Through-Glass Via Drilling with a UV Laser Source: Temporal Pulse Tailoring for Improved Throughput and Quality

Laser processing of glass and other transparent brittle materials is of increasing importance for the manufacturing of a wide range of products we use on a daily basis. For touch panel displays on mobile devices, lasers have shown themselves as capable tools for cutting chemically strengthened glass with both high speed and good quality. For the LED lighting industry, lasers have been a valuable tool over the years for device singulation on the sapphire substrate. Currently, glass is increasingly considered as an interposer material for advanced high density IC packaging architectures, and lasers are being considered as a tool for drilling the through-glass vias (TGVs) required for lead connections. Recently, researchers from Spectra-Physics' industrial application laboratory collaborated with Laser Zentrum Hannover (LZH) located in Hannover, Germany on a series of experiments aimed at developing high-quality and high-throughput processes for drilling thin glass plates using a state-of-the-art nanosecond pulse diode-pumped solid state laser (DPSS) operating at the 355 nm ultraviolet (UV) wavelength.

Spectra-Physics' Quasar® UV lasers have a novel temporal pulse tailoring feature known as TimeShift™ technology. This allows a single laser to output a wide variety of pulse types – from short (<2 ns) to long (>100 ns) pulse width, stand-alone or burst configuration, and with pulse burst separation times from <5 ns to greater than 200 ns. Besides pulse width adjustability, TimeShift technology can also be used to customize the shapes of individual pulses as well as the envelope containing a burst of pulses (i.e. tailor the relative intensity of pulses a burst). In short, complete pulse tailoring in time is possible with TimeShift.

We tested a range of pulse durations from 2–10 ns as well as a double 10 ns pulse output. For the double pulse output, as shown in Figure 1 the pulse separation time and the relative intensity of the two pulses was varied. Energy was distributed unequally as 2:1 and 1:2 ratios, and equally as a 1:1 ratio; pulse separation times ranged from 5–200 ns.

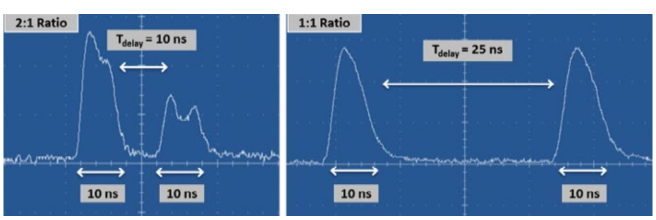

Figure 1: Oscilloscope traces demonstrating pulse outputs that can be generated with the TimeShift temporal pulse-shaping technology.

In a first round of experiments, single line scans at 1000 mm/s were used to scribe 400 μm thick borosilicate glass (Schott D-263) and the machining depth and edge chipping dimension were characterized. The goal of this test was to check for a fundamental difference in processing speed and quality for the various pulse outputs. The bar chart in Figure 2 summarizes the single pass ablation depth and edge chipping size for various pulse durations as well as for a double-pulse burst output with differing pulse relative intensities (1:1, 2:1, and 1:2) with a pulse separation time of 10 ns.

From Figure 2, it is clear that longer pulses as well as the 2×10 ns pulse configuration generate deeper scribes and at the same time generally have larger edge chipping. However, by shaping the relative intensities in the double pulse output to have a 1:2 ratio, the deepest scribe depth is achieved while maintaining the smaller edge chipping. It is also noteworthy that the edge chipping with the 2 ns output is particularly small, even while offering an ablation depth similar to that of the longer 5 ns pulse output. This significant edge chipping reduction is clearly apparent upon microscopic inspection, as shown in Figure 3.

Using the temporal pulse shaping capability of TimeShift technology, users can tailor their various processes to optimize for better quality or better throughput, depending on the overall requirements. Furthermore, it is possible that a single process can be divided into multiple sub-processes, each using a particular pulse output which has a pre-defined balance of speed and quality, which may result in a unique combination of high throughput and good quality.

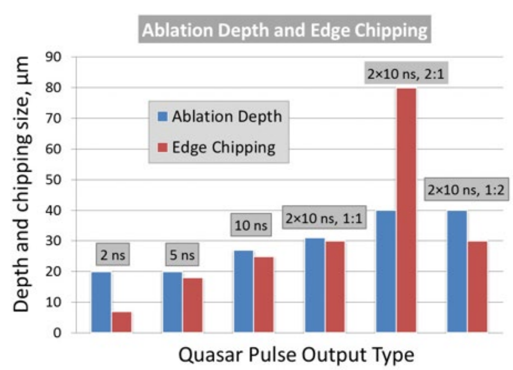

Figure 2: Ablation depth and edge chipping of scribes machined with single pulse output of 2, 5, and 10 ns duration as well as 2×10 ns with relative intensities of 1:1, 2:1, and 1:2.

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This approach was applied as a demonstration by LZH researchers for the machining of 500 µm diameter thru-glass vias in 50 µm thick Schott D-263 borosilicate glass. Using a high speed galvo scanner to trepan circular scribes in the material, it was found that by using the 2×10 ns pulse output the drilling throughput improved by more than 50% compared to a single 10 ns pulse output. In both cases, however, the size of the chipping was unacceptably large. With the knowledge that a shorter pulse width would improve the chipping, it was decided to divide up the single process and create a hybrid process which began with the short 2 ns pulse output to generate better quality edges and then transitioned to the 2×10 ns pulse output to take advantage of the higher throughput. The result in Figure 4 shows that the approach met with good success.

With this hybrid process approach, the chipping was reduced from >70 µm to around 20 µm, a reduction of more than 65%, and the higher throughput of the 2×10 ns output was mostly preserved. This is a clear example which demonstrates that the smart application of TimeShift technology of the Quasar UV laser can indeed lead to the best of both worlds: a high quality machining result without sacrificing throughput.

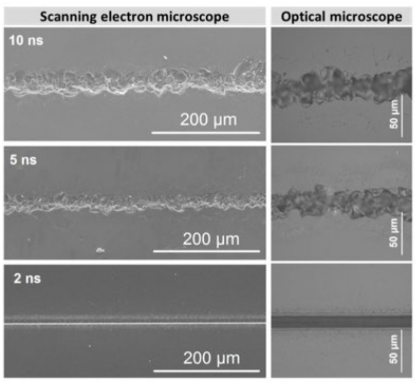

Figure 3: Scanning electron (left) and optical (right) microscope images show the dramatic reduction in edge chipping with the 2 ns pulse output.

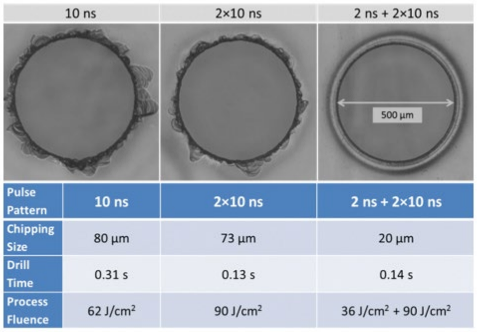

Figure 4: Good quality and high throughput were achieved with a hybrid process when drilling 500 µm diameter TGVs in 50 µm thick borosilicate glass.

PRODUCTS: *QUASAR 355-45, QUASAR 355-60, QUASAR 532-75, QUASAR 532-95*

The breakthrough performance of the Quasar series leads the industry with unprecedented highest UV average power and energy at high rep rate for fast micromachining. Quasar features novel TimeShift technology for programmable pulse profiles for the ultimate in process speed, flexibility, and control. Quasar 355-60, produces >60 W of UV output power at 200 kHz and 300 kHz, and >300 µJ pulse energy, complementing Spectra-Physics' breakthrough Quasar 355-45 laser. Quasar 355-60 operates over a wide repetition rate range from single-shot to 3.5 MHz, with pulse widths from <2 ns to >100 ns. Quasar 532-95 rounds out the Quasar series with >95 W of green output power. The Quasar family of lasers has excellent beam characteristics and very low noise.

	Quasar 355-45	Quasar 355-60	Quasar 532-75	Quasar 532-95
Wavelength	355 nm	355 nm	532 nm	532 nm
Power	>45 W @ 200 kHz >45 W @ 250 kHz >41 W @ 300 kHz	>60 W @ 200 kHz >60 W @ 1500 kHz ~40 W @ 3000 kHz	>75 W @ 200 kHz	>95 W @ 200 kHz
Repetition Rate	0 to >1.7 MHz	0 to >3.5 MHz	0 to >1.7 MHz	0 to >3.5 MHz
Pulse Width	Programmable with TimeShift			

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