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Femtosecond Lasers Extend Glass Cleaving to Mixed Materials

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Filamentation cutting is a relatively new process that uses ultrafast lasers to cut a wide range of glass substrates, from soft borosilicates to chemically hardened glass used in smartphone displays. There are numerous advantages of filamentation cutting, including the ability to produce curved shapes and cut-outs, cutting speeds of up to 2000 mm/s and superior edge quality devoid of stress, which eliminates the need for post-processing.

In technical terms, the high peak intensity created by a focused, ultrafast laser produces self-focusing of the beam due to the nonlinear optical Kerr effect. This self-focusing further increases power density, until, at a certain threshold, a low density plasma is created in the material. This plasma lowers the material refractive index in the center of the beam path and causes the beam to defocus. If the beam-focusing optics are properly configured, this focusing/defocusing effect can be balanced to repeat periodically and form a stable filament that extends over several millimeters in depth through an optically transparent material. In order to achieve a continuous cut, these laser-generated filaments are produced close to each other by a relative movement of the work piece with respect to the laser beam. The typical filament diameter is in the range of 0.5 μm to 1 μm, enabling very high precision cutting.

Until recently, all commercial versions of this cutting technique, such as SmartCleave from Coherent | Rofin, have utilized picosecond lasers. Several display manufacturers now make extensive use of these systems, which can cost-effectively cleave glass up to 10 mm in thickness.
However, one limitation in some applications is that these picosecond systems are not material-neutral. Cutting mixed layer substrates, such as polyimide on glass and metal on glass, usually requires an additional laser process to cut the non-glass layer with the requisite high quality edge.

Femtosecond lasers have a much higher peak-power-to-average-power ratio than picosecond lasers and are known to be able to process nearly any material by conventional ablation, i.e., cutting by material vaporization. However, femtosecond lasers have not been employed in filamentation applications because of their higher cost and lower power compared with picosecond lasers.

But, the increasing demand in industry to cut multi-layer substrates has led laser manufacturers to develop more cost-effective femtosecond lasers that also offer high average power. This has been accomplished by switching to ytterbium-doped fiber, rather than the traditional titanium:sapphire, as the gain medium.

The Coherent Monaco is an example of this new generation of industrial femtosecond lasers, which already offer average power as high as 60 watts. Moreover, the Monaco pulse width can be software tuned by the operator from <350 fs to >10 ps, enabling the output to be optimized for different filamentation conditions, as well as other material cutting and texturing processes.

Engineers in Coherent’s applications laboratory performed tests of this laser for glass filamentation. Monaco can cut glass up to several millimeters in thickness by utilizing so-called “burst mode,” where the laser output is grouped into a series of fast bursts. The brief spacing (20 ns) between individual pulses creates a material interaction proportional to the entire burst energy rather than the energy of a single pulse.

Most importantly, they have demonstrated that by careful process optimization, layered substrates with two or more dissimilar materials can be completely cut in a single pass, with superior edge quality, virtually no residual edge stress and no heat affected zone in the “delicate” layers. The example here shows an edge view of 20 microns of polyimide on 0.5 mm glass, cut with a femtosecond laser with 40 watts of average power and a pulsewidth ~350 fs. The surface roughness was < 350 nanometers, as measured with an AFM.