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Research progress of ultrafast laser industrial applications based on filamentation

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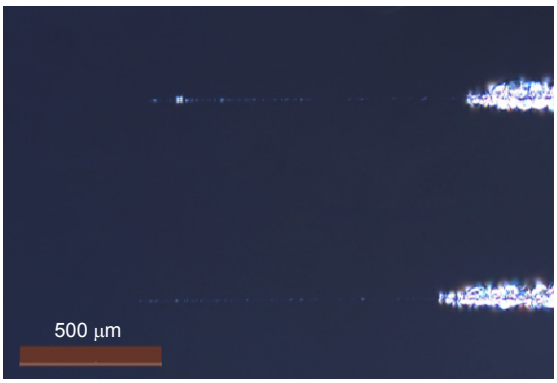

Filamentation in sapphire irradiated by picosecond laser.

Abstract: The research progress of ultrafast laser industrial application based on filamentation effect is introduced. Ultrafast laser filamentation is an attractive nonlinear phenomenon as a consequence of dynamic balance between Kerr self-focusing and defocusing effect in the electron plasma generated through the ionization process. It has been observed for various laser wavelengths from the ultraviolet to the infrared domain and for the pulse durations from several tenth of femtosecond to picosecond. The optical intensity in the filamentary volume can become high enough to induce permanent structural modifications which can be utilized in material processing with high precision and some special features. The basic characteristics and the theoretical modes of the filament propagation were described briefly for better understanding the effect. However, the main emphasis of the paper is on the laser industrial application from filamentation effect which is found as a promising and exploring research field in recent years. To achieve non-diffractive ultra-long transmission of filament propagation will play an important role in the development of the novel ultrafast laser material processing technology. From the physical feature, basic mechanism and characteristic advantages of filamentation effects, the representative research achievements on the laser applications of filamentation induced in gas, liquid and solid different media were presented. It is demonstrated that laser filamentation induced in gas provides high intensity plasma strings of micrometric diameters and lengths of tens of centimeters which can achieve remotely drilling, cutting and milling of metals, biological materials, ceramics and single crystal (sapphire). Complex 3D shapes can be machined without any adjustment of the technique because the processing is carried out under defocusing condition. Micromachining techniques of cutting and welding by water acting as a medium for filament formation were introduced afterwards. Filament formation in water leads to decrease of the focal spot diameter and increases of fluence and axial focal length, which is capable of drilling holes in thick soda-lime and hardened glasses, even for complex –shape fabrication. Filament formation at the interface of two glass samples was also used for welding applications. By varying repetition rate, scanning speed and focal position optimal conditions, strong glass welding via filamentation were obtained. The development problem and prospect of the technique were also considered and discussed. Ultrafast laser processing using filamentation must be a versatile technique in the future industrial material machining because the material modification is initiated by nonlinear absorption with the advantages which is quite different from common ablation.

Keywords: ultrafast laser; filamentation; transparent material; laser material processing

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