FAST FLEX-PCB CUTTING WITH GREEN NANOSECOND PULSED LASERS

The expanded use of flexible printed circuit boards (FPCBs) has enabled the development of multi-functional mobile devices. FPCBs have found use in organic light emitting diode (OLED) displays, smartphones and wearable devices, laptops and tablets, as well as medical devices and automotive components. They offer an attractive solution to miniaturizing components and providing complex interconnections, while maintaining high reliability and long lifetimes. As a result, FPCBs are used in many applications with varying needs for processing requirements. This range of requirements opens possibilities for different types processing equipment.

For high-quality and precision high-speed cutting and drilling, ultraviolet (UV) lasers have become a primary tool of choice for processing FPCBs and complex PCBs. At the same time, green ns lasers have proven to be quite suitable in some areas, such as less complex FPCBs and thicker FR4 cutting. Their lower overall costs (initial and cost of ownership), along with longer lifetimes of both the laser and system optics make green ns lasers an attractive choice for some less demanding processes. Additionally, green ns lasers can produce comparatively higher power at high repetition rates, which can be leveraged to achieve high throughputs.

While green ns lasers clearly offer a compelling value proposition, there is the question of technical feasibility for cutting FPCB materials, which are largely comprised of copper (Cu) and polyimide (PI) film laminates. Green wavelengths have similar absorption in copper compared to UV, and therefore similar performance is expected. With PI on the other hand, green light is absorbed much less strongly and hence spreads further into the bulk of the material. While this leads to a fundamentally different cutting process compared to UV lasers—one that is more thermal as opposed to the UV photoablation—the larger irradiation volume with green tends to enable higher processing throughputs.

To study the ability of green ns lasers for FPCB cutting, experiments were conducted using a Spectra-Physics Talon® GR70 high-power green ns laser to optimize the process and determine the quality and throughput that could be achieved. The Talon GR70 laser offers 70 W average power at a nominal 275-kHz pulse repetition frequency (PRF) and is capable of operating up to 700 kHz with high output power (>62 W). Combined with relatively short ns pulse widths, this allows for flexible operation of the laser for achieving best results with a variety of material types and thicknessesses. To demonstrate this, the laser were used to cut three different Cu/PI/Cu FPCB film laminates. Each laminate's composition included ~12.5-µm thick front and back Cu foils, however the inner PI film was different for each, at 12, 25, and 50 µm thick. Hence, the combined thicknesses of the laminates were ~37, 50, and 75 µm. In Figure 1, the single-pass cutting speeds are plotted for the laminates, along with the laser operating parameters used to achieve these speeds.

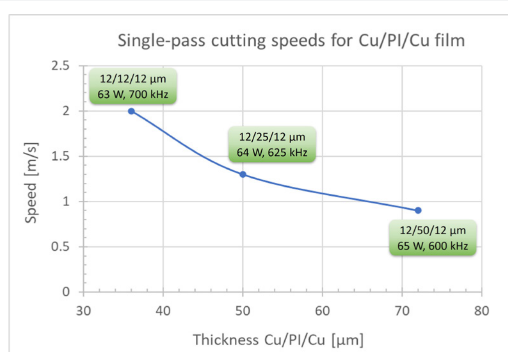

Figure 1. Single-pass cutting speeds for different Cu/PI/Cu laminates at optimized PRFs.

These results were generated with a 2-axis scanning galvanometer and a focused beam diameter of ~16 μm ($1/e^2$ diameter). The data demonstrates the high cutting speeds achievable with high-power green lasers, ranging from 2 m/s for the thinnest and close to 1 m/s for the thickest laminate. For the ~37 μm (Cu/PI/Cu) stack the optimal conditions were 63 W at 700 kHz, while for the 50 μm and 75 μm laminate the optimal conditions were ~64.5 W at 625 kHz and ~65 W at 600 kHz respectively. Thicker laminates clearly benefit from higher pulse energies at lower PRFs, whereas thinner materials benefit from lower-energy pulses at a higher rate. Generally, ideal process optimization includes changing the focus condition to accommodate different material thicknesses. However, using a laser that offers high power output over a wide range of PRFs mitigates this need, enabling high cutting speeds across a large thickness range when constrained by a fixed optical spot size.

The wide PRF range of the Talon GR70 laser also produced good cut quality in all three laminate materials. This is apparent in Figure 2, which shows the entry and exit surfaces of the cuts.

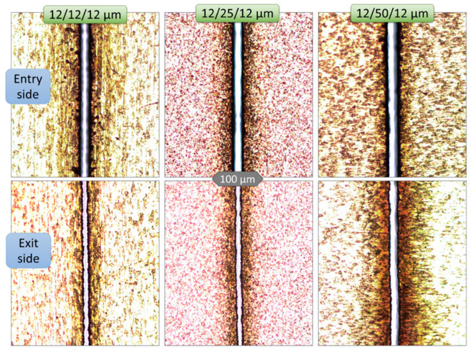

Figure 2. Entry side (top) and exit side (bottom) microscope images showing cuts in three different thicknesses of FPCB laminate material.

Figure 2 shows that both the entry and exit surfaces are cleanly sliced, with minimal heat affected zone (HAZ). The lack of debris and molten material is particularly noteworthy, along with the similarity in appearance across the wide (2×) material thickness range. Overall, the quality appears similar to what is typically seen when cutting with UV wavelengths.

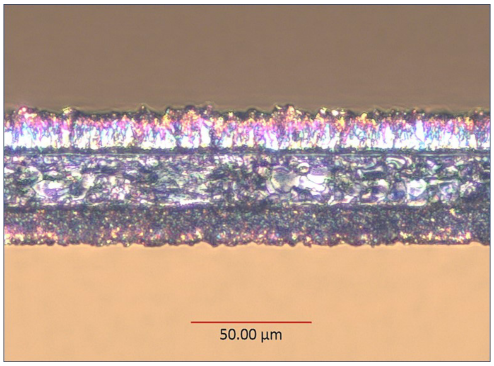

Figure 3. Cross-section view of a 50-μm thick FPCB laminate cut with a Talon GR70 laser.

Cross-section microscope inspection of the cut sidewalls allows further quality assessment. In Figure 3 (50-μm laminate cut), we see the copper ablation is relatively clean, consistent with views from the entry and exit sides. While the PI layer does show some surface irregularity, it is minor and likely due to the somewhat thermal nature of the ablation mechanism. Most critically, there are no signs of delamination or other excessive HAZ at the Cu/PI interfaces.

For FPCB routing or for singulation of final devices along their outer periphery where the highest quality is not necessarily required, ns green lasers provide a cost effective and high-throughput option. In these cases, where cutting quality is not a primary consideration, having inherent flexibility in the processing tool is almost always highly desirable. It has been demonstrated that the Talon GR70 laser is a highly flexible tool, capable of good-quality cutting for a range of laminate thicknesses at high PRFs and with high throughputs.

PRODUCT

The Talon® UV and Green Lasers

The Talon laser platform is a family of UV and green diode-pumped solid state (DPSS) Q-switched lasers that deliver an unprecedented combination of performance, reliability, and cost. Talon is based on Spectra-Physics' *It's in the Box*™ design, with the laser and controller combined in a single, compact package. Talon exhibits high pulse-to-pulse stability and excellent TEM_{00} mode quality for tens of thousands of operating hours. The Talon laser is designed specifically for micromachining applications in a 24/7 manufacturing environment where system uptime is critical. As presented in this Application Focus, there is a strong advantage to having available a broad range of powers and wavelengths, which is provided with the complete Talon portfolio. The Talon provides disruptive cost-performance: lowest cost-of-ownership in the industry with no compromise in features, performance, or reliability.

	Talon UV45	Talon UV30	Talon UV20	Talon UV15	Talon UV12	Talon UV6	Talon GR70	Talon GR40	Talon GR20
Wavelength	355 nm	355 nm	355 nm	355 nm	355 nm	355 nm	532 nm	532 nm	532 nm
Power[2]	>30 W @ 100 kHz	>15 W @ 50 kHz	>10 W @ 50 kHz	>15 W @ 50 kHz	>12 W @ 50 kHz	>6 W @ 50 kHz	>70 W @ 275 kHz	>20 W @ 50 kHz	>20 W @ 50 kHz
	>45 W @ 150 kHz >35 W @ 200 kHz	>30 W @ 100 kHz >23 W @ 200 kHz	>20 W @ 100 kHz	>13 W @ 100 kHz	>10 W @ 100 kHz	>4 W @ 100 kHz		>40 W @ 100 kHz >36 W @ 200 kHz	>18 W @ 100 kHz
	>23 W @ 300 kHz	>17W @ 300 kHz	>11 W @ 300 kHz	>3 W @ 300 kHz	>3 W @ 300 kHz	>1 W @ 300 kHz		>30 W @ 300 kHz	>13 W @ 300 kHz
Repetition Rate	0-500 kHz						0-700 kHz	0-500 kHz	
Pulse Width	<35 ns @ 150 kHz	<25 ns @ 100 kHz					<43 ns @ 550 kHz	<25 ns @ 100 kHz	
Pulse-to-Pulse Energy Stability	<2% rms @150 kHz	<2% rms @100 kHz, typical				<2% rms @50 kHz, typical	<3% rms up to 550 kHz	<2% rms @ 100 kHz, typical	
	<3% rms up to 300 kHz <5% rms above 300 kHzl	<3% rms up to 150 kHz <5% rms up to 300 kHz, typical						<3% rms up to 300 kHz <5% rms above 300 kHz	

		Talon HE UV500	Talon HE UV275	Talon HE GR1000
Wavelength		355 nm	355 nm	532 nm
Power[2]	15 kHz	—	—	15 W typical
	20 kHz	>10 W	5.7 W typical	>15 W
	40 kHz	7.7 W typical	>11 W	13 W typical
	100 kHz	4.2 W typical	5.9 W typical	10 W typical
Repetition Rate		0 to 150 kHz		
Pulse Width		25–40 nsec @ 20 kHz	40–60 nsec @ 40 kHz	25–40 nsec @ 20 kHz
Pulse-to-Pulse Energy Stability		<3% rms		

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