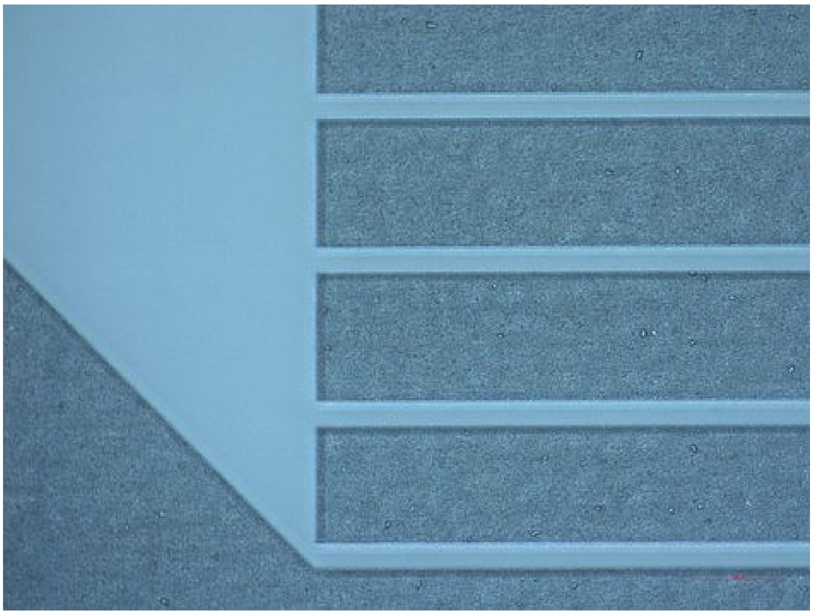
Excellent surface smoothness of laser engraved microstructures in glass

Reduced complexity with the LPKF ProtoLaser R4



LPKF
Laser & Electronics

Micro-Structures in Glass

LPKF ProtoLaser R4 drastically reduces complexity and process steps to your microfluidic design on popular BOROFLOAT® 33 or Mepax® glass – a straight forward process from CAD design to glass sample in hand.

BOROFLOAT® 33 from Schott, Jena, Germany, is a superior performance borosilicate glass produced with micro-float technology. It's high transparency in visible and near IR and UV wavelengths, as well as its visual quality and optical clarity, together with high chemical and shock resistance, makes it ideal for different laboratory applications including microfluidics.

Microfluidics is common for many research branches, for example, to name a few: in physics to study the mechanical properties of fluids when channels narrow to several molecular diameters, in chemistry for studying reactions with pico-liter quantities, in biology, single cells can be separated and captured, and for biochemistry research of a chemical processes in living organisms. Common to all is the handling of very small quantities of fluids, measurable in µL, nL or pL and closely related are microfluidic circuits in sub-millimeter or sub-micron range.

These days there are a lot of lab-on-a-chip applications on the market, different wearables like automatic glucose monitoring or handheld rapid blood or fecal biochemical tests, which can be performed at point of care.

Materials used for microfluidics are different, commonly used materials are PDMS, PMMA, COC, LTCC and glass. These are all also suitable and commonly used for prototyping. Depending on the application, many other inexpensive organic transparent materials may be used for mass production.

Glass has clear advantages compared to other microfluidic materials mentioned above, but traditionally used wet processing - photolithography and chemical etching – is clear disadvantage. With today's contemporary picosecond lasers, human hair thick channels are produced in a single, chemical free process. Similarly, any post-process cleaning can be also chemical free.

Equipment selection

The high optical transmission of BOROFLOAT® 33 already from deep UV wavelengths requires processing with short-pulse lasers. For the experiment, a 515 nm, pico-second LPKF ProtoLaser R4 has been used. Drilling and cutting of borosilicate glass were known processes, whereas deep engraving had not yet been performed.

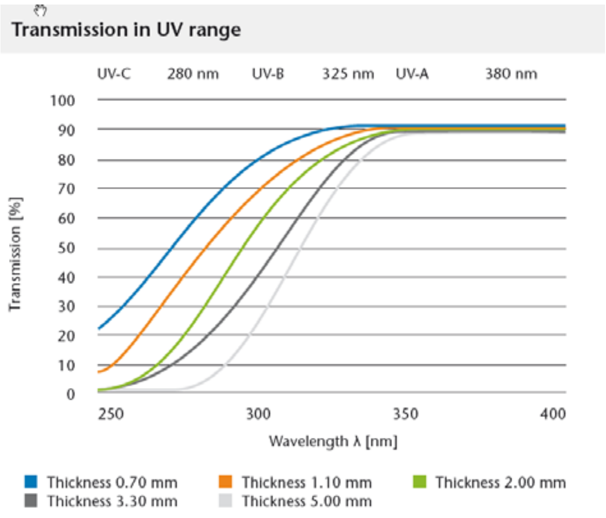


Figure 1: Transmission of different thickness of BOROFLOAT® 33 in UV range (Property of SCHOTT)

Figure 2: LPKF ProtoLaser R4

The sample design and job preparation

The typical microfluidic design idea (Figure 3) was taken from a publication[i], where laser processing of a microfluidic circuit was part of the experiment. The design's overall dimensions are 46 x 10mm, with 150 µm wide channels.

Figure 3: 2D CAD design of microfluidic circuit

The microfluidic circuit was designed directly in the LPKF CircuitPro PL software - it could also be imported from one of many supported vector-based design files. Defining a new material is a few easy clicks in CircuitPro PL software, while the laser parameters for a new material are defined during testing.

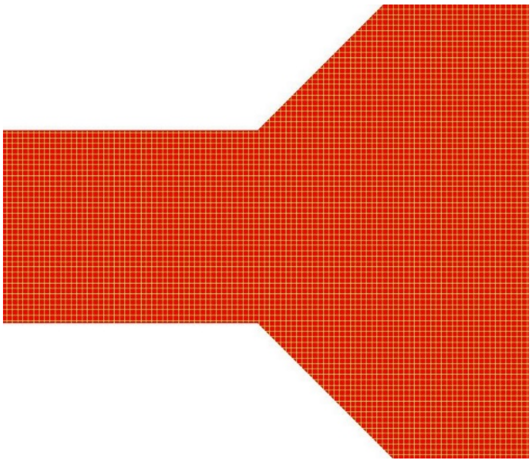
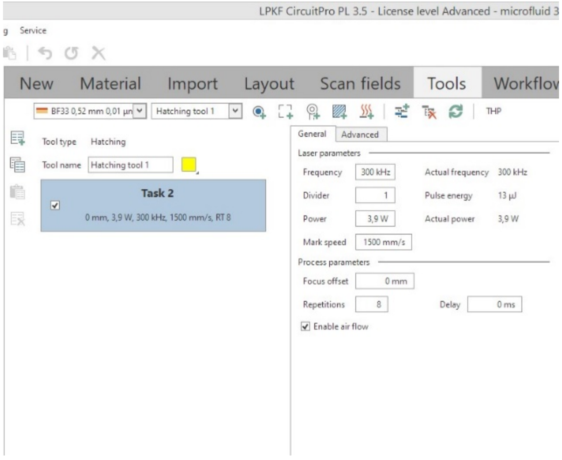


Figure 4: Calculated hatch lines for large surface removal

With the X/Y hatch algorithm and a pitch defined, as default setting, at 7 µm – approximately half of the laser spot diameter. Enlarged detail can be seen in figure 4 – the surface is equally covered with a crosshatch pattern of calculated beam movements – yellow lines.

The LPKF ProtoLaser R4 uses different software-defined laser tools, based on frequency, speed of laser beam movement and power. For deep engraving of Borofloat® 33 in our test, these parameters were set to 300 kHz, 1500 mm/s, 3.9 W which generates pulses with 13 µJ of energy. A target depth of 40 µm was expected to be reached with 8 successive repetitions. Processing time was 31 minutes.



BF33 0,52 mm 0,01 µn

Hatching tool 1

Tool type Hatching

Tool name Hatching tool 1

Task 2

☑ 0 mm, 3,9 W, 300 kHz, 1500 mm/s, RT 8

Frequency 300 kHz

Actual frequency 300 kHz

Divider 1

Pulse energy 13 µJ

Power 3,9 W

Actual power 3,9 W

Mark speed 1500 mm/s

Focus offset 0 mm

Repetitions 8

Delay 0 ms

☑ Enable air flow

Figure 5: Process parameters for Borofloat® 33 processing

For easier measurements, the sample was cut out to the standard microscope slide dimension of 75 x 25 mm. Cutting took 15 minutes or 0.22 mm/s for 0.5mm thick glass.

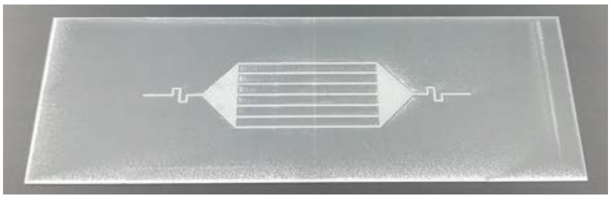


Figure 6: Structured (deep engraved) and cut-out sample on a dark surface prior any cleaning, outer dimension 75 x 25 mm

Results

Besides taking some time, processing ran smoothly. The measured thickness showed a depth of 42 µm. Particles from structuring (especially from the outline cutting phase) can be seen on the surface after processing. Cleaning in an ultrasonic bath with DI water successfully washed them away. Figure 7 shows the overall sample as a composition of partial images taken by microscope.

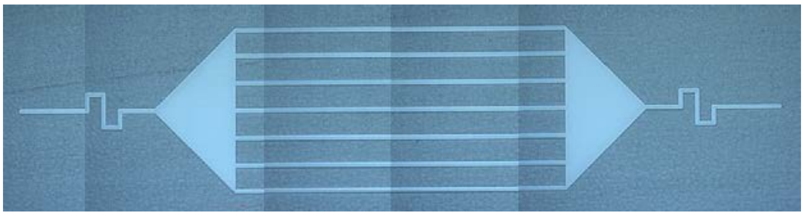


Figure 7: Sample after cleaning, partial pictures taken by Keyence VK-X210 laser microscope and aligned together using VK software

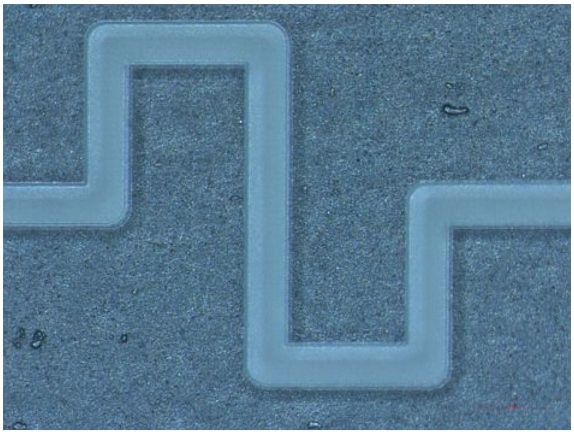


Figure 8: Detail of processed channel on Borofloat® 33

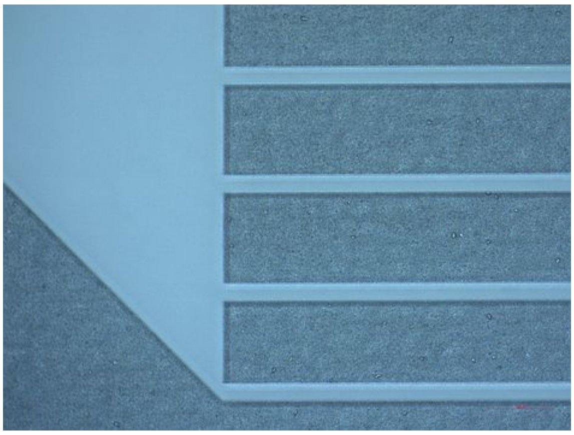


Figure 9: Detail of processed structure Borofloat® 33

3D analyses from a Keyence VK-X210 laser microscope show excellent edge quality (figure 10 and figure 11) and superior surface smoothness for laser glass processing – Ra = 0.6 µm. Detail on Figure 12.

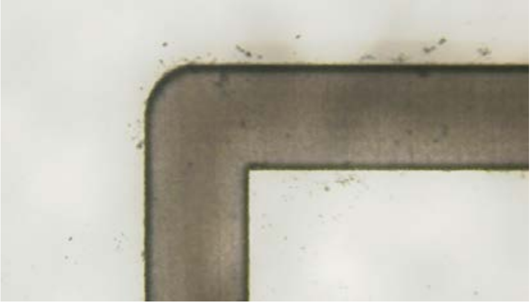


Figure 10: Optical view on detail of structured Borofloat® 33 before cleaning

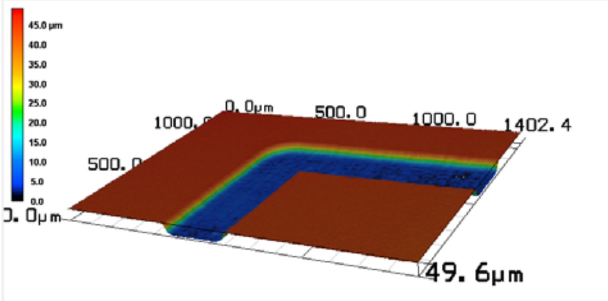
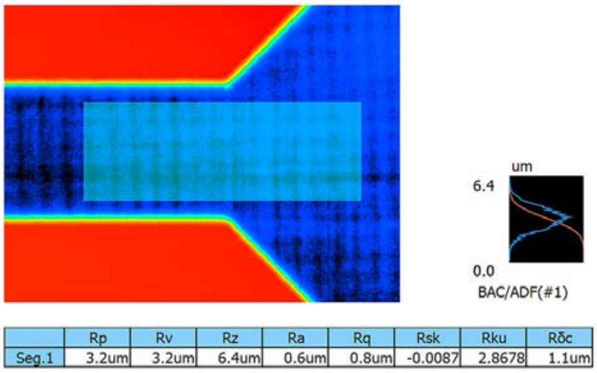


Figure 11: 3D analysis of detail on left (figure 9) processed structure on Borofloat® 33



	Rp	Rv	Rz	Ra	Rq	Rsk	Rku	Rδc
Seg.1	3.2um	3.2um	6.4um	0.6um	0.8um	-0.0087	2.8678	1.1um

Figure 12: Surface analysis of selected area displays an average roughness of 0.6 µm

The transparency of Borofloat® 33 is slightly reduced in the processed area. The level of opacity can be estimated from the test below – measurement was not performed. Figure 13.

Figure 13: Transparency of processed sample

While processing Mepax® 0.3 mm thick glass from SCHOTT, our observations and findings were the same as for Borofloat® 33. We find both materials are easily processed with the ProtoLaser R4.

Additionally, on both glass types, we also structured a 75 µm channel. The pictures for Borofloat® 33 and Mepax® are displayed in figures 14 and 15 below.

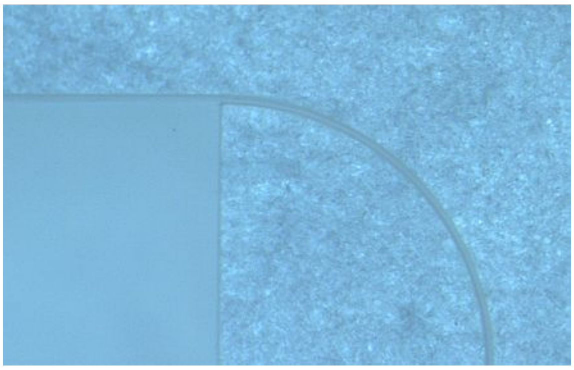


Figure 14: Detail of processed 75 µm channel on Borofloat® 33

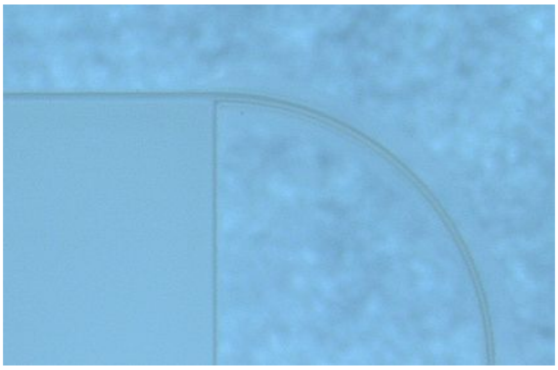


Figure 15: Detail of processed 75 µm channel on Mepax®

Drilling, which may be necessary in a cover glass for microfluidic applications as an inlet or as holes for mechanically mounting glass-based samples on to additional measurement modules, are easily processable using the LPKF ProtoLaser R4.

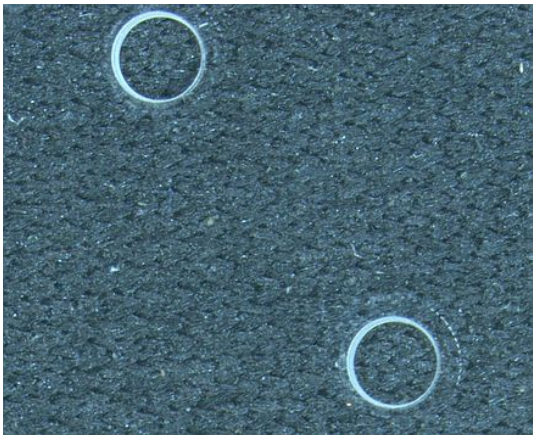


Figure 16: Detail on 0.5 mm thick Borofloat® 33 drilling

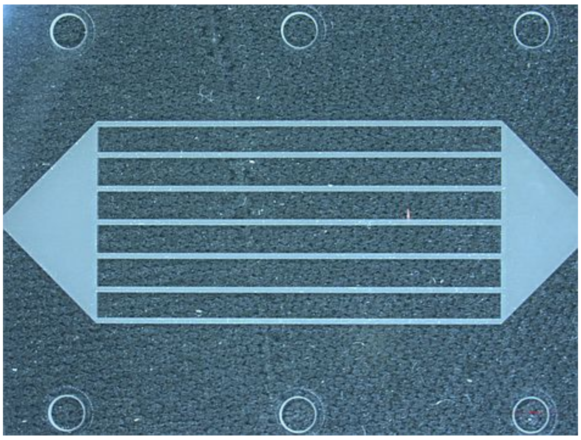


Figure 17: Borofloat® 33 drilling, thickness 0.5 mm

Some applications may also require an electrical sensor or heater directly on the glass-based microfluidic device. Removing sputtered or vapor deposited metals from the glass surface (Figure 18) is just one more common application of the LPKF ProtoLaser R4.

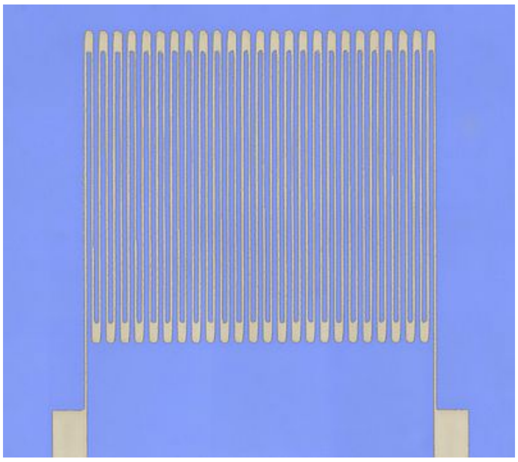


Figure 18: Structured deposited copper on glass

Conclusion

The LPKF ProtoLaser R4, laboratory class 1 laser system, can increase speed and freedom of processing glass-based microfluidic designs, especially in Boroflot® 33 and Mepax® glass from SHOTT. Channel structuring, drilling, and cutting can be processed in well under an hour for most designs. The additional ability to combine electrical circuit structuring into glass-based substrate applications opens the door to more innovations in lab-on-chip and MEMS applications.

About the LPKF ProtoLaser R4

The LPKF ProtoLaser R4 has been particularly developed for the innovative research with sensitive materials. With pico-second short laser pulses, it processes the substrates "cold" and thus particularly gentle. This allows the structuring of sensitive materials as well as the cutting of hardened or fired technical substrates. The precision laser system thus opens up new possibilities for micro-processing in laboratory experiments with completely new materials. The ProtoLaser R4 is a ready-to-use laser class 1 laboratory system and comes with intuitively operable CAM software.

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[i] *Wlodarczyk, K.L., Hand, D.P. & Maroto-Valer, M.M. Maskless, rapid manufacturing of glass microfluidic devices using a picosecond pulsed laser. Sci Rep* ***9,*** *20215 (2019).*

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