falling below the absorption threshold of the material, making laser absorption insufficient. The results show that the optimal second pulse duration is in the microsecond range, where absorption efficiency is maximized, allowing for effective energy transfer.

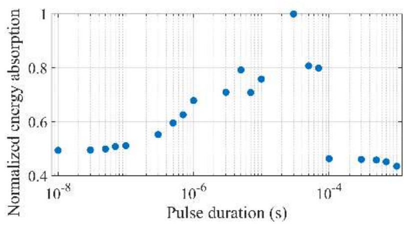

Figure 1: Dependence of energy absorption on second pulse duration

Future experimental validation will confirm the accuracy of the simulation results and further refine the optimal processing conditions.

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References:

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