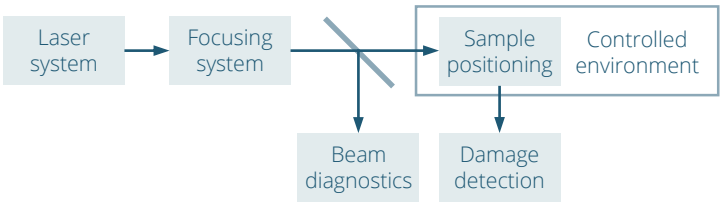
LIDARIS
LIDT Service

TEST EQUIPMENT

Test setup

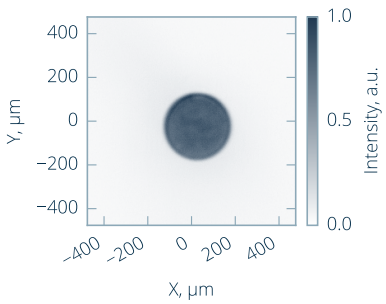


Laser and its parameters

Type	Continuous wave Yb:fiber laser
Manufacturer	IPG
Model	YLS6000-U
Central wavelength	1070.0 nm
Angle of incidence	12.0 deg
Polarization state	Random
Spatial beam profile in target plane	Near flat-top
Beam diameter in target plane (effective)	(306.8 ± 6.8) µm
Longitudinal pulse profile	CW
Power stability	0.2 %

Energy/power meter

Manufacturer	Ophir
Model	10K-W-BB-45-V3
Calibration due date	2023-03



(a) Beam profile

Figure 1. Laser parameters used for measurements.

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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)	1.01 cm^2
Area tested per scan level relative to clear aperture	19.84 %
Scan speed in x-direction	15.97 mm/s
Beam overlap in y-direction	36 % of effective beam diameter
First irradiance level	0.00570 MW/cm^2
Irradiance level step	21 % increase for every subsequent level
Irradiance levels	31
Irradiance level scan duration	34 s

Analysis information

Online detection	Scattered light diode
Offline detection	Nomarski microscope
Software version	51a711d

Test environment

Environment	Air
Cleanroom class (ISO 14644-1)	ISO7
Pressure	1 bar
Temperature	22.9 - 23.9 C
Humidity	48.3 - 51.2 %

Sample preparation

Storage before test	Normal laboratory conditions
Dust blow-off	None
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)

LIDT TEST RESULTS

LIDT VALUE

	Irradiance	Linear power density
Lidaris' Raster Scan	$> 7.98\ ^{+0.75}_{-0.75}$ MW/cm^2	$> 198.4\ ^{+9.4}_{-9.4}$ kW/cm

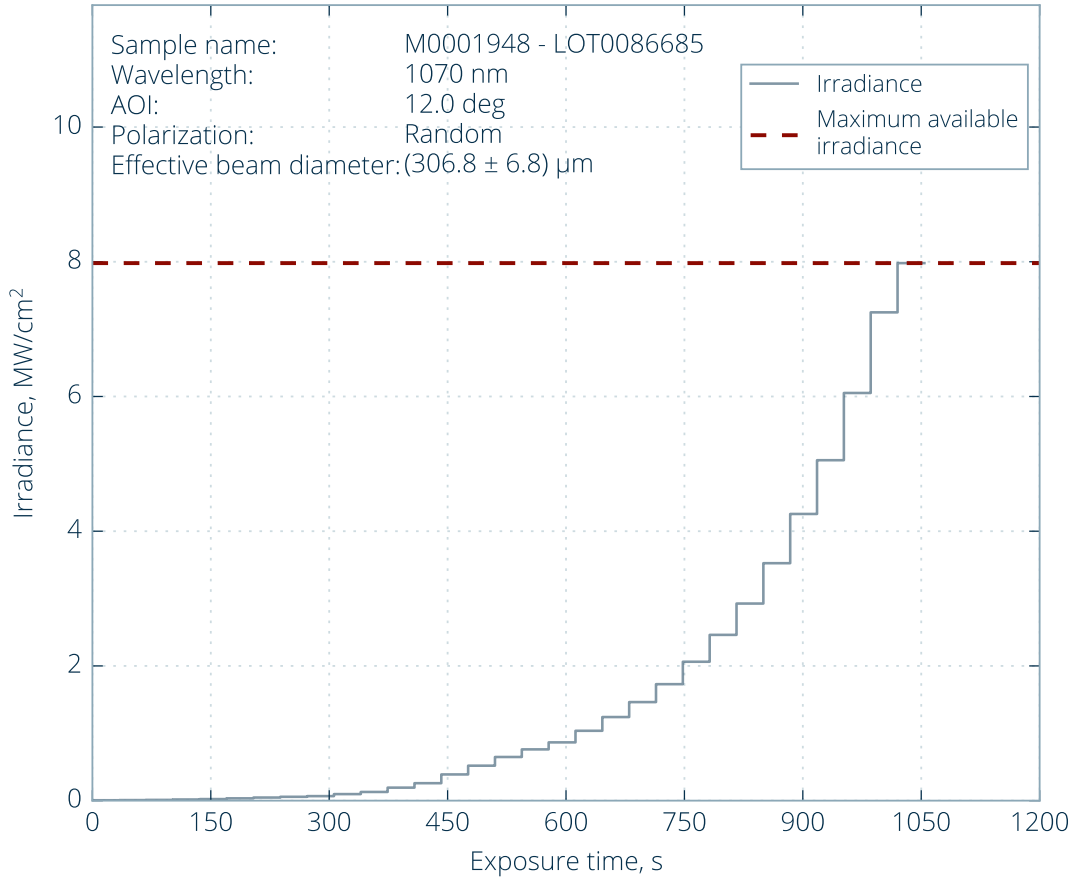

Figure 2. Raster scan test results.

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.

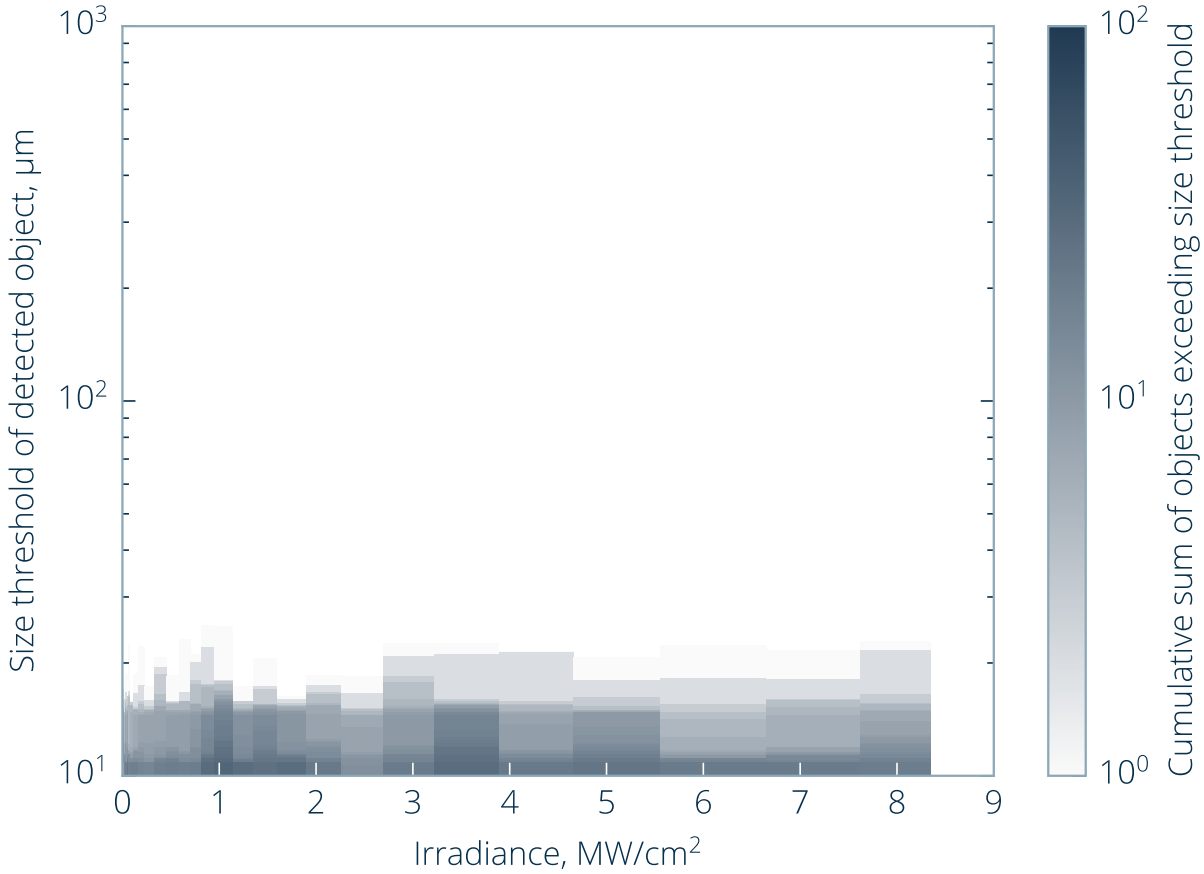

Figure 3. New objects distribution.

IRRADIANCE LEVELS

Table 1: Lidaris' Raster scan irradiance levels for sample M0001948 - LOT0086685.

Level	Irradiance, MW/cm[2]	Linear power density, kW/cm	Status [2]
1	0.00570	0.142	Passed
2	0.00800	0.199	Passed
3	0.0110	0.274	Passed
4	0.0170	0.423	Passed
5	0.0230	0.572	Passed
6	0.0340	0.845	Passed
7	0.0460	1.14	Passed
8	0.0570	1.42	Passed
9	0.0670	1.67	Passed
10	0.0970	2.41	Passed
11	0.129	3.21	Passed
12	0.193	4.80	Passed
13	0.259	6.44	Passed
14	0.389	9.67	Passed
15	0.519	12.9	Passed
16	0.648	16.1	Passed
17	0.761	18.9	Passed
18	0.865	21.5	Passed
19	1.04	25.8	Passed
20	1.24	30.9	Passed
21	1.46	36.4	Passed
22	1.73	43.0	Passed
23	2.06	51.3	Passed
24	2.46	61.2	Passed
25	2.93	72.8	Passed
26	3.52	87.7	Passed
27	4.26	106	Passed
28	5.05	126	Passed
29	6.05	150	Passed
30	7.25	180	Passed
31	7.98	198	Passed

[2]Read Technical Note 1

SCANNED SAMPLE AREA

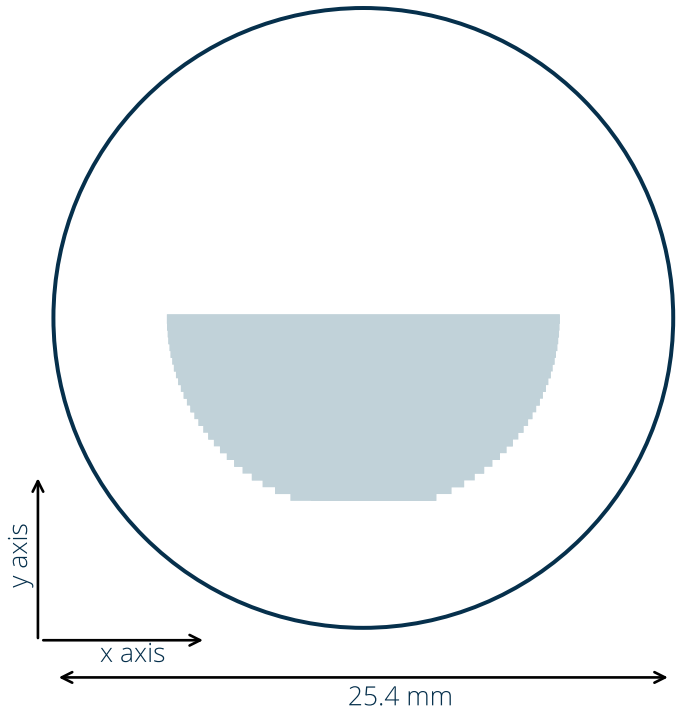

Figure 4. Scanned sample area.

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 5).

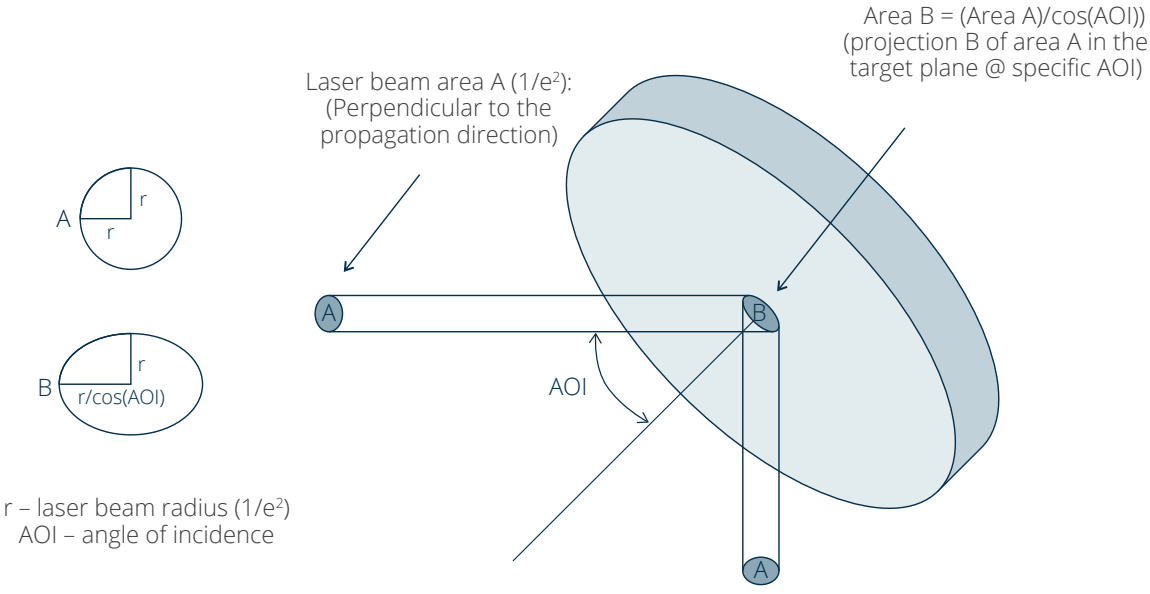

Figure 5. Oblique incidence.

TECHNICAL NOTE 3: Requested level was not scanned

Due to technical issues requested level (20 kW/cm^2) was not scanned. Applying raster scan test results the optical element would survive scanning with 20 kW/cm^2 irradiance level.

TECHNICAL NOTE 4: Catastrophic damage was reached with smaller laser beam

Ramping laser power up to maximum catastrophic damage was not reached using 307 µm laser beam. Therefore, it was decided to diminish laser beam and continue Raster scan procedure starting from the linear power density value that was maximum available with 307 µm beam. Catastrophic damage was obtained after scanning the first level with 139 µm laser beam, damage morphology is displayed in Figure 6.

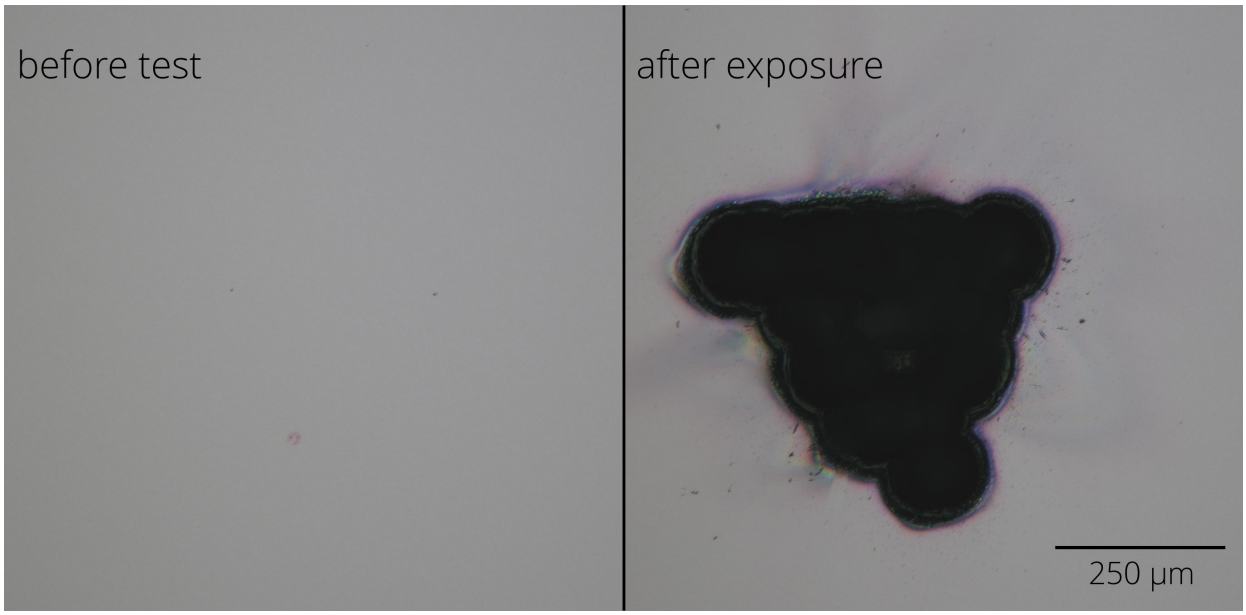

Figure 6. Image of catastrophic damage after exposition with 139 µm laser beam radiation: irraidance - 13.71 MW/cm^2 (linear power density - 145.3 kW/cm).