Bulk Laser Damage Threshold of Optical Glasses

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Actual values of bulk laser damage thresholds of optical glass are rarely found in literature. Therefore SCHOTT has started a project for the characterization of the bulk laser damage threshold of various optical glasses over the wavelengths 532 nm and 1064 nm with pulse lengths in the pico- and nano-second range.

1 Introduction

Qioptiq F-Theta lenses are used for high power laser material processing like marking and structuring. Qioptiq offers lenses that can be used up to damage thresholds of 26 J/cm^2 at 1064 nm and 12 ns pulse width. The main damage risks are reflecting laser beams from the work piece that focus inside the lens system. Therefore not only the surface damage threshold is relevant but also the bulk damage threshold of the lens materials being used. Fused silica is currently the material of choice for such kind of lenses because of its reputation high laser damage thresholds (LIDT). Nevertheless there are disadvantages for the use of fused silica in such applications: The design is limited to the low refractive index of fused silica. Another disadvantage of fused silica is its price. Many advantages could be gained by using high refractive index glasses in F-Theta lens designs. In principle the maximum energy densities of the reflected beams inside the lenses are known from calculation. Therefore the lens designer could build alternative designs if he knows the limit LIDT values of the glasses being used. The target of this work was therefore to provide LIDT data for a broad range of optical glass types at the most common laser damage laser wavelengths and pulse widths.

2 Optical glass and LIDT test parameter choice

532 nm and 1064 nm are among the most commonly used laser wavelengths in pulsed laser material processing. The typical pulse lengths are in the ns and ps range (up to fs). We chose a pulse width of 10 to 12 ns and 74 ps. The glasses tested are N-BK7, N-FK5, F2, N-LAF21, N-LASF44 and SF6. As reference fused silica material Suprasil CG (standard grade) was being used (the same quality that can usually be found in the F-Theta lens setups).

The LIDT testing was done at the Laser Zentrum Hannover (LZH) according to the DIN ISO 21254.

The sample size was 30 x 30 x 35 mm polished on all surfaces. The laser beam was focused using an F-Theta-Ronar lens with 255 mm focal length. The incoming beam diameter of 5-6 mm (532 nm) and 10 mm (1064 nm) was focused to an effective spot diameter of 33 to 41 µm depending on the wavelength. The focus was placed into the center of the sample. The maximum peak intensity fraction between surface and bulk was 1:130 to assure that the material got damaged in the bulk of the material and not on the surface. 150 test sites were used with a maximum of 2000 shots (ps-range) and 10000 shots (ns-range). The distance between the test sites was 1.7 mm. The statistical evaluation was done according to ISO 21254-2.

3 Results for ps pulse width

The results are displayed in diagrams of energy density in J/cm^2 over the number of pulses. Additionally the extrapolated LIDT values for 1 pulse (H_{1on1}) and infinite pulses (H_{inf}) are shown. Figure 1 shows the results for N-BK7 at 1064 nm wavelength and 74 ps pulse width and figure 2 the results for N-FK5. Surprisingly N-BK7 and N-FK5 show very similar behavior compared to Suprasil with respect to the test conditions, which is shown in table 1.

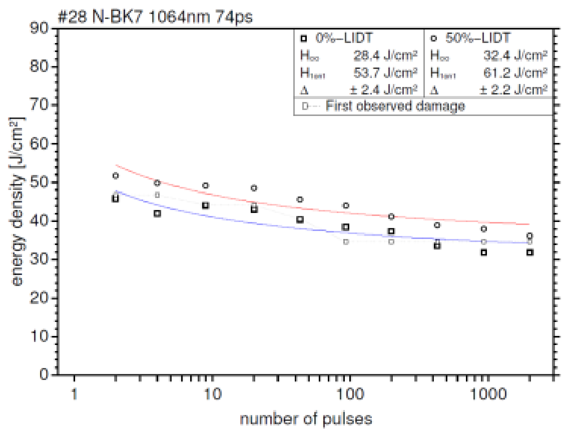

Fig. 1 LIDT results for N-BK7 at 1064 nm wavelength and 74 ps pulse width.

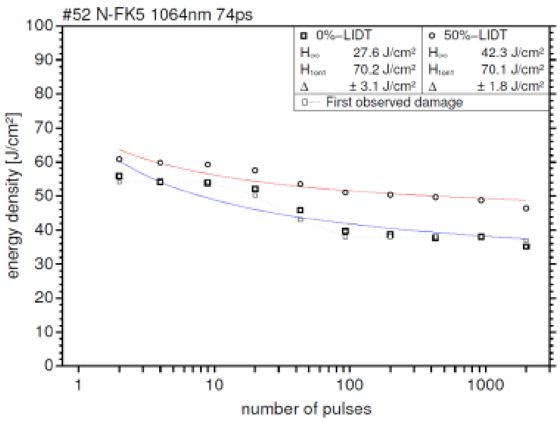

Fig. 2 LIDT results for N-FK5 at 1064 nm wavelength and 74 ps pulse width.

[J/cm2] 2000 shots @74 ps	1064 nm	532 nm
N-BK7	31,8	8,2
N-FK5	35,2	9,7
F2	16,7	3,6
N-LASF44	13,8	3,7
N-LAF21	12,6	4,7
SF6	6,4	tbd
Suprasil	39,2	11

***Tab. 1** Comparison of results for ps pulse width.*

Table 1 shows the results at 74 ps pulse width and 2000 shots for all tested glass types in comparison. Also at 532 nm N-BK7 and N-FK5 show very good behavior compared to Suprasil. The high refractive index glasses have lower LIDT values than N-BK7 or fused silica. Among the tested high refractive index glasses N-LASF44 and N-LAF21 show twice as large LIDT values compared to SF6.

4 Results for ns pulse width

The results in the ns pulse width range are still preliminary because the measurements are ongoing. Figure 4 shows the actual results. It was very surprising that the values for N-BK7 and N-FK5 were much larger than the values for Suprasil. The N-BK7 results are very high but comparable to results reported by the Sandia national laboratories [1]. Figure 5 shows a picture of a N-BK7 sample after the test. The damage sites are clearly visible. However, these results are still preliminary and incomplete. More details will be reported in the future.

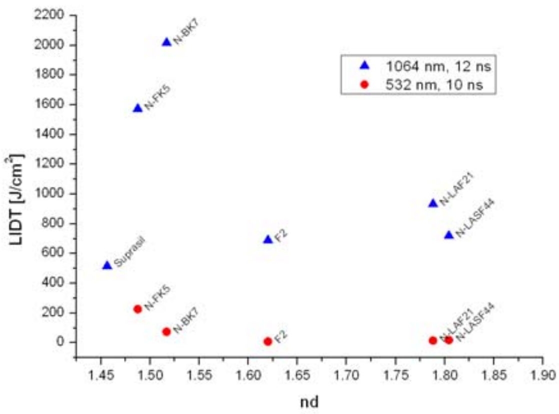

Fig. 3 LIDT results in the ns pulse width range (ongoing).

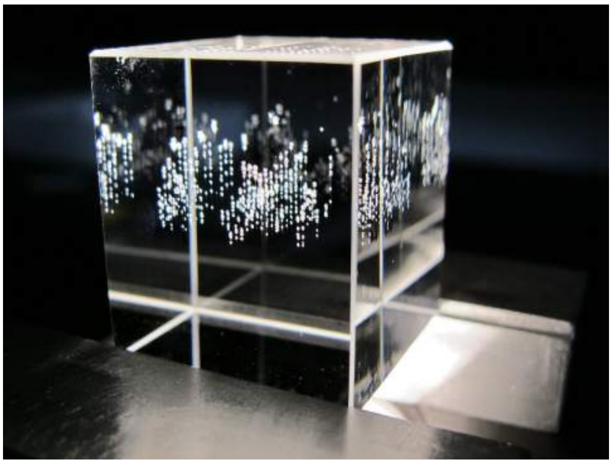

Fig. 5 N-BK7 LIDT sample treated at 532 nm and 10 ns pulse width.

5 Summary

Bulk LIDT plays an important role in the design of F-Theta lenses that need to be robust against reflected laser beams. Based on the gathered data it is possible to optimize the design of F-Theta lenses with respect to performance and cost. N-BK7 and N-FK5 seem to be alternatives to fused silica. N-LASF44 and N-LAF21 do have higher LIDT values than flint glasses like SF6.

6 Acknowledgement

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References

[1] Kimmel, Do, Smith; "Deterministic single shot and multiple shot Bulk laser damage threshold of borosilicate glass at 1.064 µm", Proc. of SPIE Vol. 8190