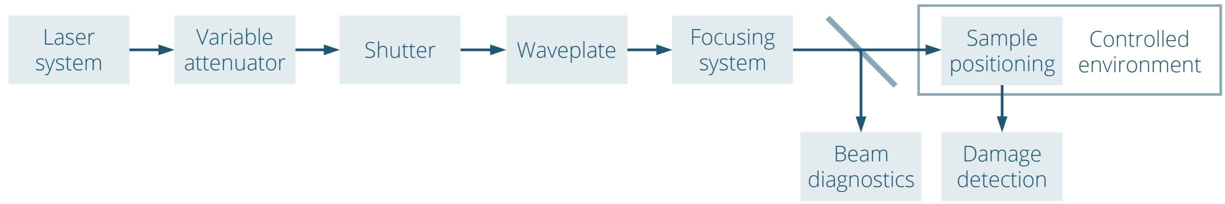
TEST EQUIPMENT

Test setup

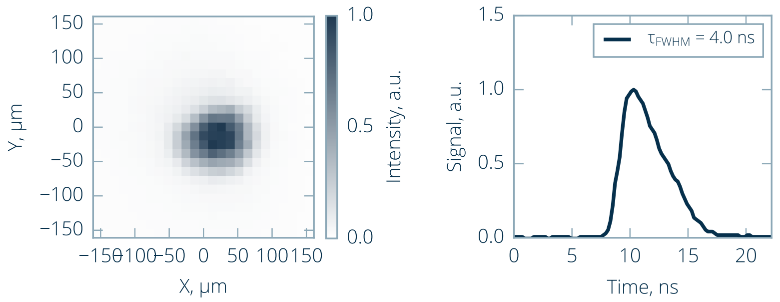


Laser and its parameters

Type	Q-switched, seeded Nd:YAG
Manufacturer	InnoLas Laser
Model	SpitLight Hybrid
Central wavelength	2090.0 nm
Angle of incidence	45.0 deg
Polarization state	Linear S
Pulse repetition frequency	100 Hz
Spatial beam profile in target plane	Near Gaussian
Beam diameter in target plane ($1/e^2$)	(147.3 ± 5.0) µm
Longitudinal pulse profile	Single longitudinal mode
Pulse duration (FWHM)	(4.0 ± 0.3) ns
Pulse to pulse energy stability (SD)	1.3 %

Energy/power meter

Manufacturer	Ophir
Model	PE50-DIF-C
Calibration due date	2021-06-01



(a) Beam profile (b) Pulse profile

Figure 1. Laser parameters used for measurements.

TEST SPECIFICATION

Definitions and test description

Laser-induced damage (LID) is defined as any permanent laser radiation induced change in the characteristics of the surface/bulk of the specimen which can be observed by an inspection technique and at a sensitivity related to the intended operation of the product concerned. Laser-induced damage threshold (LIDT) is defined as the highest quantity of laser radiation incident upon the optical component for which the extrapolated probability of damage is zero. [1]

LID of the sample is investigated by performing a standardized S-on-1 test procedure.[2]
LIDT value is determined by fitting experimental damage probability data with a model derived for a Poisson damage process assuming degenerate defect ensemble. [3]

Test sites

Number of sites	214
Arrangement of sites	Hexagonal
Minimum distance between sites	450 µm
Maximum pulses per site	1000

Analysis information

Online detection	Scattered light diode
Offline detection	Nomarski microscope
Software version	3d30819 - a465db1

Test environment

Environment	Air
Cleanroom class (ISO 14644-1)	ISO7
Pressure	1 bar
Temperature	22.2 - 22.4 C
Humidity	30.0 - 30.3 %

Sample preparation

Storage before test	Normal laboratory conditions
Dust blow-off	Compressed air
Cleaning	Isopropanol

[1] ISO 21254-1:2011: Lasers and laser-related equipment - Test methods for laser-induced damage threshold - Part 1: Definitions and general principles, International Organization for Standardization, Geneva, Switzerland (2011)
[2] ISO 21254-2:2011: Lasers and laser-related equipment - Test methods for laser-induced damage threshold - Part 2: Threshold determination, International Organization for Standardization, Geneva, Switzerland (2011)
[3] J. Porteus and S. Seitel, Absolute onset of optical surface damage using distributed defect ensembles, Applied Optics, 23(21), 3796–3805 (1984)

LIDT TEST RESULTS

LIDT VALUE

10^3-on-1	$14.0^{+3.7}_{-13.8}$ J/cm^2 [4]	$22.1^{+5.9}_{-21.8}$ J/cm^2 (scaled to 10.0 ns) [4]

CHARACTERISTIC DAMAGE CURVE

Table 1: Estimated LIDTs from fiting model for sample M0001948 LOT0068618 ID 71473.

Test mode	Threshold (Offline detection - microscopy)	Threshold (Offline detection - microscopy) scaled to 10.0 ns	Threshold (Online detection - scattering) [5]	Threshold (Online detection - scattering) scaled to 10.0 ns
10-on-1	-	-	> $18.2^{+2.5}_{-2.5}$ J/cm^2	> $28.8^{+4.0}_{-4.0}$ J/cm^2
10^2-on-1	-	-	> $18.2^{+2.5}_{-2.5}$ J/cm^2	> $28.8^{+4.0}_{-4.0}$ J/cm^2
10^3-on-1	$14.0^{+3.7}_{-13.8}$ J/cm^2	$22.1^{+5.9}_{-21.8}$ J/cm^2	> $18.2^{+2.5}_{-2.5}$ J/cm^2	> $28.8^{+4.0}_{-4.0}$ J/cm^2

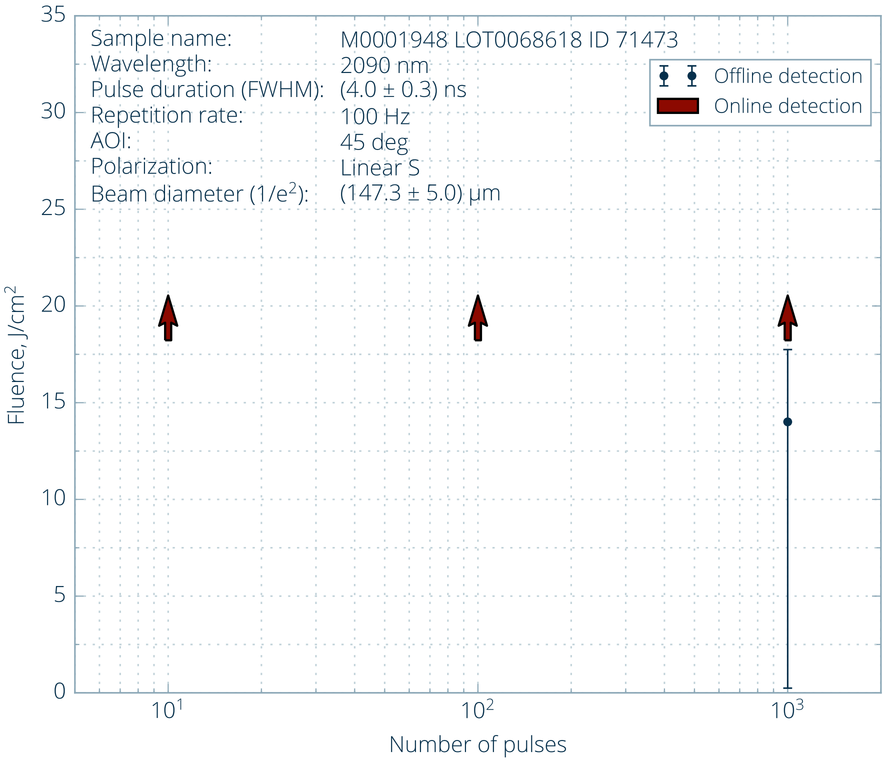
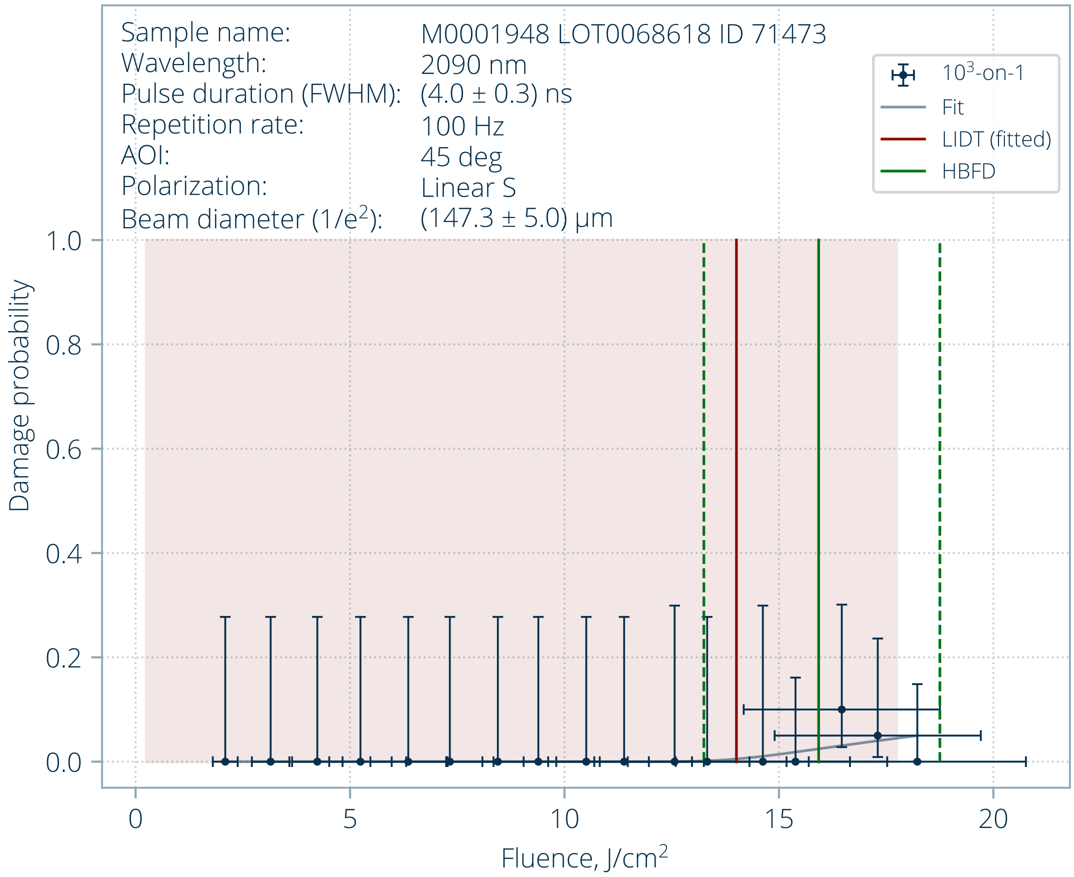


Figure 2. Characteristic damage curve.

[4] LIDT value is inaccurate due to low defects density on the Front surface. Read Technical Note 1.
[5] Read Technical Note 2

DAMAGE PROBABILITY (OFFLINE DETECTION)



(a) 10^3-on-1

Figure 3. Damage probability plot. [6]

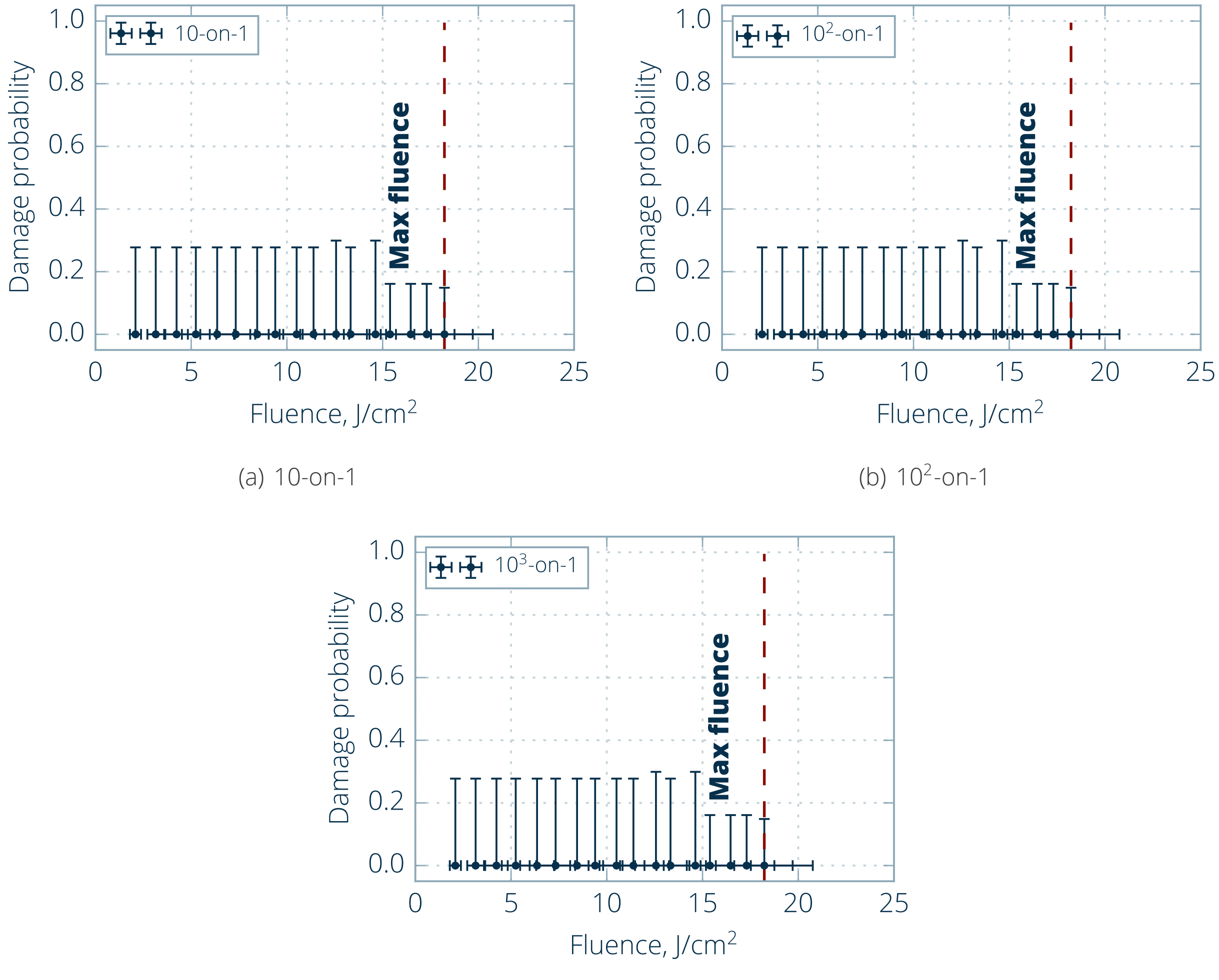
[6] Read Technical Note 3

TYPICAL DAMAGE MORPHOLOGY (OFFLINE DETECTION)

Figure 4. Typical damage morphology: fluence 16.3 J/cm^2, damage after 1000 pulse(s).

Figure 5. Typical damage morphology: fluence 17.4 J/cm^2, damage after 1000 pulse(s).

DAMAGE PROBABILITY (ONLINE DETECTION)



(a) 10-on-1

(b) 10^2-on-1

(c) 10^3-on-1

Figure 6. Damage probability plots. [6]

HIGHEST THRESHOLD BEFORE FIRST DAMAGE CURVE (NOT ISO STANDARD)

Table 2: Estimated thresholds as HBFD for sample M0001948 LOT0068618 ID 71473.

Test mode	Threshold (Offline detection - microscopy)	Threshold (Offline detection - microscopy) scaled to 10.0 ns	Threshold (Online detection - scattering)	Threshold (Online detection - scattering) scaled to 10.0 ns
10-on-1	-	-	-	-
10^2-on-1	-	-	-	-
10^3-on-1	$15.9^{+2.8}_{-2.7}$ J/cm^2	$25.2^{+4.5}_{-4.2}$ J/cm^2	-	-

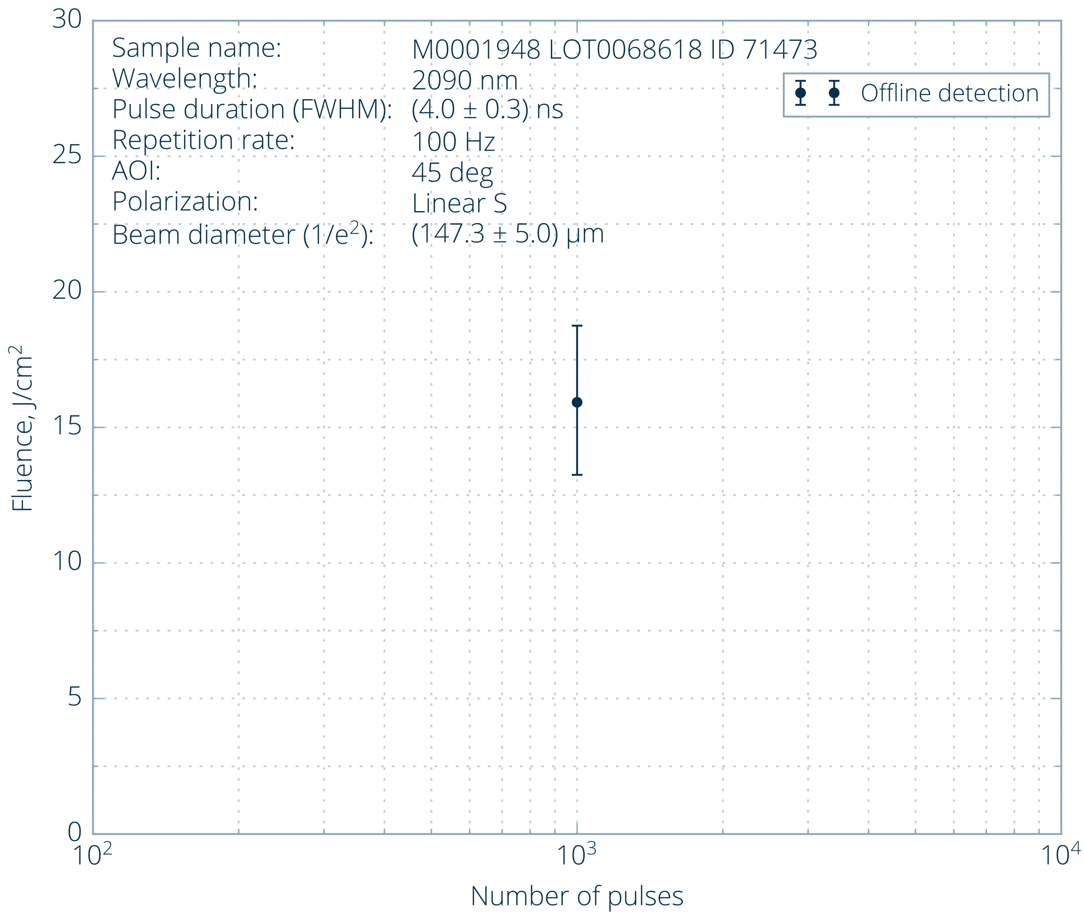


Figure 7. Highest threshold before first damage curve. [7]

[7] Read Technical Note 3

TECHNICAL NOTES

TECHNICAL NOTE 1: Low defects density on the Front surface

Density of surface defects in the sample was very low. In these conditions standardized S-on-1 test procedure results are inconclusive, as using S-on-1 test procedure only small fraction of sample surface is tested. In this particular case rare defect density damage probabilities are always low, thus there is high risk that surface defects are not exposed with the laser radiation. Accordingly, fitting low damage probabilities with a model derived for a Poisson damage process assuming degenerate defect ensemble leads to inaccurate estimation of LIDT and large error bars.
To sum up, standardized S-on-1 test procedure results inconclusive LIDT. Raster scan procedure is recommended for proper LIDT determination in such cases (please contact us for more details).

TECHNICAL NOTE 2: No damages were found

No damages were found for this type of analysis, therefore, LIDT value could not be evaluated. LIDT value should be higher than maximum fluence value used in the test. This fluence value is written in the thresholds table.

TECHNICAL NOTE 3: Non standard HBFD threshold estimation

HBFD (Highest Before First Damage) values represent threshold values determined by taking the average of the highest fluence value before which no damage was observed and the lowest fluence value at which damage was first observed. This value is not ISO standard threshold and it should be considered as complimentary information. It was included in the report because error of the highest pulse class LIDT value exceeded 30%.

TECHNICAL NOTE 4: Oblique incidence

According to the ISO 21254-2:2011 standard, for spatial beam profiling perpendicular to the direction of beam propagation and angles of incidence differing from 0 degrees, the cosine of the angle of incidence is included in the calculation of the effective area, which leads to correct evaluation of laser fluence at different angles of incidence (Figure 8).

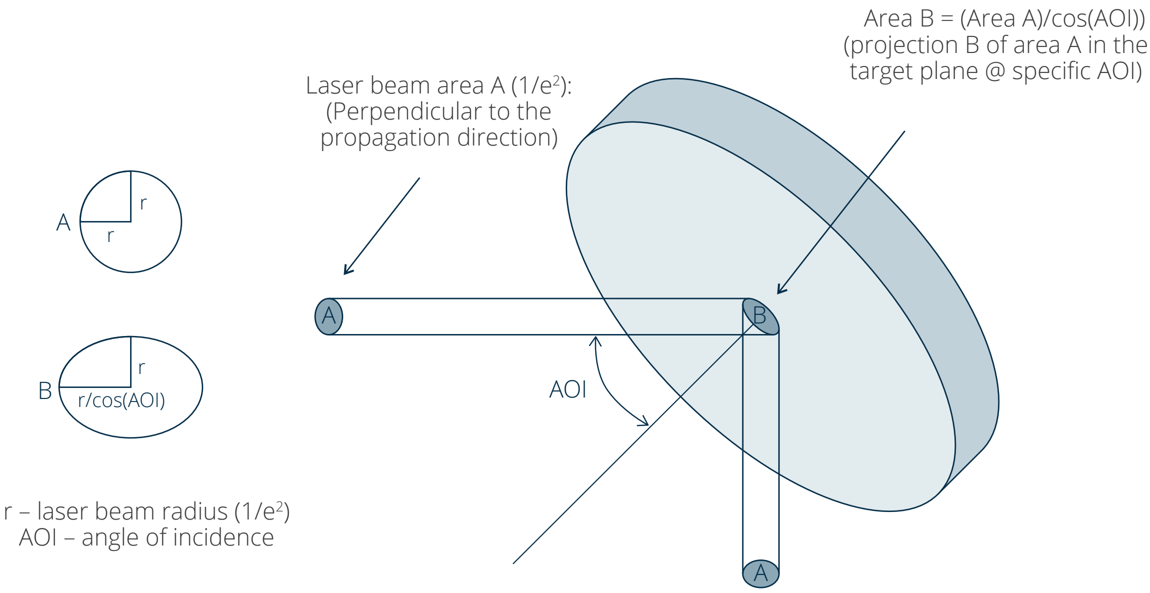


Figure 8. Oblique incidence.