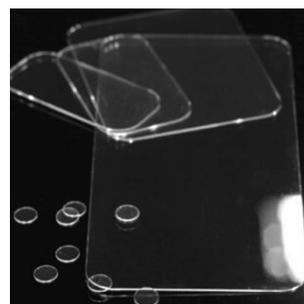


# High Quality, High Speed Processing of Transparent Brittle Materials using Femtosecond Lasers

Laser processing of optically transparent, brittle materials is finding wide use in various manufacturing sectors. For example, in consumer electronic devices such as smart phones, e-readers, and tablet cover glass needs to be cut precisely in various shapes. For machining of curvilinear and internal features, a laser direct ablation process is normally used. Processing of transparent brittle materials using ultrashort pulse lasers has advantages in comparison with long pulse lasers. When an ultrashort laser pulse is focused inside glass, only the localized region in the neighborhood of the focal volume absorbs laser energy by nonlinear optical absorption. Therefore, the processing volume is strongly defined very locally, while the rest of the target stays unaffected. While ablative femtosecond processing provides the quality industrial manufacturers demand, processing speed needs to be improved in order to achieve widespread economical industrial use. Recently, Spectra-Physics has developed a non-ablative femtosecond process (ClearShape™) using the Spirit® laser. ClearShape process allows machining of curvilinear and internal close-shaped features in transparent, brittle materials such as chemically strengthened glass, non-strengthened glass, and sapphire with high quality and speed.

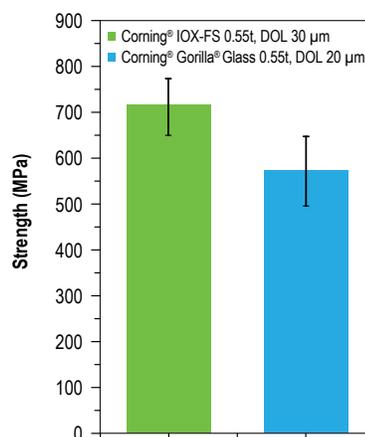


*Spirit femtosecond laser - custom designed for ClearShape process. Spirit is an industrial grade one box femtosecond laser with high repetition rate and average power of up to 16 W.*

## PROCESSING EXAMPLES

The industry standard to gauge the effectiveness of the glass laser cutting process is to perform a four point bending test of as cut samples. Samples cut using ClearShape shows very high bending strength of up to 700 MPa.

### High Quality (four point bending test)

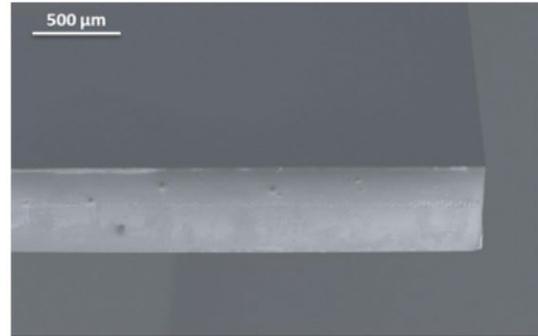


*Results of four point bending tests. The tests show very high bending strength as-cut (up to 700 MPa).*

# High Quality, High Speed Processing of Transparent Brittle Materials using Femtosecond Lasers

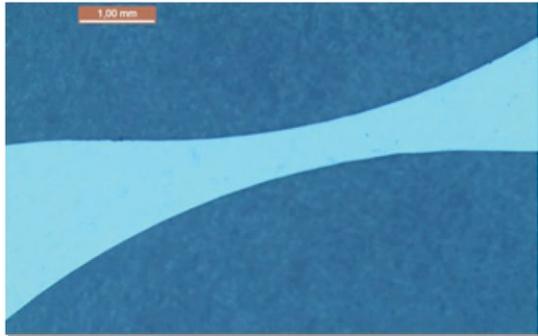
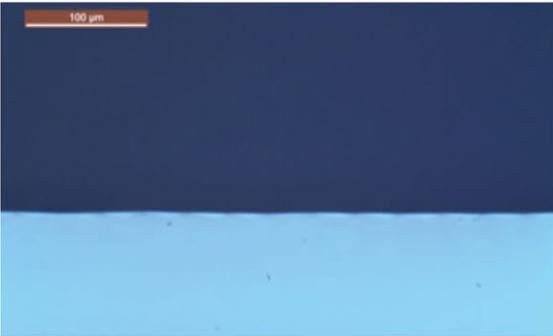


## Chemically Strengthened Glass



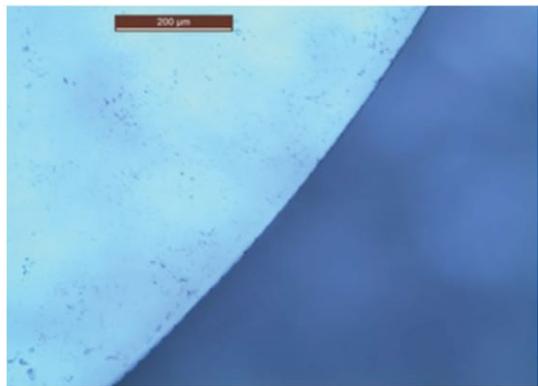
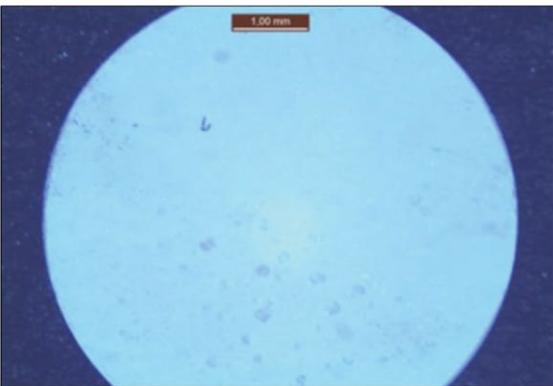
Example of straight line cut in chemically strengthened glass (0.55 mm thick, DOL 20 μm) with ClearShape process using the Spirit laser. The cutting speed of up to 4 m/sec can be achieved. LEFT: Top view the cut edge shows a very high cut quality without chipping on the surface. RIGHT: Side view of the cut edge shows clean smooth surface with average roughness of  $R_a < 0.1 \mu\text{m}$ .

## Non-Strengthened Glass



Example of straight (left) and curvilinear (right) cuts of non-strengthened glass (0.3 mm thick) with ClearShape process using Spirit laser. Top view the cut edge shows a very high cut quality without chipping on the surface. The cutting speed of up to 1 m/sec can be achieved.

## Sapphire



Example of 6.4 mm diameter round camera lens cover window cut from a 0.43 mm thick sapphire wafer with ClearShape process using Spirit laser. The cutting time of <math>< 0.5 \text{ sec}</math> per window can be achieved.



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