High-aspect-ratio elliptical nanochannels for ultrafast laser stealth dicing of glass

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Stealth dicing is a laser separation method for transparent materials, which generates virtually no debris. A single-pass laser illumination generates a weakened plane in the material's bulk. Then, a weak bending yields cleaving: a fracture is guided along the weakened plane, which separates the material in two parts. The weakened plane can easily and quickly be written using ultrafast laser pulses that allow for a precise energy deposition in the material bulk thanks to the confinement of the highly non-linear interaction [1]. Stealth dicing has been reported using filamentation, offering energy deposition along extended depth [2]. Non-diffractive beams such as Bessel beams provide an even better energy deposition control. Nanochannels series with few microns pitch have indeed shown to be great candidates for stealth dicing applications [3].

However cylindrically-symmetric channels do not induce a well-confined stress distribution when the workpiece is bended (fig 1.a). In this case, cleaving does not follow precisely the laser machined plane as one can observe from fig 1.d. To solve this problem, we have developed a novel elliptical nondiffracting Bessel beams that create channels featuring elliptical cross-section.

The beam has been developed from spatial filtering of a Bessel beam (fig 1.c) and preserves the non-diffracting properties [4]. Using such beam for single-shot ablation allows for generating nanochannels that exhibit both >200 aspect-ratio and 2:1 elliptical cross-section (fig 1.f). The elliptical cross-section oriented along the processing axis enhances and confines the stress at ellipse vertices (fig 1.b). Here we report a sub-micron stealth dicing precision (fig 1.e) along the whole sample 20 mm length and 150 µm depth. In addition, we demonstrate with 3 line-bending measurements that elliptical nanochannels strongly improve cut glass cleavability and resistance in comparison with cylindrically-symmetric laser illumination [5].

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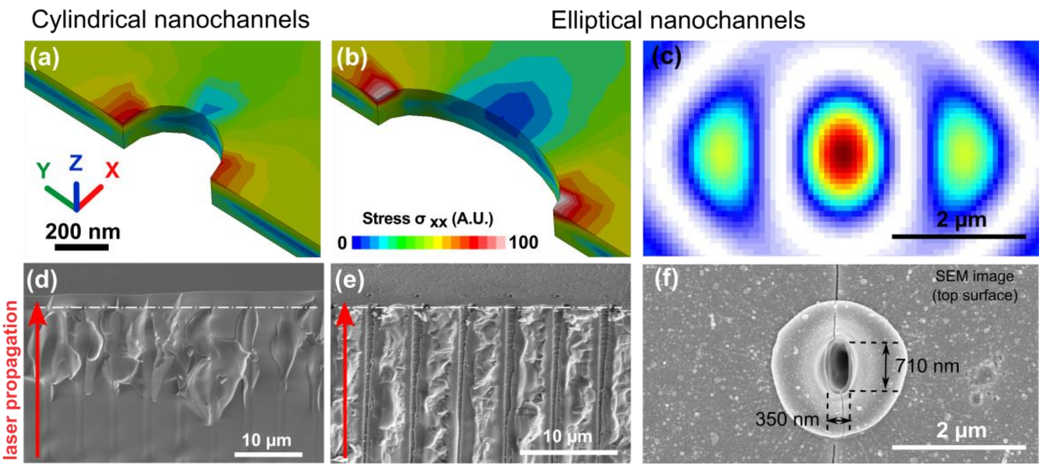

Figure 1: Finite Element Method simulation of stress distribution around nanochannels for (a) cylindrical and (b) elliptical cases. (c) shows the laser beam intensity cross-section at its maximum intensity (simulation). Scanning electron microscopy allows for side view of sample cleaved edges (d,e) and top surface (f) investigations. Red arrow represents beam propagation direction and white dashed line stands for the laser-processed line.

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