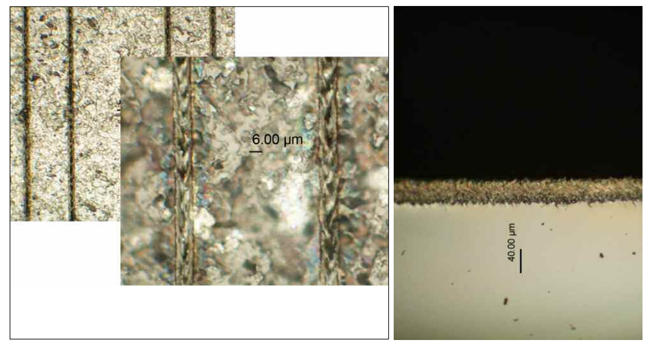
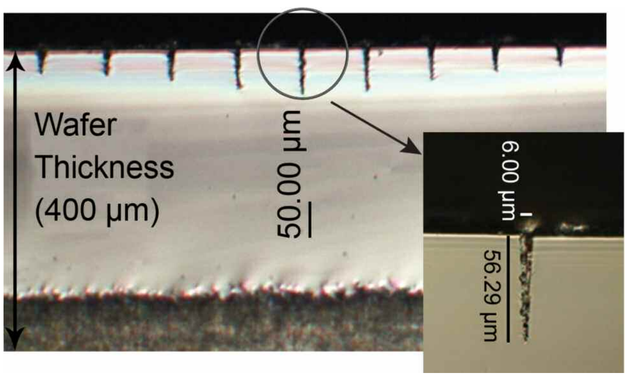
LED Sapphire Wafer Scribing Using 355 nm Lasers

With the increasing demand for more energy-efficient lighting alternatives, light-emitting diodes (LEDs) are becoming one of the most widely used optoelectronic devices today. LEDs are used in traffic control, automotive headlights, consumer electronics, display technology, transportation, photosensor, mobile device and general illumination applications.

Indium gallium nitride (InGaN)-based LED devices are commonly fabricated on a single crystal sapphire (Al_2O_3) substrate that has excellent thermal conductivity. A typical two-inch LED wafer contains several thousands of LED devices. The street width available between LED active devices are very narrow, typically 20–50 µm. Traditional mechanical and diamond saws used for die separation are not only often too wide (50–250 µm kerf width) but also can produce undesirable effects such as chipping, micro-cracking, and delamination, negatively impacting die yield and throughput. Laser scribing technology has proven to be an efficient technique for LED dies separation with overall advantages of increased throughput, low cost, ease of use, and high yields.



Example scribes at the processing focal plane
(left) Top View of Laser Scribe: Clean scribe with little heat damage to surrounding material and circuitry.
(right) Cross-sectional View Along the Scribe: Smooth, consistent laser scribing translates to clean cleaving of Sapphire for higher yield and higher brightness LEDs.



Edge-view cross-sectional picture of scribe depths corresponding to various focal planes

Frequency tripled (355 nm) and frequency quadrupled (266 nm) diode-pumped solid state (DPSS) Q-switched lasers are the most common lasers used for LED scribing. Typically, the laser is tightly focused on the wafer substrate to ablate material and create a narrow scribe line between the active devices.

Spectra-Physics offers lasers with a variety of wavelengths, pulse widths, and power levels to address LED wafer sapphire scribing and laser lift off applications. In the Spectra-Physics Industrial Laser Applications Lab, we have characterized the effect of 355 nm DPSS Q-switched laser pulse width and repetition rates on sapphire scribe depth. We have shown that sapphire material removal thresholds are dependent upon pulse durations. Shorter pulse width lasers (<30 ns) tend to have lower material removal thresholds than longer pulse width lasers (>40 ns). The shorter pulse width of lasers offered by Spectra-Physics allows material removal at lower fluence with negligible HAZ and minimal heating of the wafer and surrounding circuitry. We have also shown that deeper scribes are achieved by operating lasers at higher repetition rates.

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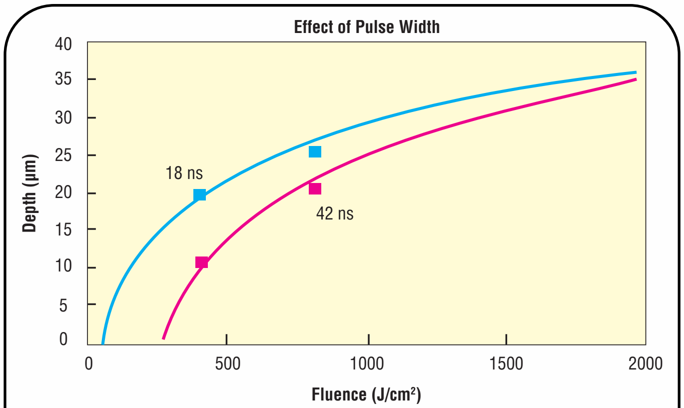
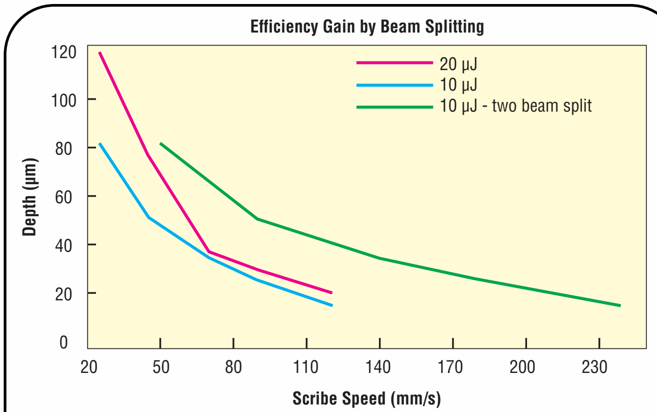


Plot of scribe depth versus fluence, showing the advantage of short pulse widths



Plot illustrating efficiency gain by beam splitting for the higher power Pulseo 355-10 laser

Today's laser products offer ever increasing power levels – and this also holds true for short pulse width, 355 nm wavelength lasers. With this trend, it can be challenging to increasingly utilize this higher power and pulse energy as efficiently as possible. In Spectra-Physics' Industrial Applications Lab, we have explored techniques to increase process efficiency while maintaining quality of Sapphire scribes using different lasers and beam delivery systems.

With lower power Tristar™ 355-3 laser system we have determined that the increase in process efficiency can be achieved by operating laser at low fluence and high repetition rates (up to 150 kHz).

With higher power Pulseo® 355-10 laser system we have shown that the potential gain of up to 75% in processing speed by beam splitting is possible. For 25 µm-deep scribes, a scribing speed of up to 188 mm/sec can be achieved.

The Spectra-Physics Tristar and Pulseo lasers' short-pulse and 355 nm wavelength also result in exceptional scribing quality with very little heat damage to surrounding material which is essential for higher yield and higher brightness LEDs. Finally, using Spectra-Physics 355 nm DPSS Q-switched lasers, 25 µm deep scribes with excellent quality can be achieved in sapphire wafer at speeds in the range of 60–200 mm/sec by proper laser selection and optical beam delivery design.

Products: Tristar Laser

The Spectra-Physics Tristar 355 nm DPSS Q-switched laser offers high peak power, short pulse width, and high-quality manufacturing. The Tristar laser is ideal for demanding UV laser applications that require a highly focused spots, precision positioning and the highest throughput.

Products: Pulseo Laser

The Spectra-Physics Pulseo laser family continues the tradition of high power, high repetition rate Q-switched DPSS laser products. With high peak power, short pulse width, and high-quality manufacturing, Pulseo lasers are ideal for demanding industrial applications that require a high degree of precision.

Model	Wavelength	Peak Power	Average Power	Pulse Width	Repetition Rate (nominal)
Tristar 355-3	355 nm	0.9 kW	>2 W	<25 ns	90 kHz
Pulseo 355-10	355 nm	~5 kW	>10 W	<23 ns	90 kHz

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