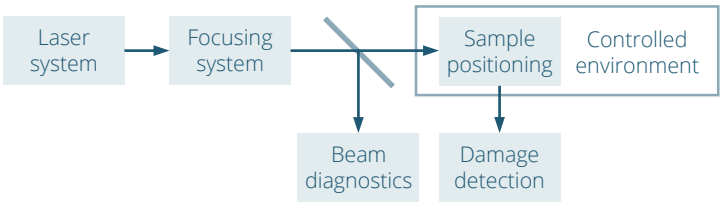
TEST EQUIPMENT

Test setup

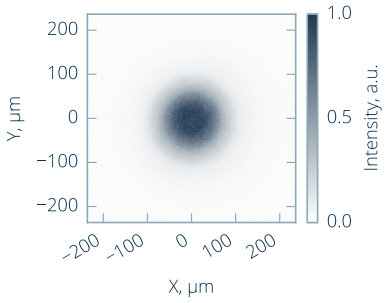


Laser and its parameters

Type	Continuous wave Yb:fiber laser
Manufacturer	IPG
Model	YLS6000-U
Central wavelength	1070.0 nm
Angle of incidence	45.0 deg
Polarization state	Random
Spatial beam profile in target plane	Near flat-top
Beam diameter in target plane (effective)	152.0 - 156.2 µm
Beam diameter stability	< 2.26 %
Longitudinal pulse profile	CW
Power stability	< 1.82 %

Energy/power meter

Manufacturer	Ophir
Model	10K-W-BB-45-V3
Calibration due date	2021-02-01



(a) Beam profile

Figure 1. Laser parameters used for measurements.

LIDARIS
LIDT Service

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. [1]
LIDARIS' RASTER SCAN test procedure involves exposure of pre-defined surface region with spatially overlapping test sites so that 90% of onset peak irradiance coverage is guaranteed. For every new scan, the irradiance is ramped up until damage criteria or maximum available peak irradiance of the test system is reached.
Laser-induced damage threshold (LIDT) is defined as the average irradiance of lowest observed damaged level and first undamaged level below.

Test specification

Area tested per scan level ($1/e^2$ beam intens. level)	1.06 cm^2
Area tested per scan level relative to clear aperture	20.84 %
Scan speed in x-direction	7.99 mm/s
Beam overlap in y-direction	68 % of effective beam diameter (90% intensity level)
First irradiance level	0.062 kW/cm^2
Irradiance level step	26 % increase for every subsequent level
Irradiance levels	6
Irradiance level scan duration	300 s

Analysis information

Offline detection	Nomarski microscope
Software version	7957275 - 53e7367

Test environment

Environment	Air
Cleanroom class (ISO 14644-1)	ISO8
Pressure	1 bar
Temperature	22 C
Humidity	24 %

Sample preparation

Storage before test	Safe
Dust blow-off	Compressed air
Cleaning	Ethanol

[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)

LIDT TEST RESULTS

LIDT VALUE

Lidaris' Raster Scan	$0.134\ ^{+0.024}_{-0.020}$ MW/cm^2	$1.62\ ^{+0.26}_{-0.23}$ kW/cm

Table 1: Evaluated Lidaris' Raster scan LIDT for sample 71960.

Analysed Threshold type	Threshold	
Damage initiation	$0.134\ ^{+0.024}_{-0.020}$ MW/cm^2	$1.62\ ^{+0.26}_{-0.23}$ kW/cm
Catastrophic failure	$0.174\ ^{+0.037}_{-0.032}$ MW/cm^2	$2.09\ ^{+0.39}_{-0.35}$ kW/cm

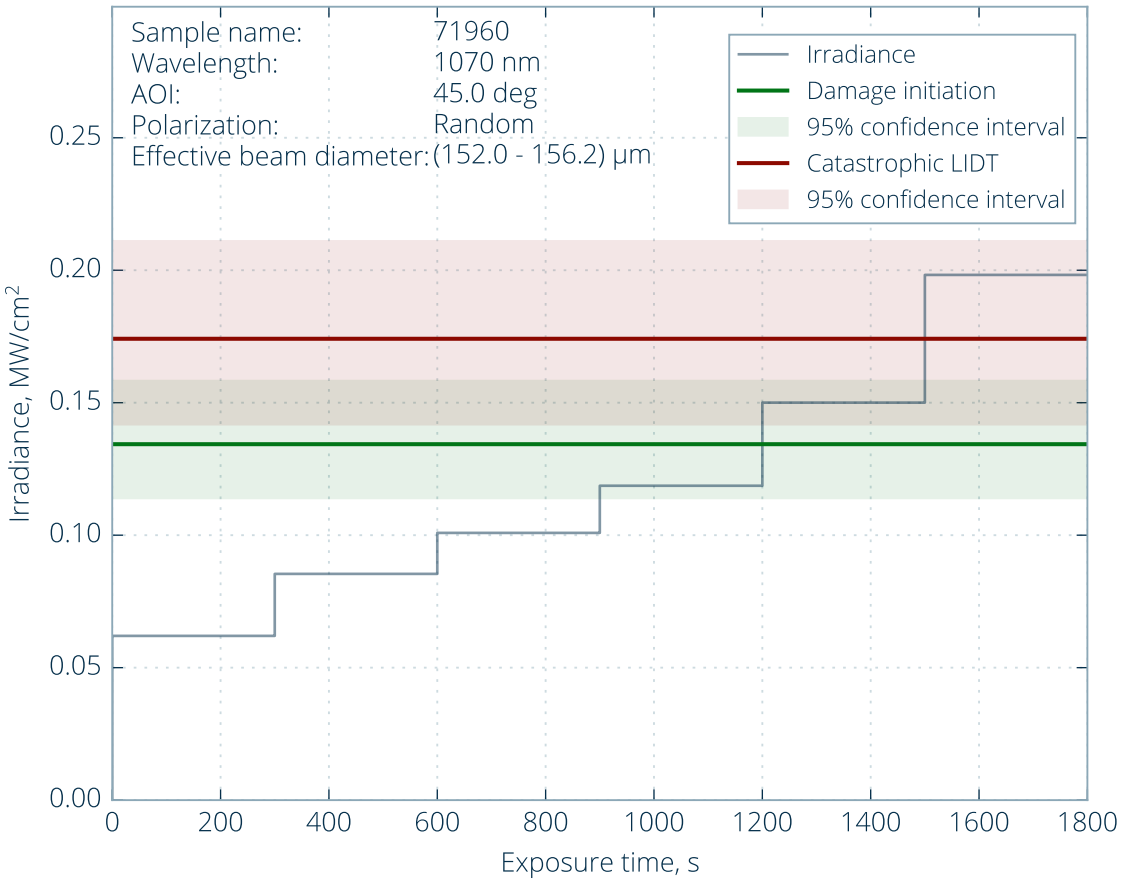


Figure 2. Raster scan test results.

NEW OBJECTS DISTRIBUTION

Microscopic images are taken before the test and after each new scan. All images are analyzed for new objects (defects). A figure of new object distribution displays the cumulative distribution of objects exceeding defined object size for each new scan level. New objects are defined as objects, that can be distinguished from surrounding area while applying various image analysis methods.

Due to variability in sample initial preparation condition (cleaning) and complexity in image analysis tools, there exists some "noise level" that can be seen at low irradiance levels. At higher irradiance levels, where counts of new objects increase exponentially, the majority of new objects can be attributed to laser-induced damages of ablation products. The cumulative sum of all found objects is calculated for each irradiance level. The apparent area of the object is approximated with the circle and turned into the effective diameter. The size of the object is calculated as the diameter of that circle, independently of the shape of the object.

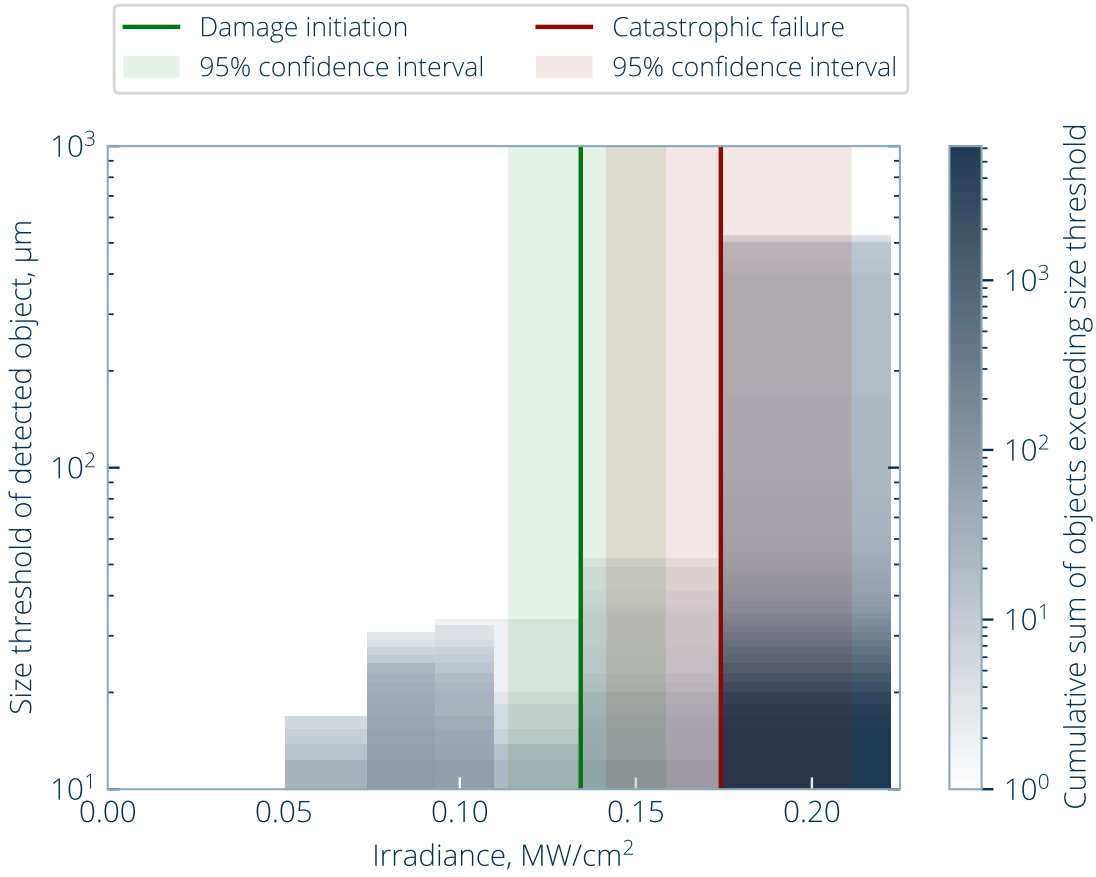


Figure 3. New objects distribution.

IRRADIANCE LEVELS

Table 2: Lidaris' Raster scan irradiance levels for sample 71960.

Level	Irradiance, MW/cm^2	Linear power density, kW/cm	Status [2]
1	0.0620	0.749	Passed
2	0.0854	1.03	Passed
3	0.101	1.21	Passed
4	0.119	1.43	Passed
5	0.150	1.81	Damage initiation
6	0.198	2.38	Catastrophic failure

SCANNED SAMPLE AREA

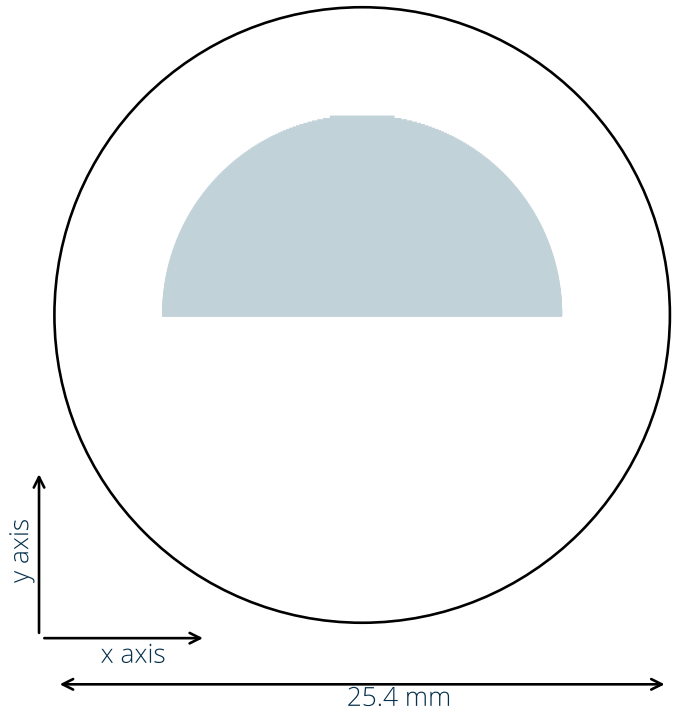


Figure 4. Scanned sample area.

[2]Read Technical Note 1

TYPICAL DAMAGE MORPHOLOGY (INITIATION)

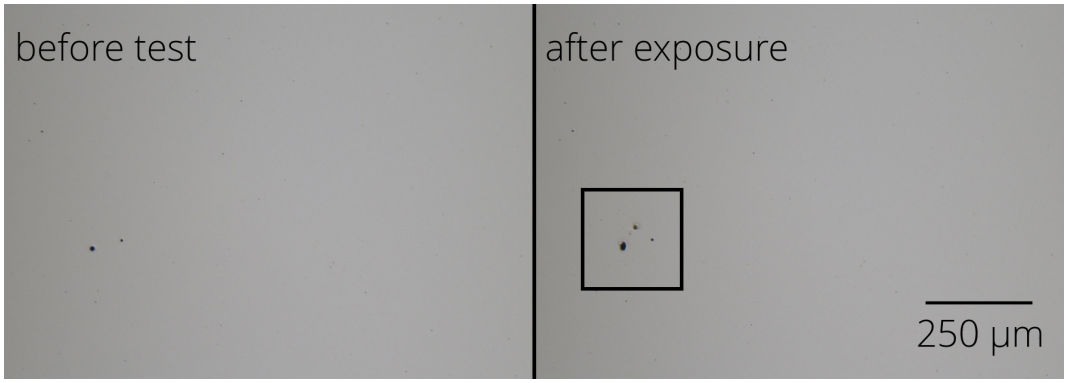


Figure 5. Typical damage morphology: irradiance 0.150 MW/cm^2.

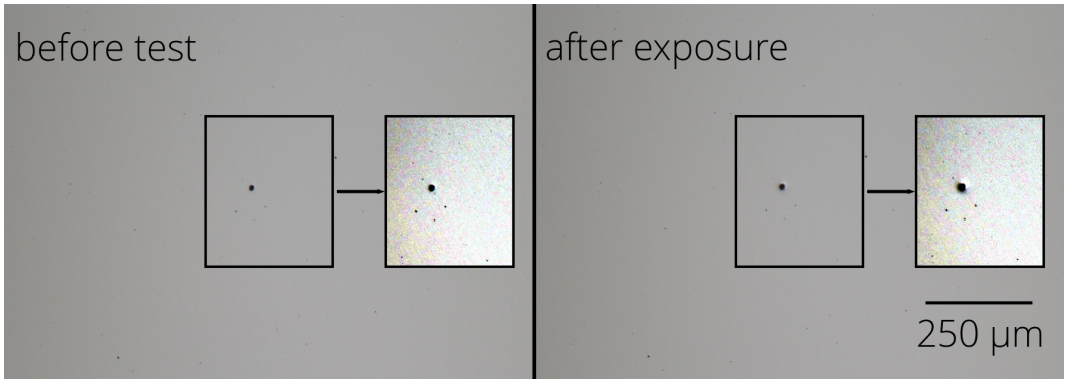


Figure 6. Typical damage morphology: irradiance 0.150 MW/cm^2. High contrast image.

TYPICAL DAMAGE MORPHOLOGY (CATASTROPHIC)

Figure 7. Typical damage morphology: irradiance 0.198 MW/cm^2.

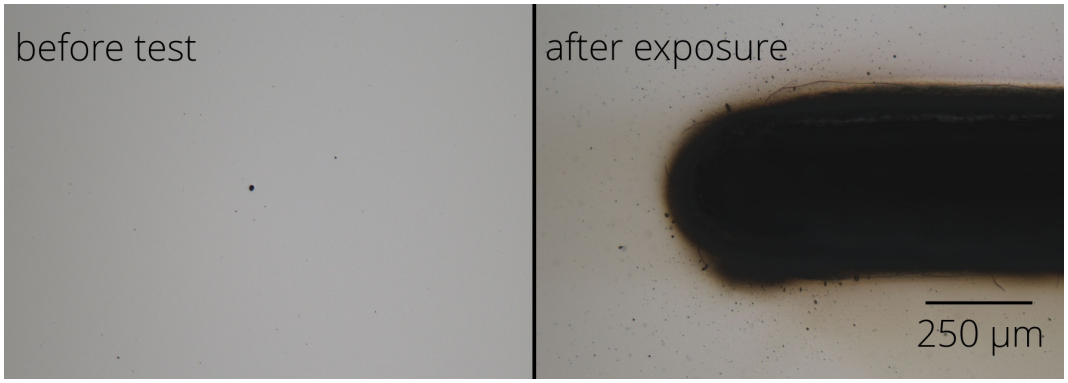


Figure 8. Typical damage morphology: irradiance 0.198 MW/cm^2.

TECHNICAL NOTES

TECHNICAL NOTE 1: Lidaris' Raster scan statuses

Performing Lidaris' Raster scan test scanned area is imaged with Nomarski microscope (10x) after each irradiance level. Using additional image analysis tools each irradiance level is labeled with one of the following statuses:
Passed – no apparent change in morphology was observed.
Laser cleaning – dust or other artificial object was cleaned with laser radiation and, as a result, sample surface might be affected by plasma scalding. It is assumed that sample survived specific irradiance radiation.
Damage initiation – minor damages (small pin-points, smooth color changes, etc.) occurred. In general, they might not affect spatial properties of laser beam that irradiates the optical element but these damages can grow into further upon laser exposure.
Catastrophic failure – clearly observed damage that is bigger than 100 µm or the damage that experienced exponential or asymmetric growth after scanning the surface with higher irradiances.

TECHNICAL NOTE 2: 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 irradiance at different angles of incidence (Figure 9).

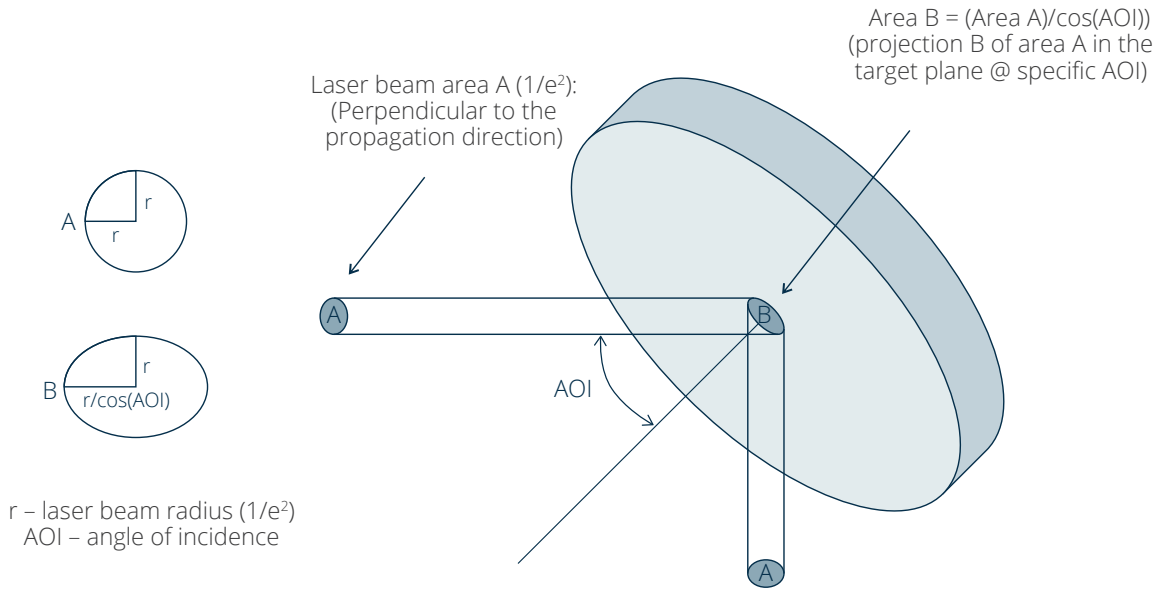


Figure 9. Oblique incidence.