VERY HIGH-QUALITY CUTTING OF THIN GLASS AND SAPPHIRE WITH THE ICEFYRE® PICOSECOND LASER

Processing of glass and other transparent brittle materials is an important application area for lasers. Laser cutting of glass is used in areas such as display and mobile device manufacturing, electronics packaging, automotive glass, and photovoltaics manufacturing. Across these industries, a variety of glass thicknesses needs to be addressed. For mobile devices, the trend is toward thinner glasses. This is due to the requirement for devices to be lighter weight, flexible and bendable.

Leveraging prior work in Bessel beam glass processing (Application Focus #46; SPIE technical paper [1]) we have used Bessel beam optics specifically selected to produce a short Bessel region (Figure 1) from the output of a Spectra-Physics IceFyre 1064-50 industrial picosecond laser to process thin glass and sapphire. The materials selected for these tests were ~300 µm thick Corning® Eagle XG® (alkaline boro-aluminosilicate) glass, ~100 µm thick Corning Willow® (alkali-free borosilicate) glass, and ~300 µm thick sapphire. Since Bessel beams produced from a gaussian beam profile have variable intensity on the z axis (Figure 2), it is desirable for the Bessel region to be longer than the material thickness to allow for more uniform intensity over that thickness.

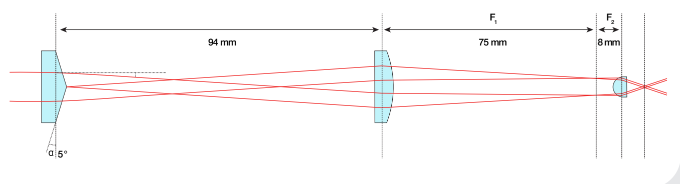

Figure 1. Optical Schematic for thin glass processing tests.

The optical configuration described by the schematic in Figure 1 results in a Bessel region that, in air, is approximately 440 µm long with a radius of 1.1 µm. In the material, the Bessel region and radius are both larger, as determined by the refractive index. For the two glasses, this leads to a Bessel region of ~680 µm long and a radius of ~1.7 µm. Sapphire's greater refractive index leads to a slightly longer ~780 µm and radius of ~2 µm.

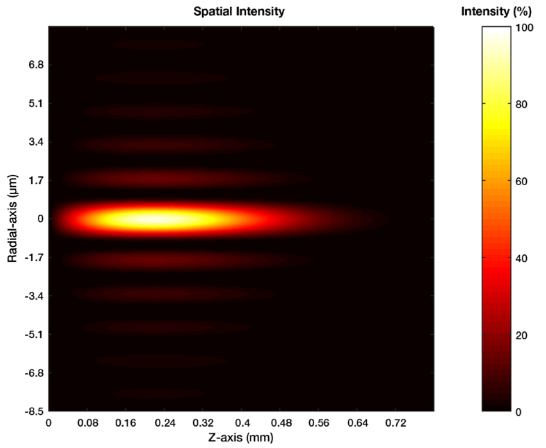

Figure 2. Side view of spatial intensity of the Bessel beam (in air) generated with IceFyre laser.

The optical system in Figure 1 is similar to that used in previous Bessel cutting work but has been adjusted for thinner material by reducing the incident beam diameter. This results in a shorter Bessel region while maintaining the same core diameter proven effective in those previous tests. Also similar to previous results, TimeShift™ ps bursts of 2–4 pulses were used for best results.

References: [1] Terence Hollister and Jim Bovatsek "Ultrafast lasers for advanced manufacturing of flat panel displays", Proc. SPIE 10905, Laser Applications in Microelectronic and Optoelectronic Manufacturing (LAMOM) XXIV, 109050I (4 March 2019); https://doi.org/10.1117/12.2510941

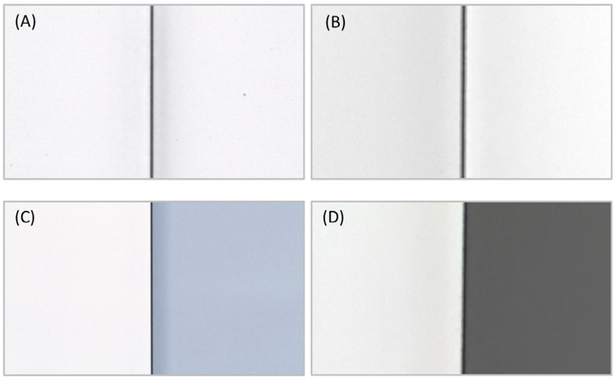

Figure 3. Images taken from the top down of (A) Corning Eagle XG glass, and (B) Corning Willow glass after processing but prior to breaking. (C) Corning Eagle XG, (D) Corning Willow after breaking. The low pitch Bessel processing leads to a continuous modification plane in the material visible as a uniform line on the entry and exit surfaces.

The Corning Eagle XG and Corning Willow glasses were both processed at a translation speed of 100 mm/s and at 100 kHz pulse repetition frequency (PRF), leading to a very low pitch process and a continuous and uniform modification line on the top and bottom surface of the material, as seen in Figure 3.

After manual cleaving, visual inspection shows complete and uniform modification of the edge surface (Figure 4). The surface shows a lightly granular texture, and the surface roughness as characterized via optical profiler were approximately 0.2 µm and 0.1 µm for the 300 µm Eagle XG glass and 100 µm Willow glass, respectively.

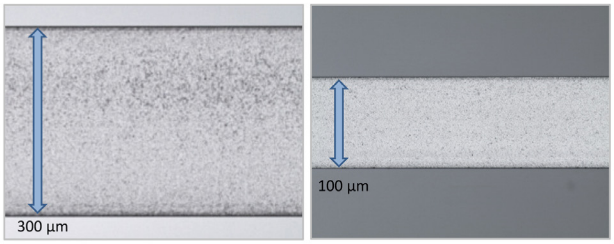

Figure 4. Images of cleaved edges of (left) Corning Eagle XG glass, and (right) Corning Willow glass. Surfaces show uniform and complete modification of the surface. Ra of the surfaces are (left) ~0.2 µm and ~0.1 µm.

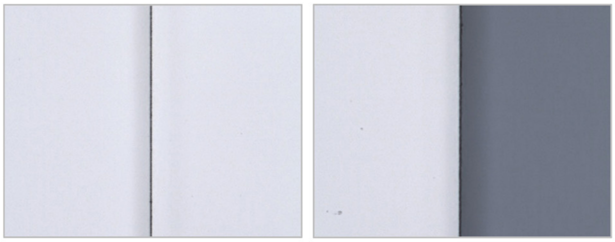

Figure 5. Top down images of sapphire after Bessel processing before (left) and after (right) cleaving.

In addition to the glasses, the Bessel process was also found to be effective for cutting thin sapphire, a material used in LEDs, wearables and mobile devices. Unlike the glasses that were tested, the optimal sapphire cutting results were with a higher PRF, higher speed process. At 1000 mm/s and 400 kHz PRF, the pitch (distance between laser pulses incident on the material) is larger than that used for glass; however the cut line and edge surface, shown in Figure 5, still appear continuous and uniform much like the results for glass.

The cleaved edge was inspected visually (Figure 6) and by optical profiler. Visual inspection showed the expected granularity similar to the glasses, but perceptibly coarser. This additional coarseness is reflected in the Ra, which was measured to be ~0.3 µm, slightly higher than that of the glasses, possibly due to the larger Bessel radius and higher pitch required for the process.

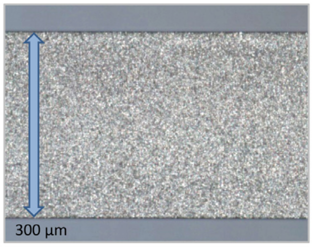

Figure 6. Side view of cleaved edge of sapphire. Measurements via optical profiler put the Ra at ~0.3 µm.

Due to the narrowness of the Bessel region, the required pulse energy for material processing is well below the max energy available at the given rep rates. This allows for the throughput to be scaled up via parallel processing using beam splitting according to Table 1 below.

With the appropriate optics and process parameters Bessel beam cutting using the IceFyre 1064-50 laser is capable of fast, very high quality processing of a variety of thin transparent materials.

	Single Beam Throughput (mm/s)	Single Beam Power (W)	Number of Beams (#)	Scaled Throughput (mm/s)
Corning Eagle XG Glass	100	7	5	500
Corning Willow Glass	100	4	10	1000
Sapphire	1000	13	3	3000

Table 1. Columns 1 and 2 list the cutting speed and laser power used for the tests. Column 3 shows the number of beams to which the process could be scaled using the energy available from the IceFyre 1064-50 laser at the process PRF; column 4 shows the effective throughput for parallel processing with that number of beams.

PRODUCT

IceFyre Industrial Picosecond Lasers

The IceFyre 355-50 is the highest performing UV ps laser on the market, providing >50 W of UV output power at 1.25 MHz (>40 µJ) with 100's µJ pulse energies in burst mode, and pulsewidths of 10 ps. The IceFyre 355-50 sets new standards in power and repetition rates from single shot to 10 MHz. The IceFyre 355-30 offers >30 W of typical UV output power with pulse energy >60 µJ (greater pulse energies in burst mode) and delivers exceptional performance from single shot to 10 MHz. The IceFyre 1064-50 provides >50 W of IR output power at 400 kHz single pulse and delivers exceptional performance from single shot to 10 MHz.

IceFyre laser's TimeShift™ unique design exploits fiber laser flexibility and Spectra-Physics' exclusive power amplifier capability to enable TimeShift ps programmable burst-mode technology for the highest versatility and widest range in the industry. A standard set of waveforms is provided with each laser; an optional TimeShift ps GUI is available for creating custom waveforms. The laser design enables true pulse-on-demand (POD) and position synchronized output (PSO) triggering with the lowest timing jitter in its class for high quality processing at high scan speeds, e.g. when using a polygon scanner.

	IceFyre 1064-50	IceFyre 355-30	IceFyre 355-50
Wavelength	1064 nm	355 nm	
Power	>50 W @ 400 kHz	>30 W typical @ 500 kHz >25 W @ 800 kHz >20 W typical @ 1 MHz	>50 W @ 1250 kHz
Maximum Pulse Energy, typical (greater pulse energy per burst possible with TimeShift ps)	>200 µJ single pulse @ 200 kHz	>60 µJ typical @ 500 kHz >31 µJ @ 800 kHz >20 µJ typical @ 1 MHz	>40 µJ @ 1250 kHz
Repetition Rate Range	Single shot to 10 MHz		
Pulse Width, FWHM	<20 ps (15 ps typical)		<12 ps (10 ps typical)
TimeShift ps	yes		
Pulse-to-Pulse Energy Stability	<1.5% rms, 1 σ	<2.0% rms, 1 σ	
Power Stability (after warm-up)	<1%, 1 σ, over 8 hours		

mks | Spectra-Physics®

www.spectra-physics.com

Application Note_54_11/03/21