Basic Investigations on Laser Micromachining of Glass with sub 100 fs Pulses and an Industrial Grade Laser System

White Paper

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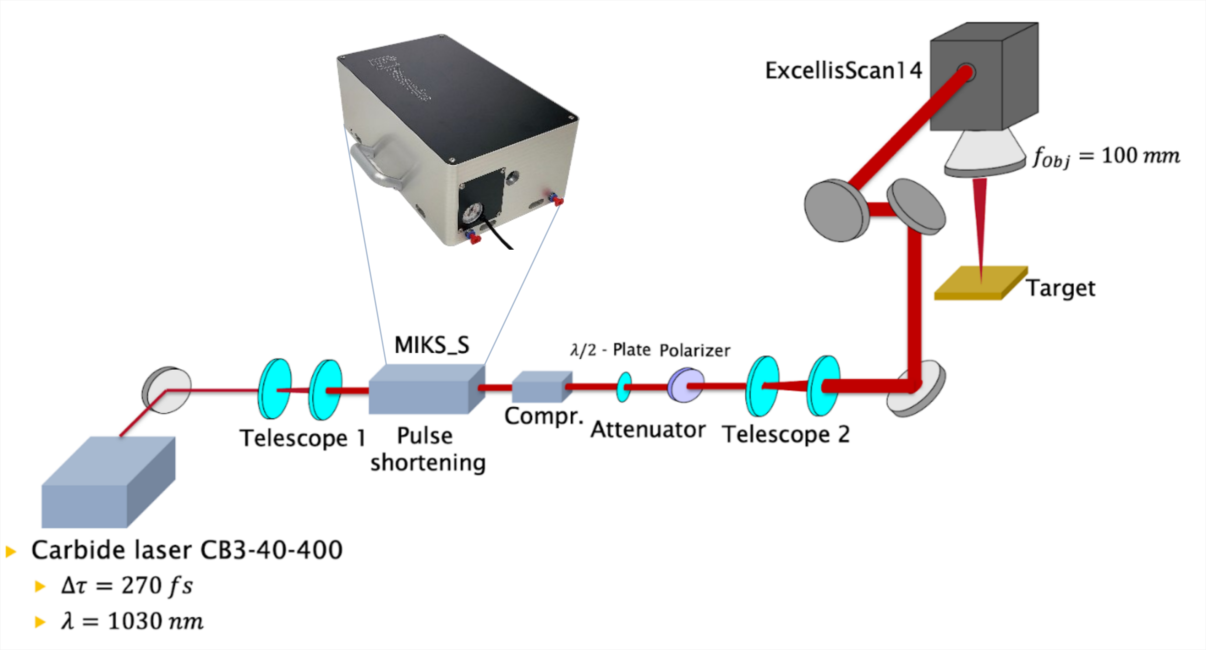
PROBLEM

For a long time, the sub-100 fs regime was only accessible with Ti: Sapphire laser systems. These laser systems enabled a lot of proof-of-principle experiments in research laboratory environments. However, real-world applications in industry were taken over by more reliable and economical Yb-based femtosecond lasers, which hardly reach 100 fs output pulse durations and normally run at 500-900 fs.

Are sub-100 fs going to be useful for material processing and ablation? In the first proof-of-principle experiments, we empirically show that the ablation of transparent materials can benefit from shorter pulses.

EXPERIMENTAL SETUP



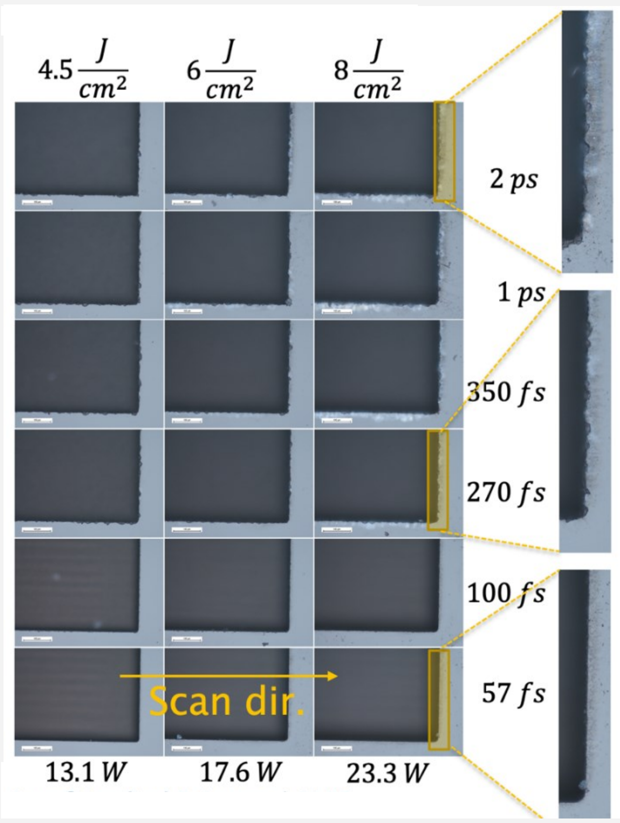
EXPERIMENTAL SETUP

Our experimental setup is described below. The output beam from Carbide laser (Light Conversion) is mode-matched to the MIKS1_S pulse shortening module from n2-Photonics. The output pulses of 250 fs are compressed below <50 fs at the output of MIKS1_S pulse shortening module. Afterwards we implement additional passive compressor or dispersion pre-compensation unit to make sure that after multiple optical elements, the output pulses are still compressed on the sample/target. Also, an attenuation unit is implemented consisting of a half-wave plate and a thin-film polarizer. Afterward, the beam is expanded and sent into the scanner head and f=100 mm f-theta objective. The main dispersion contribution comes from the f-Theta objective. The pulses after the f-Theta objective were measured to be 57 fs (Gauss fit). We did no further optimization of the pulse duration and proceeded with the experiments.

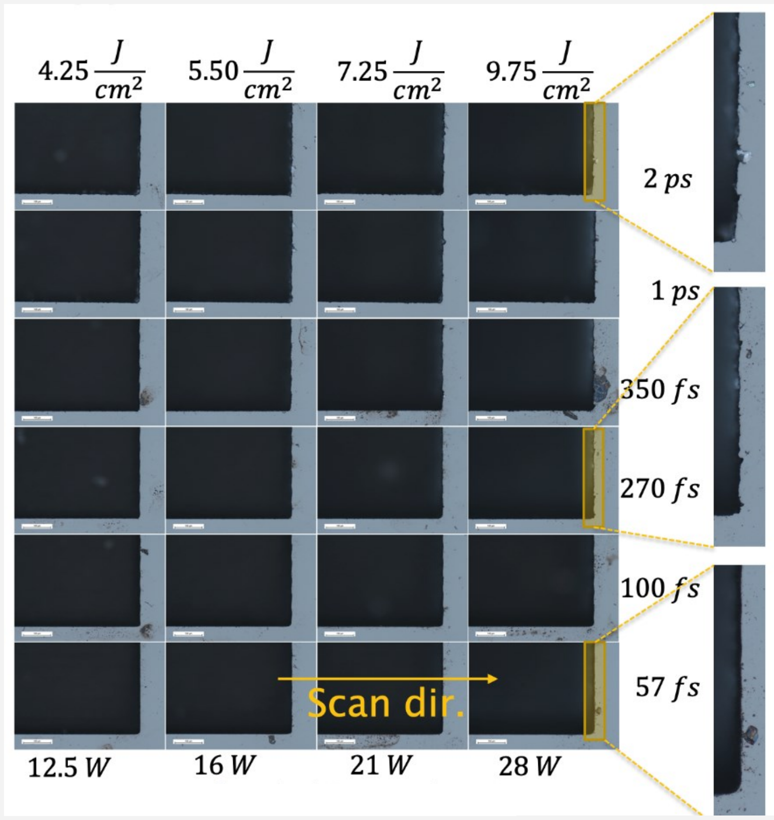
EXPERIMENTAL RESULTS

Preliminary experiments showed significant improvements in the ablation of transparent materials such as sapphire and UV-grade fused silica, particularly in edge quality, which demonstrated clean chipping-free edges. The spot beam radius on the sample was 15 micrometers. The light was circularly polarized. The laser repetition rate was fixed to 800 kHz and peak fluence increased from the threshold to several $J/cm2$. Squares of side length of 1 mm machined with spot and line distance p_x=p_y=5 μm and a fixed number of pulses per area. The scan speed was 4 m/s.

UV Grade Fused Silica



Sapphire



EXPERIMENTAL RESULTS

Main findings for both sapphire and fused silica ablation are:

- Significantly reduced ablation threshold for $\Delta\tau$=57 fs and $\Delta\tau$=100 fs.
- The roughness of the process stays almost constant for peak fluences above the threshold.
- Smaller for $\Delta\tau$=57 fs and $\Delta\tau$=100 fs.
- Edge quality massively improved for shorter pulse durations $\Delta\tau$=57 fs and $\Delta\tau$=100 fs.
- No visible chipping for pulse duration of 57 fs and average power of 28 W respectively 23.3 W
- Sub 100 fs pulses lead to high edge quality in combination with high average powers.

CONCLUSION

We demonstrated one of the experiments on ablating transparent materials such as sapphire, soda lime, and fused silica with pulses of around 50 fs duration. Significantly better edge quality could be achieved with ultrashort laser pulses. This was possible thanks to combining the industrial-grade laser from Light Conversion and the pulse shortening/compression module from n2-Photonics .

Thanks to Prof. Beat Neuenschwander for making those experiments happen, innovating and being excited about new applications.

Questions or interest in testing our technology?
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