Laser cutting technology for thick glass and value-added glass stacks

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Abstract

There is the trend towards new structural and design features in architectural glass and smart windows that are increasingly difficult or quite cumbersome to achieve with conventional glass cutting methods like scribe & break. Laser cutting technology, in particular ultrashort pulsed lasers, enables the possibility for a very confined energy delivery, resulting in high quality laser cuts. With the advancement of laser technology in general and the wider commercial availability of industrial ultra-fast laser sources with even higher power and pulse energy, we are able to scale the laser cutting performance such that also thicker glass materials (e.g. 10mm) or functionalized and stacked glasses can be accurately cut at high processing speeds.
In this way, we provide a highly economical and reliable laser cutting solution for architectural glass, smart windows and other complex glass structures that opens the doors to new possibilities.

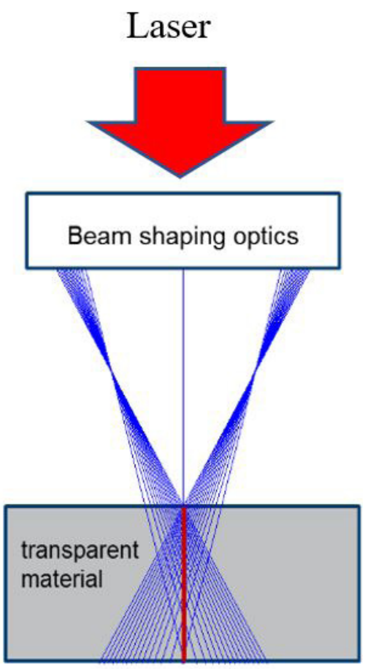

Fig. 1: Line focus generated by beam shaping optics

Introduction: Corning® nanoPerforation

In general, glass is a highly transparent optical material. Hence, there occurs no linear absorption. However, if the glass is exposed to extremely high electrical field strengths one can reach the regimes of various non-linear effects like multi-photon absorption or the optical Kerr effect, to name just a few.
For our nanoPerforation process we combined means: Ultrashort laser pulses in conjunction with our proprietary beam shaping technology (Fig. 1) to achieve a controlled non-linear interaction zone within the glass being processed.
The high intensity interaction zone produces a cylindrical zone of localized material modification. It is important to note, this is not a thermal process, there is no melting, no ablation, i.e. no material removal in the high intensity interaction zone.
In practice the laser beam, consisting of a continuous train of ultra-short laser pulses, follows the cutting contour (Fig. 2) and thus, induces the desired material modification precisely in the desired contour.
In a second step, a CO2-laser beam follows the cutting contour (Fig. 2 bottom). The absorption of the CO2-laser radiation leads to a thermo-mechanical stress profile that in turn causes a clean separation along the cutting contour.
Virtually any free-form geometry can be cut with this process as can be seen from the small selection of examples in Fig. 3.
For more details see [1].

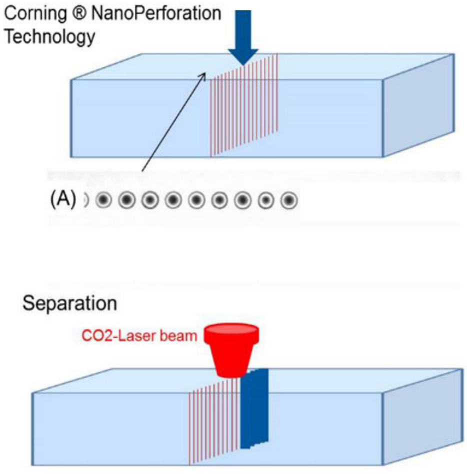

Fig. 2 top: nanoPerforation with pulsed Laser
bottom: Separation with CO2-Laser

The main benefits of the nanoPerforation process can be summarized as:

- Highly precise and accurate cutting that enables net-shape / near net-shape cutting
- No edge taper
- Minimal material loss and debris
- Contactless, dry & clean process (no tear & wear, no or less washing required)
- Minimal surface roughness (Ra typ. +/-1.5 µm)
- Very high uniformity

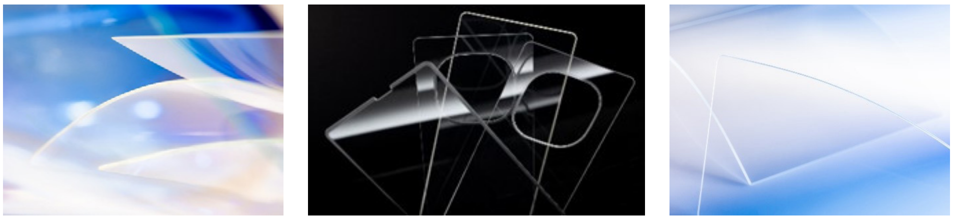

Fig. 3: Examples for laser cut free-form shapes

Laser cutting of glass thickness >3mm

So far, laser cutting has been mostly applied to glass thicknesses of ≤2mm. Typical applications are in areas like automotive glass, cover glass for automotive and consumer electronics displays, or glass wafer for the semiconductor industry. Net-shape or near net-shape cutting (hence, no or little need for post processing), high yield, throughput and material utilization are key advantages of the laser cutting technology, bringing down the cost per part to unrivaled levels.
For architectural glass applications, glass thicknesses of >3mm are more common. Thick glass cutting may require two or even more nanoPerforation passes with z-stepping of the line focus height to achieve pseudo-longer interaction zones to cut a greater thickness. While this multi-pass cutting can still deliver the benefits mentioned above, throughput is compromised.
Recent advances in the ultra-fast laser technology towards increased laser power have improved the situation. Using a high-power laser source in conjunction with tailoring of the temporal and spatial beam properties, we are able to shape the laser beam interaction zone within the glass in such a way that we can nanoPerforate through a glass thickness in one single pass. We achieve our single pass nanoPerforation technique on soda lime glasses of up to 12mm thick.
The following photographs (Fig. 4) show two samples of 8mm thick soda-lime glass that were nanoPerforated in a single pass and separated with the CO2-laser separation process.
Applying the improved nanoPerforation process to larger glass thicknesses overcomes the deficiencies of previously described multi-pass cutting technique. With the implementation of the higher power laser source and the further developed beam shaping technology into our field-proven 24/7 production environment platforms, the achieved high process speed of up to 0.5m/s enables high throughput for large format designs common in architectural glass.

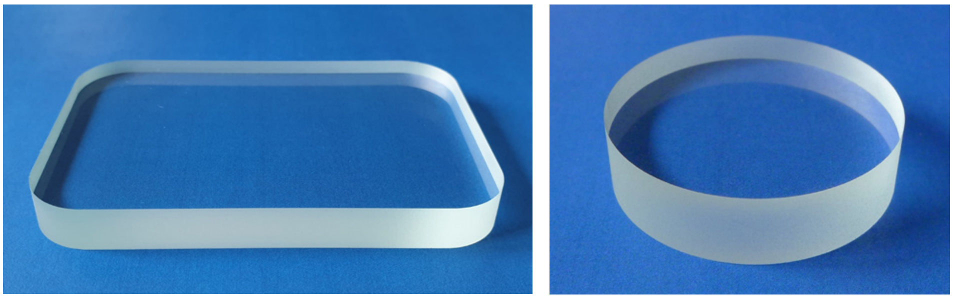

Fig. 4: Samples of 8mm soda-lime glass nanoPerforated in a single pass; on the left: rectangle with corner radius 10mm, on the right: circle with 30mm diameter (as-cut edge, no post processing at all)

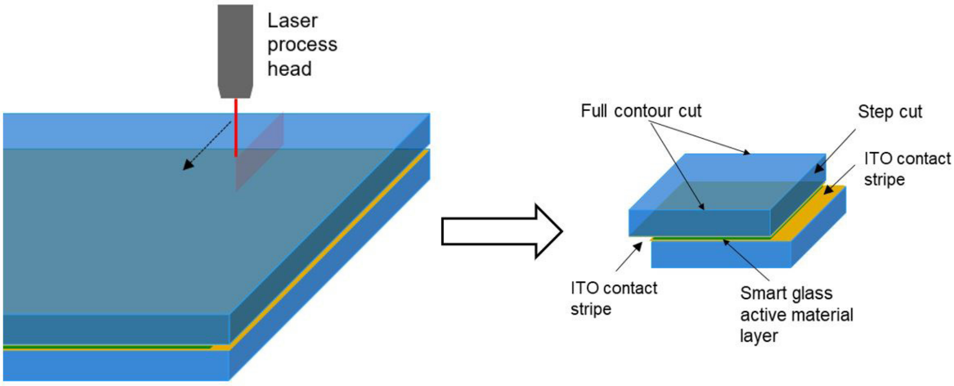

Fig.5: Laser cutting of prefabricated smart window stack to individual size with step cut for electrical contacting of ITO

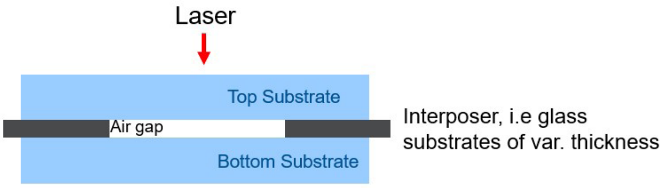

Fig.6: Cutting of a stack of two layers of soda lime glass with 3.2mm thickness each, with different air gaps ranging from 200 to 700µm

Laser cutting of functionalized and stacked glass, e.g. smart window

An interesting application of the thick glass laser cutting capability is the cutting of stacked and coated glass, as used for smart windows. An actively switchable window consists of a stack of at least two glass sheets, the inner surfaces coated with a transparent conductive oxide (mostly ITO) and with the active material in between (e.g. electrochromic or liquid-crystal based). The electrodes need to be accessible for the electrical connection.
In a conventional way, one can pre-cut the single mother sheets to the shapes later needed, and do the ITO coating, active layer deposition, sealing etc. after the cutting process, i.e. all on the individual shapes and sizes.
A more economical approach however is to do the coating, layer deposition, sealing etc. all on a uniform mother sheet size. Laser cutting can then be employed for the singulation process of the functional smart window structure and in this manner enables a streamlined process flow with high design flexibility.
We have optimized the process to obtain the desired nanoPerforation of the upper sheet but at the same time with minimum damage to the ITO-layer of the lower sheet. This is important to ensure that the electrical sheet conductivity of the ITO is not impaired.
For the purpose of high throughput, one is interested to cut the outer contours, where no step cut is needed, in a single pass. A series of tests were conducted with a stack of two layers of soda lime glass with 3.2mm thickness each, with different air gaps ranging from 200 to 700µm to verify the full stack cutting capability in one single pass.
Very good results were obtained with virtually no difference in cutting performance and edge quality for the different spacings between the glass sheets.
As a representative example, presented below in Fig. 7 and Fig. 8 are microscope images of a single pass nanoPerforated laser cut edge showing both the top and bottom as cut edges of the substrates that were separated with an air gap of 0.5mm in between.
This stack of 2 x 3.2mm thick soda-lime glass with air gap is near the upper limit of smart window structure thickness. Cutting thinner structures should be an easier task.
It is also important to mention, that the nanoPerforation process does not necessarily

need to be followed by the CO2-laser separation step. Instead, the separation can also be done by other means, for example by mechanical methods.

Summary and Conclusion

This paper shows the further development of the Corning nanoPerforation technology to enable cutting of thick glass, beyond 3mm in a single pass. Achieving the single pass cutting on thick glass provides all the benefits of the laser cutting combined with high throughput. This thick glass cutting capability can also be utilized for cutting of complex shapes, coated glass and laminate structures like smart windows. Being able to flexibly nanoPerforate the smart window glass stack in a single pass and also process the half-cut with minimum damage to the ITO layer allows for an efficient smart window manufacturing process with a high design flexibility at the same time.
By incorporating this enhanced capability into our machine platforms designed for and proven in 24/7 manufacturing environments, we provide a highly economical and reliable solution for laser cutting of architectural glass, smart windows and other complex glass structures, opening the doors to new possibilities.

References

[1] S. Höhm, M. Malchus, R. Terbrüggen, U. Stute, „Precision laser cutting of glass in industrial applications", 10th CIRP Conference on Photonic Technologies [LANE 2018], 2018

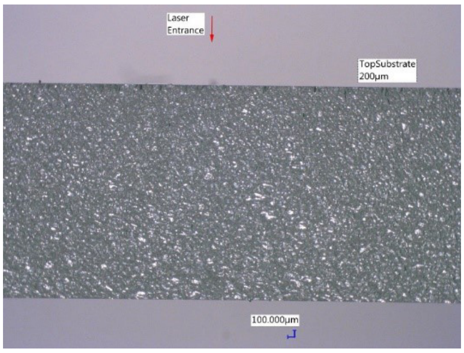

Fig. 7: Microscope image of laser cut edge of 3.2mm thick top substrate

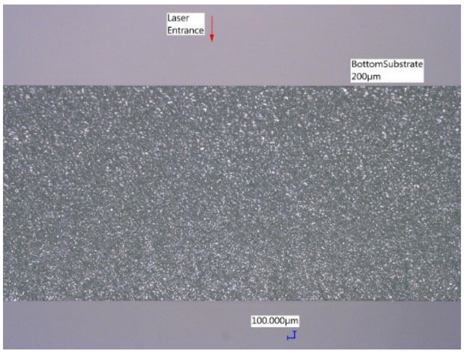

Fig. 8: Microscope image of laser cut edge of 3.2mm thick bottom substrate