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Precision laser cutting of glass for industrial applications in 2 & 3D

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Abstract

The increasing demand of fast cutting solutions for complex shapes on a variety of transparent and brittle materials in consumer electronics, automotive and semiconductor industry can be successfully addressed by laser cutting technology. A stable optical confinement (proven in 24/7 production) can be realized by the presented approach based on non-diffractive beams and the use of ultrashort pulsed lasers. The nonlinear interaction induces a localized material modification rather than material removal like ablation processes, resulting in very high quality laser cuts. Trends in automotive interior design and function are calling for 3D shaped glass. The use of laser will significantly improve the way 3D formed parts are being processed as laser cutting by itself is contactless and offers outmost flexibility. Most recently Corning's unique zero gap process for freeform laser cutting was expanded towards 3D cutting of glass, showing promising results and fulfilling the requirements for industrial implementation.

Keywords: Laser cutting of glass; ultrafast non-diffractive beam; ultrashort laser material processing

1. Introduction

Laser cutting can successfully address the high demand for fast and precise cutting solutions in industry, for example automotive, consumer electronics and semiconductor industries. Compared to mechanical methods or alternative laser cutting approaches Corning's NanoPerforation technology features numerous advantages: Generally laser cutting methods allow to directly cut complex geometries with a clean process for strengthened and un-strengthened glass as well as other transparent and brittle materials. In terms of

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chipping and edge strength highest quality is obtained. It is important to distinguish the individual laser cutting technologies.

One approach reported in the literature by e.g. Iri (2005), Okuma (2011), Bovatsek (2014) or Zühlke (2015) is so called multipass focusing. Here, focusing the laser inside the material in a way to achieve a critical energy density above the modification threshold leads to locally confined cracks in the focus point. Multiple passes are necessary in order to perforate the whole sample. Consequently this results in a very low processing speed in combination with a non-uniform cross section and often a reduced edge strength.

One possibility to increase the processing speed is to reduce the necessary number of passes by applying intensities that generate the Kerr-effect inside the material and to modify the material in an elongated region. In literature it is often referred to as filamentation by e.g. Hosseini (2012). Unfortunately the nonlinear Kerr-effect is strongly depending on material properties and chosen intensities and thus challenging to control. Corning's NanoPerforation technology is based on non-diffractive beams and combines the advantage of single pass processing (up to 2 mm) with being significantly less sensitive regarding material properties. Using a non-diffractive beam provides industrial robust machining with a standardized optic to cut a broad variety of glasses that is proven in 24/7.

A growing need for 3D shaped glass for design trends in automotive interior and consumer electronics can be successfully addressed by laser cutting as laser cutting by itself is contactless and offers outmost flexibility. Corning's unique zero gap process for freeform laser cutting was advanced towards 3D cutting of glass, showing promising results and fulfilling the requirements for industrial implementation.

2. Material and methods

A specially tuned ultrashort laser is used to generate the non-diffractive beam in propagation direction to perforate brittle material. This leads to direct material detachment via non-linear processes, rather than material removal, typically over the complete thickness of the glass. Consequently this results in a very high cut quality, compared to mechanical or alternative laser-based cutting methods, for example ablation or cracks induced by sharp focusing. Near net-shape cutting without a taper and with minimal material loss or debris at highest uniformity is possible by moving the laser beam and/or the substrate. The glass substrate is modified all the way through the entire thickness, applying the single pass process for glass thicknesses up to ~ 2 mm in 2 dimensions.

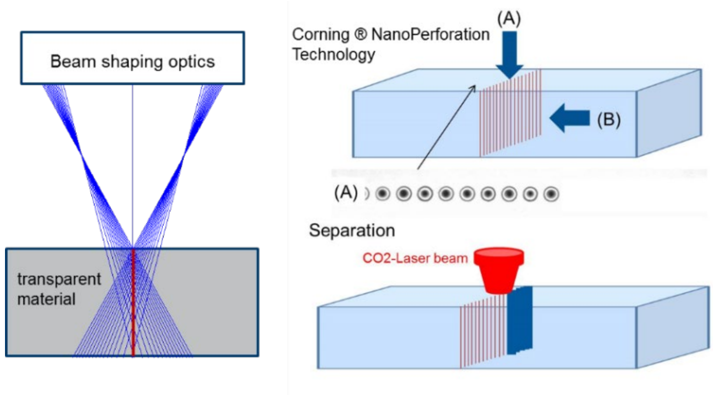

Fig. 1. Optical setup to generate a non-diffractive beam in propagation direction of the laser (left). Scheme of the Corning® NanoPerforation process (upper right) and the thermal separation process (lower right).

Figure 1 illustrates the generation of the non-diffractive beam in propagation direction with a special beam shaping optics of the laser beam, including the interaction with the transparent material (left) and the Corning® NanoPerforation process (upper right). A second process step is necessary where mechanical or thermal stress leads to a separation of the perforated contour for un-strengthened glass, e.g. using a CO_2 laser (see Fig. 1 lower right). The perforated contour releases independently within a few seconds for chemically strengthened glasses, due to the internal stress.

As oversized glass is needed for 3D hot forming an accurate trimming solution is required. Extending the NanoPerforation process towards 3D Cutting enhances the flexibility, the tool life time and offers a faster tact time compared to mechanical approaches.

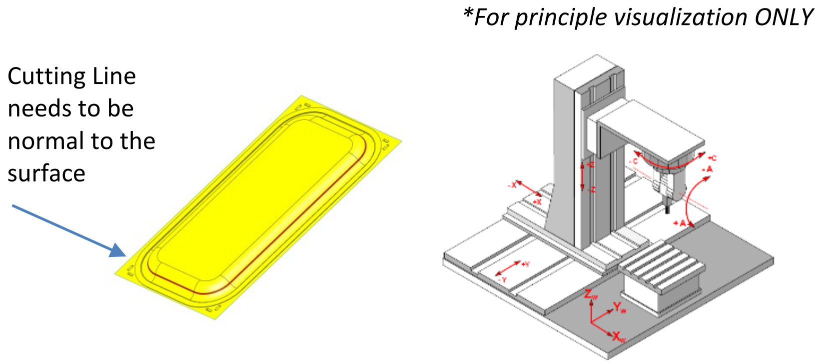

Fig. 2. Optical principle for 3D cutting: cut line needs to be normal to the surface (left). Visualization of the mechanical principle (right).

Figure 2 presents the optical principle for 3D cutting, where the cut line needs to be normal to the sample surface (left) together with a visualization of the mechanical principle (right). With this approach material thicknesses up to ~ 1.5 mm can be perforated in a single pass. Possible velocities of up to ~ 1 m/s in x,y,z direction in 2D space for straight lines and an angular velocity of up to ~ 500 ms for a 90° rotation can be realized.

3. Results

A wide selection of transparent and brittle materials can be cut with the above presented approach. Typical example (but not limited to) are Corning® Gorilla® Glass (strengthened / un-strengthened), Corning®Lotus NXT®, EagleXG ®,High index glass, Soda lime glass, Ultra-thin glass and Sapphire. Figure 3 shows representative cutting results for complex inner (1st column) and outer contours (3rd & 4th column). The second column presents a 3D part cut by Corning® glass cutting technology.

Fig. 3. Inner (1st column) and outer (3rd & 4th column) contours generated with the Corning® glass cutting technology. The second column presents a 3D part cut by Corning® glass cutting technology.

These can be realized with high accuracy and pristine edge quality at high cutting speeds up to 1 m/s (straight lines). The use of ultrashort lasers leads to low thermal interaction with the material, as the pulse duration is significantly smaller than the thermal diffusion time. Consequently the zero-gap cutting approach from Corning® facilitates very smooth edges, showing only minimal chipping and basically no material removal.

A more detailed micrograph of the cross section and cutting edge of Corning® alumino-silicate glass is presented in Figure 4 (left). The right part of the Figure shows a picture of 3D shaped part after being cut (middle & upper right) and the corresponding cross section (lower right).

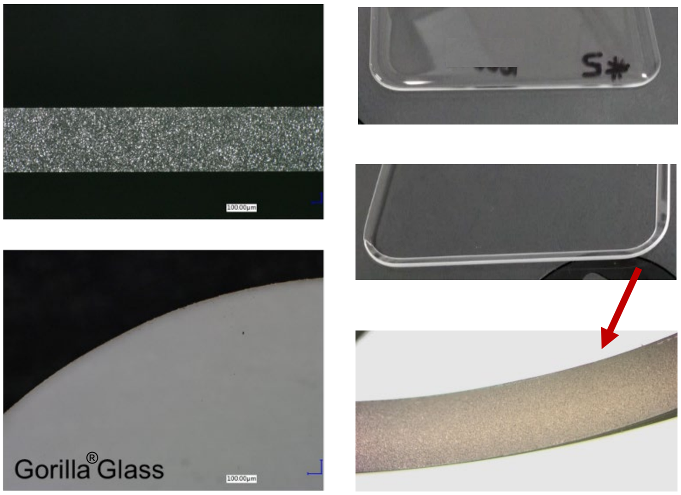

Fig. 4. Cross section (optical micrograph) of Corning® Gorilla® glass (upper left) and laser entrance side (lower left). Picture of 3D shaped part (middle & upper right) and the corresponding cross section (lower right).

4. Summary

Great customer benefits like flexible cutting of complex geometries of stengthened and un-strengthened glass can be fulfilled by the presented Corning® glass cutting technology in 2 & 3 dimensions. Realizing a clean cutting process with minimum to no debris generation at a high throughput and yield for industrial 24/7 production is a further advantage. Generally this method is used for products with thicknesses up to ~ 2 mm with a single pass in 2 dimensions and up to ~1.5 mm for 3D shaped parts. It is applicable on a wide selection of transparent and brittle materials (e.g. display glasses, glass for automotive, consumer electronics, sapphire). This new technology successfully demonstrates a high degree of automation combined with a low cost-of-maintenance in production, as no fluids or consumables are required. The very high cut-quality offers an additional benefit in a number of applications: postprocessing can be omitted.

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