Laser Scribing of Sapphire Wafers and Display Glass with a Picosecond Fiber Laser

Laser scribing and dicing of extremely hard transparent materials such as display glass and sapphire wafers is a growing application space for laser microprocessing. These applications do not typically require lasers with immense pulse energy, but they do have incredible peak power requirements due to the need for nonlinear absorption in otherwise transparent materials without UV wavelengths and especially for bulk modification. These aspects make scribing of such hard transparent materials particularly well suited to Fianium's picosecond fiber lasers.

Fianium's high energy ultrafast fiber lasers produce picosecond pulses with energy up to 125µJ and ultra-high peak power on order of 1 megawatt, which is perfectly suited for nonlinear absorption in transparent materials. The lasers have tunable repetition rates from single shot on demand up to 40MHz, which makes them versatile tools for high-throughput scribing. The HE1060/532 provides the capability of inexpensive, maintenance-free, virtually defect-free scribing of hard sapphire wafers and tempered display glass.

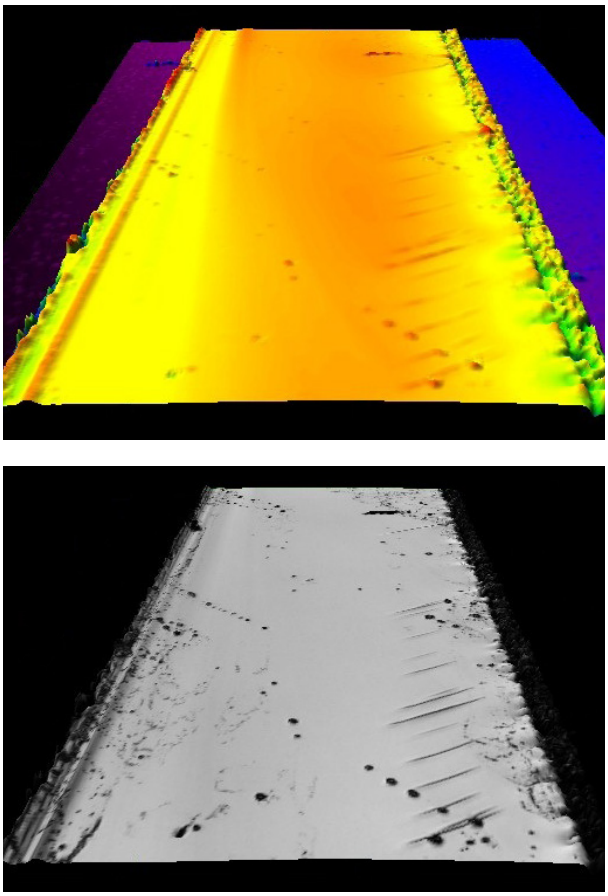
- Up to **125 µJ** pulse energy and **25W** average power
- Picosecond and femtosecond pulse widths
- Single-shot to **40MHz** variable repetition rate
- **1064 nm** or **532 nm** wavelength
- Designed for **24/7** operation and OEM integration
- Maintenance-free

Applications Lab

Fianium's application lab in Portland, Oregon is available for clients to evaluate the effectiveness of Fianium lasers for their custom application. We offer a host of micromachining application capabilities and an array of laser sources with pulsewidths spanning the entire picosecond regime.

Scribing of Sapphire For Wafer Dicing

The recent growth in both the high brightness LED and display glass markets has driven investment into new cutting and dicing technologies for such difficult to machine materials. Conventional scribing of such materials has been conducted using UV nanosecond lasers for surface scribing in a scribe and break style process. However, Fianium's ultrafast fiber lasers are capable of scribe and break processing of sapphire and tempered glass without the need for UV lasers. In fact, both green and IR wavelengths from Fianium's picosecond lasers have been used to create surface scribes in such materials as demonstrated in Figure 1.



Height map (top) and intensity (bottom) 3D images of the break edge of a 330 µm thick Sapphire wafer scribed on the surface with one of Fianium's high energy picosecond fiber lasers.

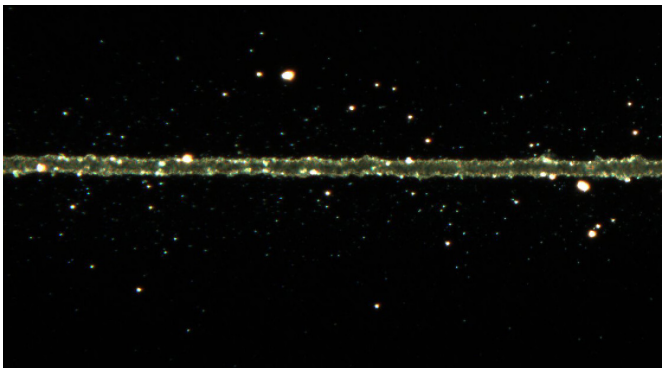


Figure 1. Dark field microscope image of a surface scribe of a sapphire wafer.

More recently, internal scribing has also become of interest and patents in this realm have been granted to several companies. We do not compare techniques, but can generally observe that the main benefit of this processing mode is that it generates no debris and thus does not require a post-processing wash step.

To create internal scribes the laser beam is focused into the bulk of the transparent material and causes a disruptive modified scribe zone typically on order of a few microns wide and a few tens of microns deep. This modified zone creates a line of weakness along the material with which to guide the break. Figure 2 shows the single-pulse internal modification zone created in tempered alumina-silicate glass using a Fianium picosecond fiber laser with a wavelength of 1064nm. Since the scribe is made internally, there is no processing debris to wash away unlike the surface scribe shown in Figure 1.

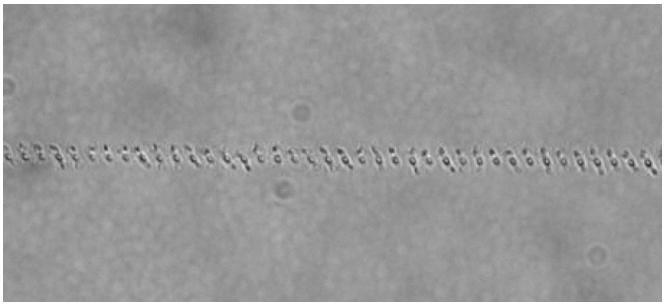


Figure 2. Transmission mode optical microscope image of an internal scribe in display glass.

UV lasers can be used for efficient surface scribing, but because the UV illumination is linearly absorbed at the surface it cannot be focused internally. Internal scribing requires nonlinear absorption of the laser energy at an internal focus in a material that is transparent to the laser energy. The requirement for nonlinear absorption in turn translates into the necessity of ultrafast pulses because of the immense peak power achievable with relatively moderate pulse energy or average power. For example, a 1µJ, 10ps pulse has the same peak intensity as a 100µJ, 1ns pulse, and thus suggests that using a nanosecond laser for this type of process would require orders of magnitude higher pulse energy relative to the requirements for picosecond lasers, which are capable of this process at only a few micro-Joules of pulse energy.

Materials such as sapphire and display glass are extremely hard and notoriously difficult to break effectively, but picosecond internal scribing and dicing can be a reliable process even in thick materials. For thick materials such as display glass, which are commonly up to 1mm thick, multiple scribe lines can be made along a single break plane to sufficiently weaken the material and reliably dice it as shown in the bottom of Figure 3.

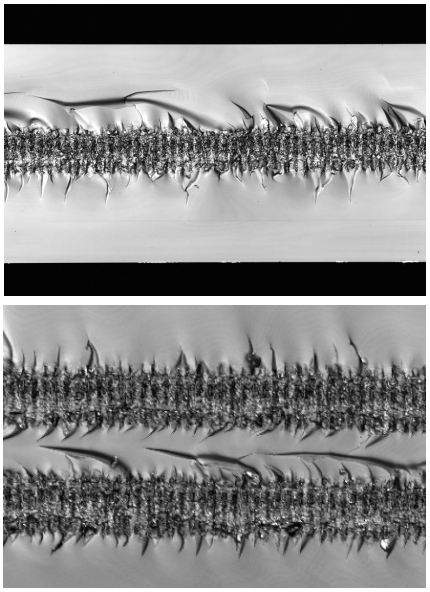


Figure 3. Microscope images of the break edge of 100 µm thick (top) and 330 µm thick (bottom) sapphire wafers. The wafers were internally scribed and the thicker wafer was double scribed for an easier and more reliable break.

Summary

Fianium's IR and green picosecond fiber lasers are suitable in a variety of laser microprocessing applications involving transparent materials, such a display glass and sapphire. The ultra-short pulsewidth provides the incredible peak power that allows for utilization of visible and IR lasers in a space conventionally filled by UV lasers, and opens up the new capability for improved surface and internal bulk material modification for scribing. Scribe and break procedures can be successfully conducted with lasers of both wavelengths in both surface and internal scribing modes. The high repetition rate of the lasers of up to 1MHz allows for incredibly high speed scribing in excess of 1m/s and for process parallelization. Fianium's ultrafast fiber lasers are air cooled and designed for zero-maintenance 24/7 operation in an industrial environment, which makes them the ideal tool for a whole host of microprocessing applications, especially sapphire and tempered glass dicing.