Precision high-aspect-ratio processing of glass by a temporally shaped ultrafast laser

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Due to the high intensity and the small heat-affected zone, ultrafast lasers have been widely used for the microprocessing of transparent hard and brittle materials [1]. However, severe cracks are generated around the processing regions [2], which degrades the precision and makes the application limited. In recent years, several methos have been proposed to improve processing precision, including the GHz burst mode ablation [3], transient and selective laser processing method [4], and liquid-assisted processing [5]. Nevertheless, these methods have either expensive equipment or complicated setups.

In this study, we achieve crackless precision microprocessing by temporally shaping an ultrafast laser [6]. The experimental setup is shown in Fig. 1(a). An ultrafast laser with a pulse duration of 5 ps is split into two sub-pulses (P1 and P2). P1 is directly delivered to the silica glass sample for electron excitation, while P2 is temporally stretched to approximately 300 ps using a CVBG, then used to heat the electrons and achieve material removal. After 3000 pulses from the laser source, numerous cracks form on the side walls in conventional single-pulse processing, as shown in Fig. 1(b). However, using the proposed method, crack formation is nearly eliminated, as seen in Fig. 1(c). Furthermore, the hole depth increases by more than 3.3 times, and the aspect ratio is improved by at least 2.2 times. This technique offers a novel approach for the fabrication of high-aspect-ratio holes in transparent materials.

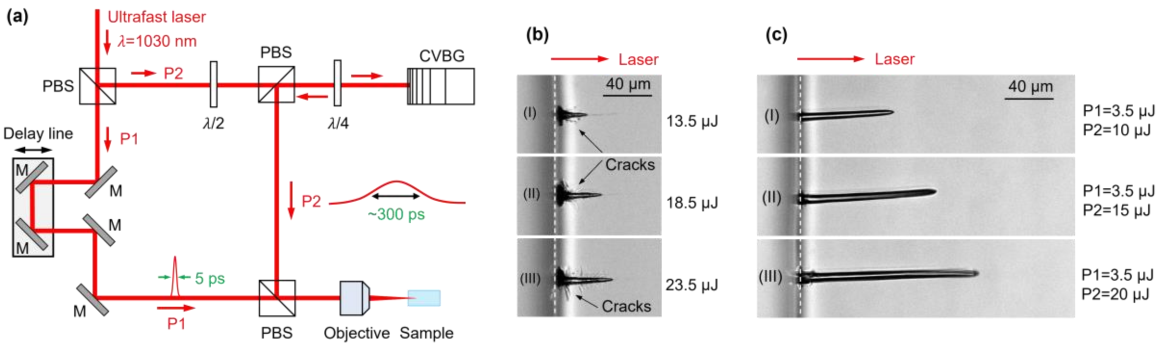

Fig. 1 (a) Experimental setup. PBS: polarizing beam splitter; CVBG: chirped volume Bragg grating; M: mirror; λ/2: half waveplate; λ/4: quarter waveplate. (b) Conventional method. (c) Proposed method.

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