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Theory of controlling avalanche process of carrier in short pulse laser irradiated dielectrics

Short pulse lasers (<10 ps) are used routinely for the investigations of high peak-power laser-matter interactions, such as laser micromachining [1-2], laser-driven accelerators, ultrafast dynamics in atoms and solids, and laser modulation spectrum in solids. However, laser-induced damage (LID) in optical components is still a limiting factor for the development of higher power laser systems and optical devices[3]. For decades, LID of dielectrics has been extensively studied by numerous theoretical and experimental methods. It is agreed that the generation of conduction band electrons (CBEs) in solids plays a critical role of LID and the damage threshold is determined by the density of CBEs for short pulse laser[4]. There are two processes to generate the CBEs in a solid. One is the valance band to conduction band photon ionization process and the other is avalanche process. Avalanche process is usually the dominant process for the generation of CBEs as the pulse width is not ultra-short (>100 fs). Thus, if the avalanche is effectively suppressed, the damage threshold of solids will be dramatically improved. In this work, a theory for controlling avalanche process of carrier during short pulse laser irradiation is proposed. The theory provides a way to suppress avalanche process and a direct judgment for the long existing debate about the dominant channel in generation of CBE for ultra-short pulse (<100 fs) in fused silica (some previous reports such as Refs.5 showed that the avalanche process is a dominant channel for the generation of CBE; whereas, some other reports such as Refs.6 showed that photon ionization process is dominant channel). The obtained temperature dependent rate equation shows that the laser induced damage threshold of dielectrics, e.g., fused silica, increase nonlinearly with the decreases of temperature. Thus present theory predicts a new approach to improve the laser induced damage threshold of dielectrics.

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Primary author(s) : Prof. YUAN, Xiaodong (China Academy of Engineering Physics)

Co-author(s) : Prof. DENG, Hongxiang (University of Electronic Science and Technology of China); Prof. ZU, Xiaotao (University of Electronic Science and Technology of China)

Presenter(s) : Prof. YUAN, Xiaodong (China Academy of Engineering Physics)