10th CIRP Conference on
Photonic Technologies [LANE 2018]

Industrial Paper

Precision laser cutting of glass in industrial applications.

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Abstract

Consumer electronics, automotive and semiconductor industry demand fast cutting solutions for complex shapes on a variety of transparent and brittle materials. These requirements can be fulfilled by laser cutting technology. Using ultrashort pulsed lasers offers the possibility for a very confined energy deposition, resulting in high quality laser cuts. Since the applied processing strategies impact the results regarding quality and tact time, a robust optical & machine solution is required. The presented approach is based on non-diffractive beams in order to provide a stable optical confinement of the laser irradiation. This intensity distribution has a great advantage with respect to quality and speed for material modification and processing of glass. The nonlinear interaction induces a localized material modification rather than material removal like ablation processes. This nonlinear interaction is combined with laser-induced thermal stress in order to precisely separate even un-strengthened glass and consequently facilitates a unique zero gap process for freeform cutting of glass.

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

1. Introduction

A high demand for cutting processes in industry, for example consumer electronics, automotive or semiconductor industry can be addressed by laser cutting technologies. Compared to mechanical dicing solutions like score and break, laser cutting enables to directly cut complex geometries with a clean process for strengthened and un-strengthened glass as well as other transparent brittle materials. High quality is achieved in terms of chipping and edge strength.
Different laser glass cutting processes are known in the literature: multipass focusing using a gaussian beam is one approach described for example by Iri (2005), Bovatsek (2014), Zühlke (2015) or Okuma (2011). Here a laser is focused inside the material in a way to achieve a critical density above the modification threshold. The induced modification is locally confined to a small focus point inside the material and generates local cracks. In order to perforate through the whole sample, the laser beam needs to pass the surface multiple times. The resulting disadvantage of this strategy is a very low speed, a non-uniform crossection and often a reduced edge strength.

In order to reduce the necessary number of passes, one tactic is to apply 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). The nonlinear Kerr-effect strongly depends on material properties and chosen intensities and hence is more difficult to be controlled compared to an optically defined interaction zone. A solution to reduce the material dependencies while generating a modification zone with a high aspect ratio is the use of a non-diffractive beam. Using non-diffractive beams for cutting we obtained industrial robust machining with a standardized optic enabling to cut a broad variety of glasses in 24/7. The quality of our method is presented with some applications in the following.

2. Material and methods

A specially tuned ultrashort laser is used to perforate brittle material using a non-diffractive beam in the propagation direction of the laser. Via non-linear processes, this leads to direct material detachment, typically

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over the complete thickness of the glass, rather than material removal. The result is a very high cut quality, compared to mechanical or alternative laser-based cutting methods e.g. ablation or cracks induced by sharp focusing. By moving the laser beam and/or the substrate near net-shape cutting without a taper and with minimal material loss or debris at highest uniformity is possible. The process modifies the glass substrate all the way through the entire thickness, applying the novel single pass process.

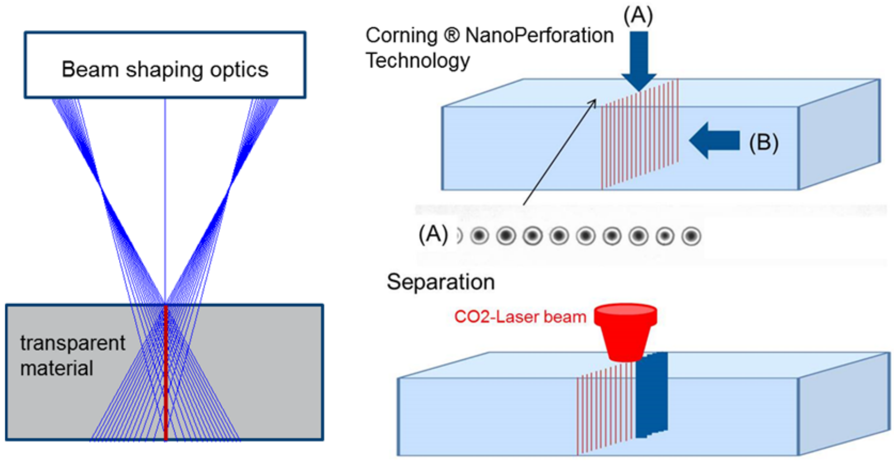

Fig. 1. Optical setup to generate a non-diffractive beam in propagation direction of the laser (left). Scheme of the Corning® NanoPerforation process (upper right) and the thermal separation process (lower right).

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

3. Laser glass cutting results

A large variety of brittle materials can be successfully processed with the above described approach. For example, but not limited to, Corning® Gorilla® Glass (strengthened or un-strengthened), soda lime glasses and sapphire.

Figure 2 exemplifies typical laser cutting results. High speed cutting up to 1 m/s (straight lines) of outer contours with high accuracy can be realized. Complex shapes (upper right), as well as inner contours (left) can be cut with a very high edge quality. The zero-gap cutting approach from Corning® facilitates very smooth edges, showing only minimal chipping and basically no material removal. Due to the use of ultrashort lasers there is low thermal interaction with the material (pulse duration is << thermal diffusion time).

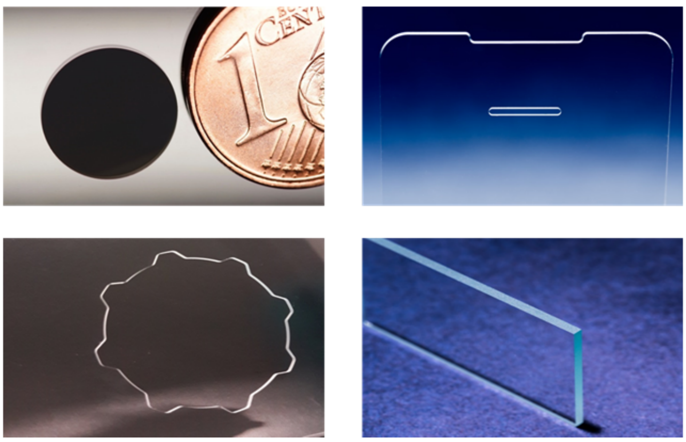

Fig. 2. Inner (left) and outer (right) Contours generated with the Corning® glass cutting technology.

Figure 3 presents more detailed optical micrographs of the resulting crossection and cutting edge of Corning® Gorilla® glass (left) and sapphire (right). A very uniform crossection can be achieved on various glasses and the “as cut” edge roughness can be less than ± 1.5 µm without any postprocessing.

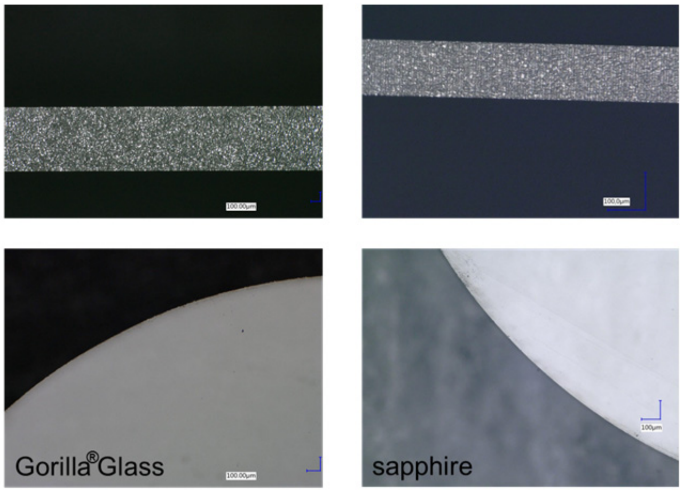

Fig. 3. Crosssection (optical micrograph) of Corning® Gorilla® glass (upper left) and laser entrance side (lower left). Crosssection of sapphire (upper right) and laser entrance side (lower right).

4. Summary

The presented *Corning®* glass cutting technology offers great customer benefits like flexibel cutting of complex geometries of stengthened and un-strengthened glass. Clean cutting processes with minimum to no debris generation at a high throughput and yield were realised and are in industrial 24/7 production. Typically this method is used for products with thicknesses up to ~ 2 mm with a single pass. This technology can be applied to a broad variety of transparent and brittle materials (e.g. display glasses, glass for automotive, consumer electronics, sapphire). In production this new technology succesfully demonstrates a high degree of automation combined with a low cost-of-maintenance, as no fluids or consumables are required. In a number of applications a further benefit of the very high cut-quality is, that postprocessing can be omitted.

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