Glass Micro-Welding with Picosecond Lasers

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There is need in several fields, such as microfluidics and medical device packaging, to bond glass to glass, or glass to other materials, without the use of an adhesive or intermediate layer. Laser micro-welding accomplishes this by using an ultrashort pulse laser to generate a high intensity focus at the interface between the two materials, causing the materials to melt and intermingle. Bonds produced by this method are very narrow, <100 µm, preserving optical clarity and are stable and inert.

Recently engineers at the MKS Spectra-Physics® industrial applications lab demonstrated laser micro-welding using a 50 W infrared IceFyre® 1064-50 picosecond laser system, for both glass-to-glass welding and glass-to-aluminum welding. Laser parameters were selected for speed and weld quality, while avoiding cracking or intermittent welding.

Prior to welding, it is necessary to bring the two surfaces to be joined into very close contact, typically sub-micron, though welding has been demonstrated with larger gaps. This can be accomplished in several ways. In all cases it is necessary that the surfaces be flat, polished, and clean. For glass-to-aluminum welding, a clamping fixture is required to create a region of contact, whereas for glass-to-glass welding, the samples can be optically contact bonded.

To achieve strong, highly-localized microwelds, the beam is tightly focused at the interface between the two materials using an 8 mm focal length lens with a 0.50 NA. The non-linear absorption at the focus spot allows for localized welding with minimal heating of the surrounding material. The focus was translated across the material interface, sometimes through regions of poor contact, producing weld lines spanning the contact area, and occasionally beyond it. Since the welds can bridge very small gaps, it is possible to work outward from a region of contact to weld a larger area.

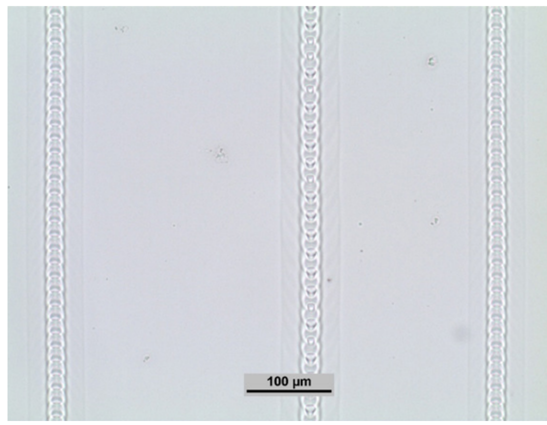

Figure 1
Glass-to-glass weld lines showing inner and outer regions of modification. High optical clarity is maintained, and no cracking is visible.

Figure 1 shows glass-to-glass weld lines with a subtle outer modification region, ~25 µm wide on each side of a ~30 µm wide inner modification region that has the appearance modulation in the melt pool, but at a much longer pitch (~20 µm) compared to the pulse spacing (<1 µm). This modulation of the melt region may be due to a feedback process; in which the melt region and associated refractive index change distorts the beam focus, reducing nonlinear absorption and diminishing the melting, only for the melting to be enhanced once the beam travels slightly away from the focus-distorting melt pool.

Parameters for the best results differ significantly between glass-to-glass and glass-to-aluminum welding. Glass-to-glass welding benefited from very high rep rate, very high overlap processing. The resultant welds are regular and show no cracking

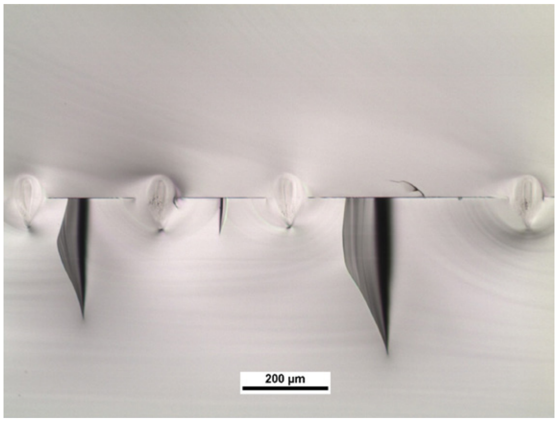

Figure 2
Cross section of several glass-to-glass weld lines. Some cracking is visible between the welds as a result of the scribe and break process.

or separation after processing (Figure 1). After processing samples were scored and broken to attain a cross section view, as in Figure 2.

The cross section (Figure 2) shows four weld lines, processed at 25 mm/s, each with the appearance of an inverted tear drop shape. Just as with the top-down view in Figure 1 there is a clear inner melt region, as well a subtler outer region. Between the welds the interface between the two glass sheets can be seen, but at the welds the interface is gone, indicating a complete fusion of the two glasses. Cracking can be seen between the welds, but this is due to the cleaving process used to obtain the cross section and is not present in the top down images taken prior to cleaving.

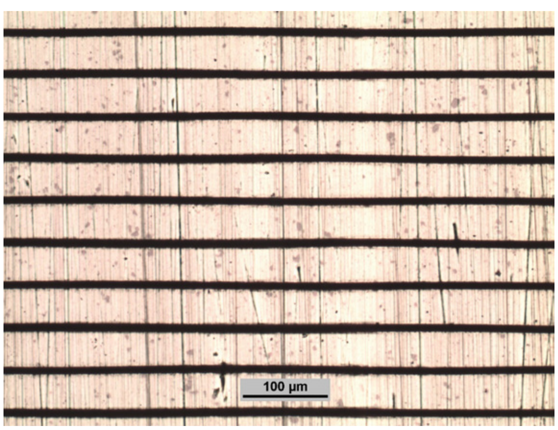

Figure 3
Glass-to-aluminum weld lines. The welds appear as dark horizontal lines.

Glass-to-aluminum was processed at the same speed as glass-to-glass, but at a significantly lower pulse repetition rate. The power was also reduced to avoid cracking and separation due to the greater absorption at the aluminum surface, when compared to glass-to-glass welding. The welds show up as black lines at the glass/aluminum interface when viewed from above as in figure 3.

In Figure 4, the aluminum surface is shown after the glass sheet has been broken free from the aluminum. Many glass chips are still adhered to the surface some several millimeters wide and taller than 100 µm, indicating a strong bond between the glass and aluminum.

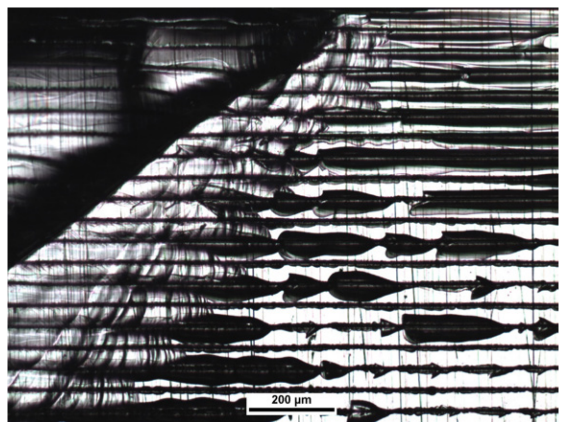

Figure 4
Glass-to-aluminum weld lines post separation. The weld lines on the aluminum surface retain glass chips, some spanning several weld lines.

Ultrafast laser microwelding is a sensitive process requiring some parameter tuning to produce strong, repeatable welds. Using the IceFyre ps IR laser system, an optimized welding process could be developed for different material combinations, demonstrating the IceFyre laser's effectiveness and flexibility for a variety of laser welding applications.

PRODUCT: *ICEFYRE®*

The new 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 3 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	Single shot to 3 MHz	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		

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www.spectra-physics.com

3635 Peterson Way, Santa Clara, CA 95054, USA
PHONE: 1-800-775-5273 1-408-980-4300 FAX: 1-408-980-6921 EMAIL: sales@spectra-physics.com

Belgium	+32-(0)0800-11 257	belgium@newport.com
China	+86-10-6267-0065	info@spectra-physics.com.cn
France	+33-(0)1-60-91-68-68	france@newport.com
Germany / Austria / Switzerland	+49-(0)6151-708-0	germany@newport.com
Japan	+81-3-3556-2705	spectra-physics@splasers.co.jp
Korea	+82-31-8021-1600	korea@spectra-physics.com
Netherlands	+31-(0)30 6592111	netherlands@newport.com
Singapore	+65-6664-0040	sales.sg@newport.com
Taiwan	+886-3-575-3040	sales@newport.com.tw
United Kingdom	+44-1235-432-710	uk@newport.com