GRADUATE STUDENT RESEARCH SEMINAR SERIES (2017)

NUMERICAL INVESTIGATION OF ULTRASHORT LASER INTERACTION WITH DIELECTRIC MATERIALS

SPEAKER: XIAO JIA

The industrial demand for the processing of dielectric materials is increasing rapidly, such as the cutting, drilling, and marking of glass, diamond, sapphire, etc. However, it is a challenge for traditional manufacturing methods due to the material high brittleness and hardness. It is also very difficult for general laser processing, because of the transparency of the materials in visible and near-infrared wavelength range. The advance in ultrashort laser technologies provides a promising solution. The ultrashort laser pulses have high enough laser intensity to trigger multi-photon ionization, which enables the processing of dielectric materials even with long wavelength. Due to its advantages in small heat-affected zone, high precision, and high flexibility, it has great potential in high precision micromachining of dielectric materials, such as the fabrication of micro-fluidic devices, waveguides, micro-sensors, etc. To improve its applications, it is essential to understand the fundamental laser-matter interaction mechanisms and material removal behaviors.

Numerical study of ultrashort laser-induced ablation of dielectric materials is presented based on a one dimensional plasma-temperature model. Plasma dynamics including photoionization, impact ionization, relaxation and electronic diffusion are considered through an improved single-rate equation. Material decomposition is captured by a temperature-based ablation criterion. Dynamic description of ablation process has been achieved through instant material removal. Behaviors of laser-induced ablation threshold, transient optical properties and ablation depth have been investigated with respect to incident fluence and pulse duration. Good agreements are shown between numerical predictions and experimental observations. Fast increase of ablation depth, followed with saturation, is observed with the increase of the incident fluence. The ablation efficiency decreases with fluence after reaching the peak value at the fluence twice of the ablation threshold. Material processing at low laser fluence and ultrashort pulse duration is proved to be able to provide higher ablation efficiency and reduced thermal damage. The divergence of tightly focused Gaussian beam in transparent materials has been revealed to significantly affect the ablation process, particularly at high laser fluence. This effect is found to be negligible in laser processing of metals.

MONDAY, NOVEMBER 6 AT 3:00 PM

EIB 132