Micromachining Transparent, Brittle Materials with IceFyre™ Picosecond Laser

Transparent and/or brittle materials such as glass, ceramics, and crystals are historically difficult to machine with good quality and high throughput. Traditional mechanical processes are often too harsh and, especially for thinner materials, must be slowed down to prevent severe cracking and chipping of the material. In addition, tool wear is problematic because the cutting edges are continually degrading throughout its lifecycle and the quality, yield, etc. of the processed parts are likely to also degrade—this on top of the consumable replacement cost that can be quite high over time. Furthermore, hard brittle materials result in high rates of tool wear and the consumable cost over time can become excessive. Hence, manufacturers have increasingly looked towards laser technology as a solution.

In many cases, nanosecond pulsed lasers offer good cost and performance for machining these materials. For alumina (Al_2O_3) ceramics, deep scribing with high speeds can be achieved even with IR (1064 nm) wavelengths, though improved quality and reduced feature sizes may be realized with shorter wavelengths. Glass cutting and drilling is increasingly common in a variety of industries, and green and UV wavelengths are commonly used with good success. As manufacturers pursue increasingly higher quality and machining of finer features, however, the laser industry must provide increasingly better tools.

To this end, picosecond laser technology is increasingly being adopted for machining these challenging materials with both good quality and high throughput. However, current picosecond lasers suffer from a number of major shortcomings – they tend to be expensive, large, inflexible and not necessarily reliable. Spectra-Physics' IceFyre redefines the market for picosecond micromachining lasers. IceFyre is a new industrial picosecond laser that delivers exceptional performance, unprecedented versatility, smallest footprint and industrial reliability – all with industry-leading cost-performance.

The IceFyre laser offers >200 µJ pulse energy as well as >50 W average power at wavelength of 1064 nm. In addition, it includes TimeShift™ ps technology, which allows burst mode operation with variable sub-pulse separation time; the intensity of each sub-pulse, the spacing, and number of sub-pulses within the burst envelop can be varied while still maintaining the same maximum output power.

Spectra Physics applications engineers conducted a series of experiment using the IceFyre 1064-50 to process transparent and/or brittle materials. These experiments were aimed at developing optimized processes for specific industrial applications. Materials tested include 200 µm thick Corning® Willow® glass, 150 µm thick sapphire, and 200 µm thick aluminum oxide (Al_2O_3) ceramic. In these materials, processes were developed for trepan cutting of holes with diameters in the 5 to 10 mm range.

In thin glass used for manufacturing of personal mobile devices, picosecond pulsed lasers have proved to be especially valuable. Closed shape cutting is important for integration of features such as buttons, speaker openings, camera windows, etc. Using the IceFyre laser combined with a high speed, multi-pass trepan cutting process, 10 mm diameter holes were cut in 200 µm thick Willow glass. Figure 1 shows a digital camera macro photo of a completed cut. The hole cutting time was ~2.5 seconds and the ablated edges appear very smooth. Edge chipping was typically 0-10 µm as determined by optical microscope inspection, and surface profile data of cut edge indicated roughness R_a of <1 µm.

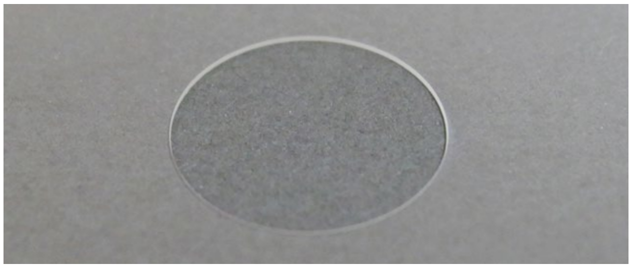

Figure 1: 10 mm diameter hole cut out in 200 µm thick Corning Willow glass

Synthetic sapphire has been used for decades for watch cover plates and is now increasingly being implemented in mobile devices as a tough, scratch resistant material for components such as buttons and camera windows. In these tests, small disks or "planchets" where machined out of 150 µm thick c-plane, double side polished sapphire. Developing high speed processes with high average power laser can be fairly challenging with such very thin, brittle materials. After a careful process optimization effort with the IceFyre picosecond laser, 5 mm diameter disks were cut in ~1.5 seconds. A camera macro and photo of the disc can be seen in Figure 2. The photo shows good machining quality of the thin sapphire

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material with no visible chipping and a smooth, frosted cut edge. For the faster cutting speeds, the sidewall roughness R_a was typically ~1.5 µm. With some tradeoff in throughput, however, the IceFyre laser also machined some features in sapphire with R_a values in the 0.5 to 1.0 µm range.

Due to its combination of high hardness, high electrical insulation, and high thermal conductivity, alumina ceramics are increasingly being used for applications such as light emitting diode (LED) heat sinks, high temperature printed circuit boards (PCBs), and device packages for harsh, high temperature environments. However, these advantages also come with challenges for precision machining, due to the hardness and somewhat brittleness of the material. Using the IceFyre's short picosecond pulses combined with a high speed, multi-pass trepanning process, 5 mm diameter holes were cut in the material with high quality and high throughput. Figure 3 shows a digital camera photo of the processed hole. The processing time was 0.8 seconds per hole, equating to a linear cutting speed of ~20 mm/s. The photo indicates that there is no darkening and debris deposition at the edges and sidewalls of the kerf that are often seen when processing with long pulse width lasers.

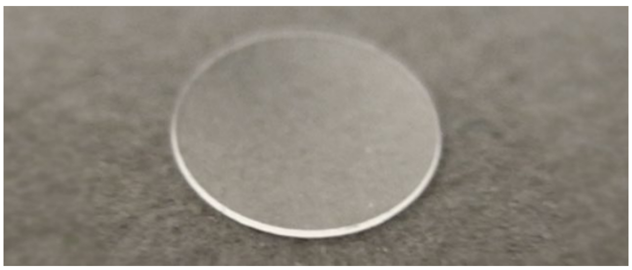

Figure 2: Macro camera photo of 5 mm disk cut from a 150 µm thick sapphire wafer

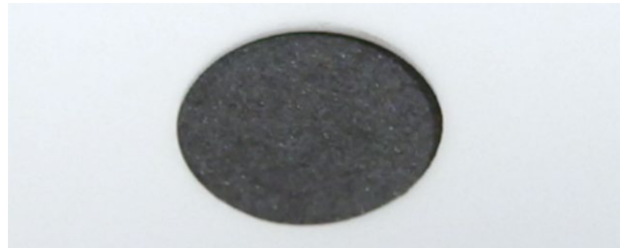

Figure 3: Digital camera photo of 5 mm diameter hole machined in 200 µm thick alumina ceramic plate shows very good edge quality and no discoloration of the material.

PRODUCTS: *ICEFYRE 1064-50*

IceFyre redefines picosecond micromachining lasers with a patent-pending design to achieve exceptional performance and unprecedented versatility at industry-leading cost-performance. Based on Spectra-Physics' It's in the Box™ design, IceFyre integrates laser and controller into the industry's smallest package.

IceFyre's unique design exploits fiber laser flexibility and Spectra-Physics' exclusive power amplifier capability to enable TimeShift ps programmable burst-mode technology and wide adjustability of repetition rates. A standard set of waveforms is provided with each laser; an optional TimeShift ps GUI is available for creating custom waveforms. The laser provides pulse-on-demand triggering with the lowest jitter in its class for high quality processing at high scan speeds, e.g. when using a polygon scanner.

	IceFyre 1064
Wavelength	1064 nm
Power	>50 W
Maximum Pulse Energy, typical	>200 µJ single pulse at 200 kHz
Repetition Rate Range	Single shot to 10 MHz
Pulse Width, FWHM	<20 ps
Pulse-to-Pulse Energy Stability	<1.5% rms
Power Stability (after warm-up)	<1%, 1σ over 8 hours
Spatial Mode (TEM_{00})	<1.3
Beam Asymmetry	1.0 ±10%
Beam Pointing Stability	<±25 µrad/°C

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