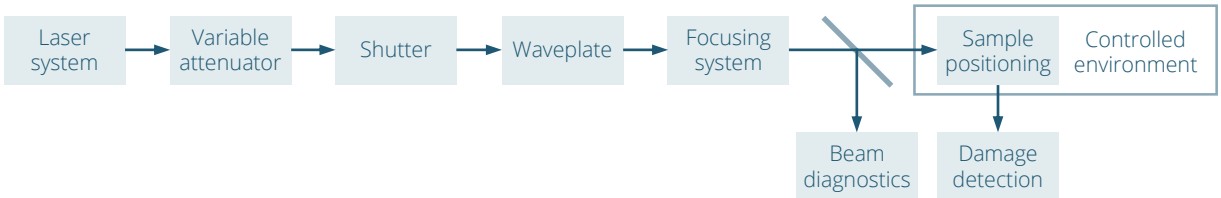
TEST EQUIPMENT

Test setup

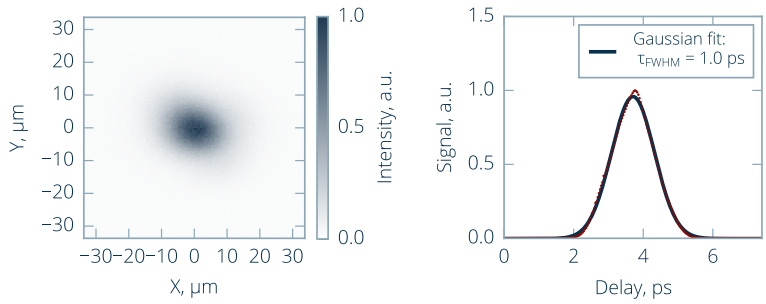


Laser and its parameters

Type	Mode-locked Yb:KGW
Manufacturer	Light Conversion
Model	Pharos SP
Central wavelength	343.0 nm
Angle of incidence	45.0 deg
Polarization state	Linear S
Pulse repetition frequency	200 kHz
Spatial beam profile in target plane	TEM00
Beam diameter in target plane ($1/e^2$)	(24.7 ± 0.2) µm
Longitudinal pulse profile	Single longitudinal mode
Pulse duration (FWHM)	1.0 ps (assuming Gaussian pulse shape)
Pulse to pulse energy stability (SD)	0.4 %

Energy/power meter

Manufacturer	Ophir
Model	12A-V1
Calibration due date	2022-08-01



(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 damage probability is zero. [1]
LID of the sample is investigated by performing a standardized S-on-1 test procedure.[2]
LIDT value is 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.
Lifetime is estimated by constructing a model that combines a stress-life relationship together with lifetime distribution. The best fit of model's parameters on LIDT data is evaluated by performing maximum a posteriori probability (MAP) estimation. Credible intervals (CI) of lifetime predictions were determined using Markov chain Monte Carlo (MCMC) technique. [3]

Test sites

Number of sites	382
Arrangement of sites	Hexagonal
Minimum distance between sites	300 µm
Maximum pulses per site	1000000

Analysis information

Online detection	Scattered light diode
Offline detection	Nomarski microscope
Software version	cc32abf

Test environment

Environment	Air
Cleanroom class (ISO 14644-1)	ISO7
Pressure	1 bar
Temperature	20.7 - 21.0 C
Humidity	7.8 - 10.8 %

Sample preparation

Storage before test	Normal laboratory conditions
Dust blow-off	Canned air
Cleaning	None

[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] Linas Smalakys and Andrius Melninkaitis, Predicting lifetime of optical components with Bayesian inference, Opt. Express 29, 903-915 (2021)

LIDT TEST RESULTS

LIDT VALUE

10^7-on-1	$0.0237\ ^{+0.0023}_{-0.0022}$ J/cm^2

CHARACTERISTIC DAMAGE CURVE

Table 1: Estimated LIDTs from fiting model for sample 76779.

Test mode	Threshold (Catastrophic)	Threshold (Color mode)
1-on-1	$0.709\ ^{+0.035}_{-0.034}$ J/cm^2	-
10-on-1	$0.674\ ^{+0.039}_{-0.038}$ J/cm^2	-
10^2-on-1	$0.654\ ^{+0.028}_{-0.027}$ J/cm^2	-
10^3-on-1	$0.654\ ^{+0.028}_{-0.027}$ J/cm^2	-
10^4-on-1	$0.654\ ^{+0.028}_{-0.027}$ J/cm^2	$0.5508\ ^{+0.0288}_{-0.0282}$ J/cm^2
10^5-on-1	$0.621\ ^{+0.025}_{-0.025}$ J/cm^2	$0.3017\ ^{+0.0216}_{-0.0209}$ J/cm^2
10^6-on-1	$0.621\ ^{+0.025}_{-0.025}$ J/cm^2	$0.1283\ ^{+0.0147}_{-0.0140}$ J/cm^2
10^7-on-1	$0.621\ ^{+0.025}_{-0.025}$ J/cm^2	$0.0237\ ^{+0.0023}_{-0.0022}$ J/cm^2

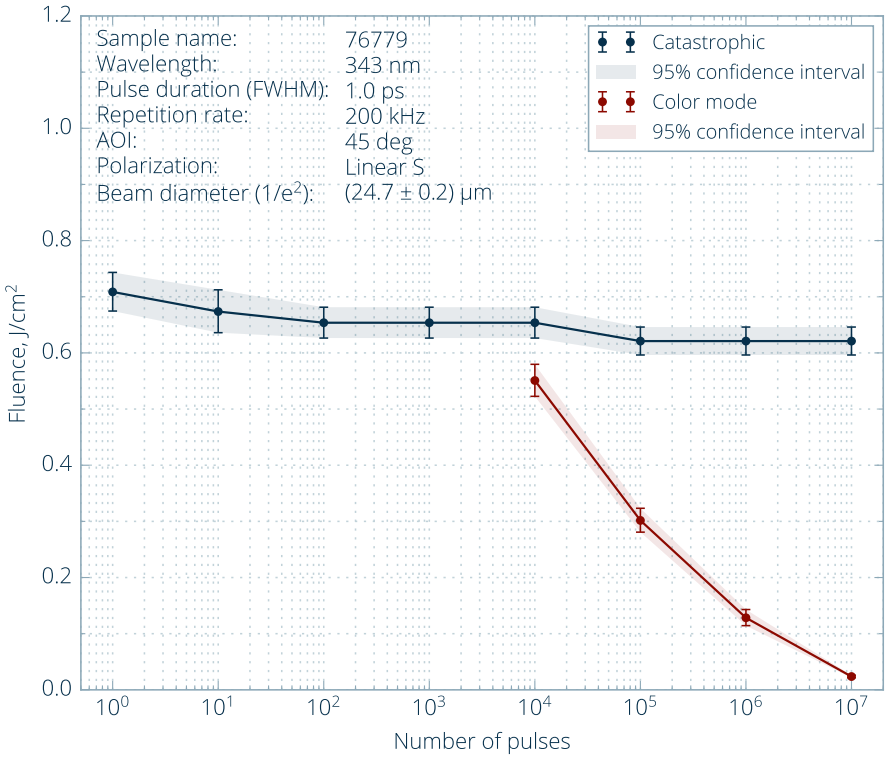
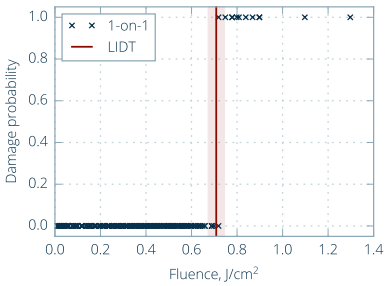
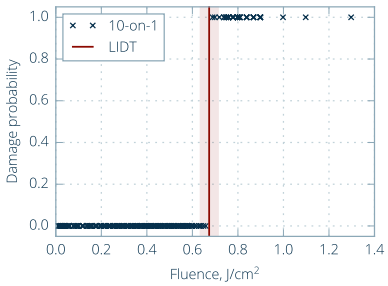


Figure 2. Characteristic damage curve.

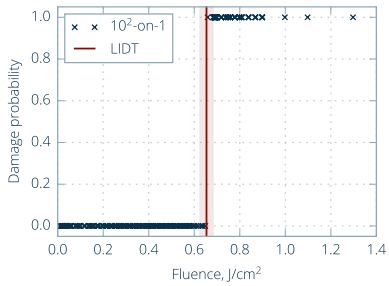
DAMAGE PROBABILITY (CATASTROPHIC)



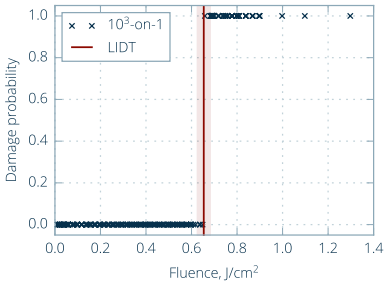
(a) 1-on-1



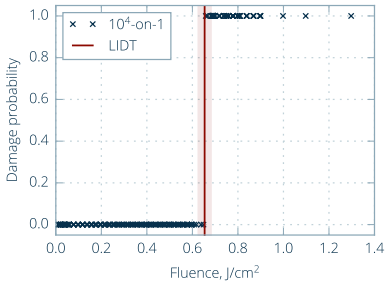
(b) 10-on-1



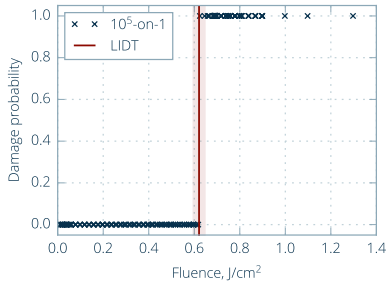
(c) 10^2-on-1



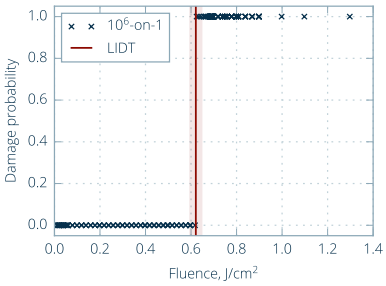
(d) 10^3-on-1



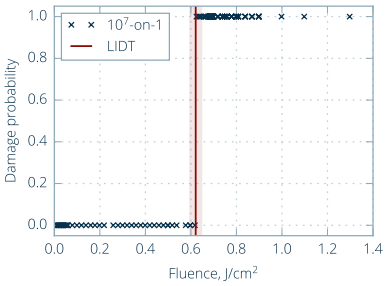
(e) 10^4-on-1



(f) 10^5-on-1



(g) 10^6-on-1



(h) 10^7-on-1

Figure 3. Damage probability plots.

TYPICAL DAMAGE MORPHOLOGY (CATASTROPHIC)

Figure 4. Typical damage morphology: fluence 0.691 J/cm^2, damage after 9667961 pulse(s), 50 s irradiation time.

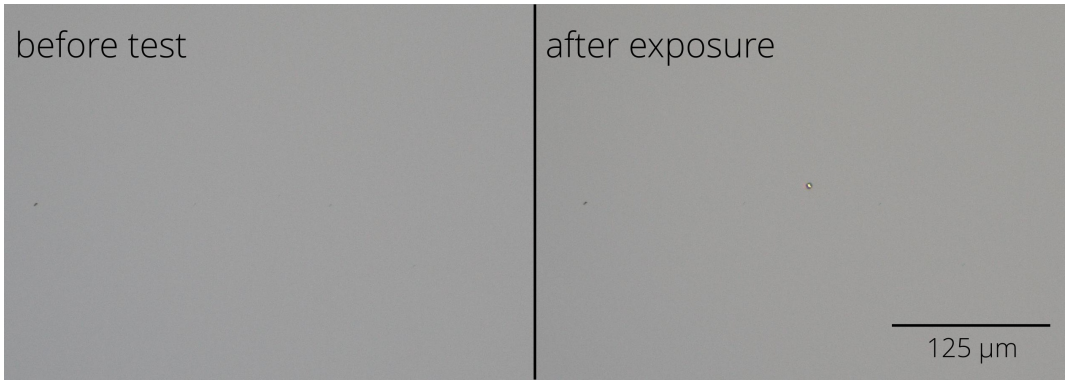
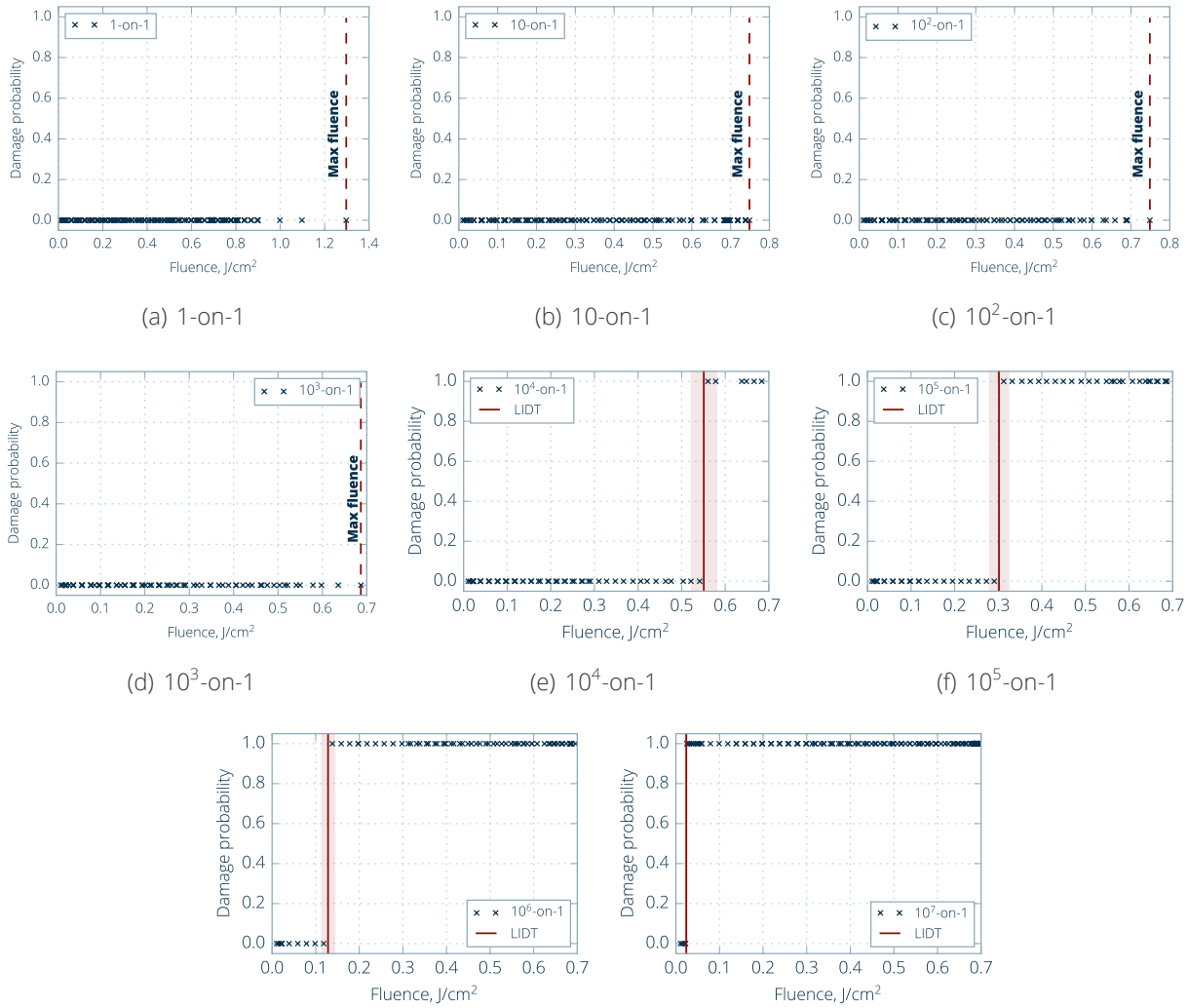


Figure 5. Typical damage morphology: fluence 0.739 J/cm^2, damage after 16 pulse(s), 0.075 ms irradiation time.

DAMAGE PROBABILITY (COLOR MODE)



(a) 1-on-1 (b) 10-on-1 (c) 10^2-on-1

(d) 10^3-on-1 (e) 10^4-on-1 (f) 10^5-on-1

(g) 10^6-on-1 (h) 10^7-on-1

Figure 6. Damage probability plots.

TYPICAL DAMAGE MORPHOLOGY (COLOR MODE)

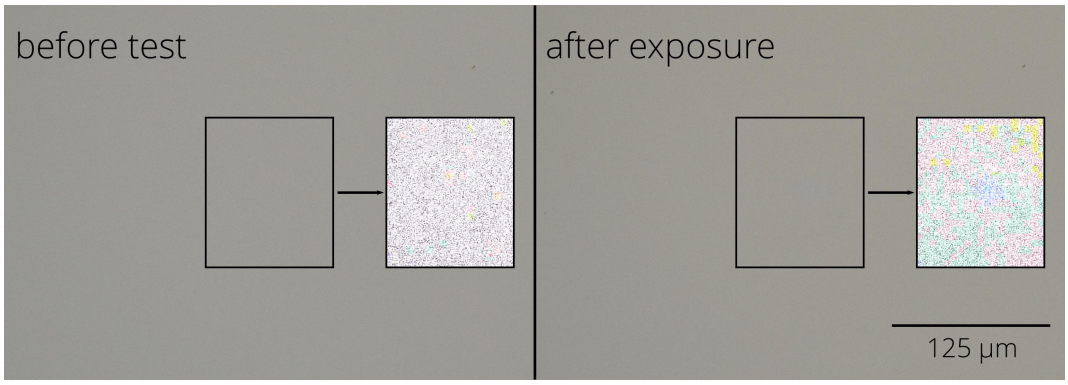


Figure 7. Typical damage morphology: fluence 0.119 J/cm^2, damage after 10000000 pulse(s), 50 s irradiation time. High contrast image.

Figure 8. Typical damage morphology: fluence 0.537 J/cm^2, damage after 10000000 pulse(s), 50 s irradiation time.

LIFETIME EXTRAPOLATION

Catastrophic fatigue limit	$0.617\ ^{+0.0079}_{-0.0415}$ J/cm^2

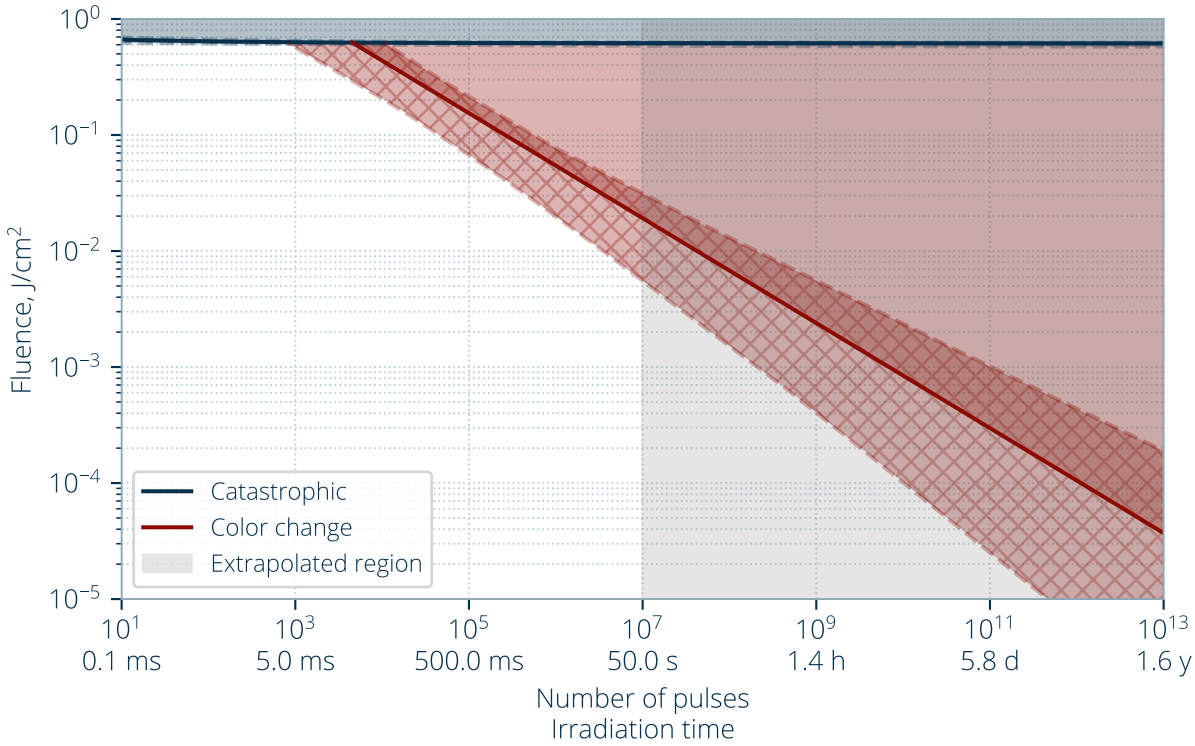


Figure 9. Summary of lifetime extrapolation.

LIFETIME EXTRAPOLATION (CATASTROPHIC)

Catastrophic fatigue limit	$0.617\ ^{+0.0079}_{-0.0415}$ J/cm^2

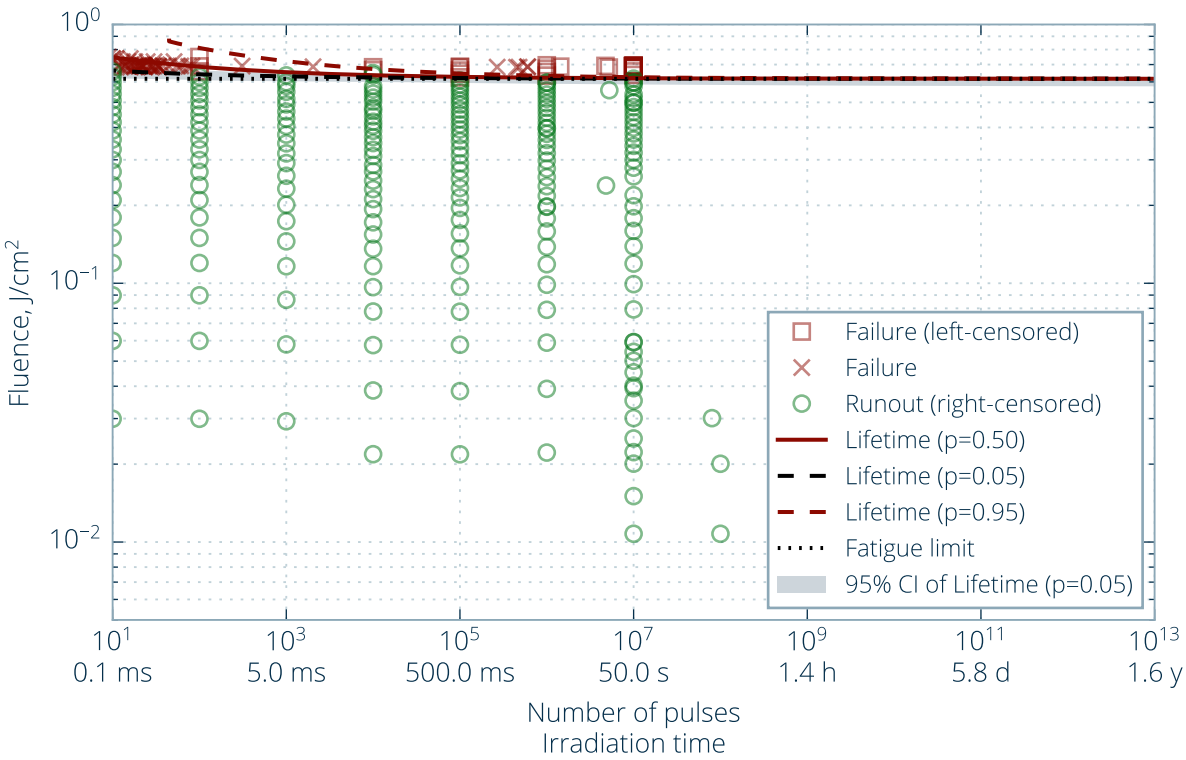


Figure 10. Lifetime extrapolation for Catastrophic damages.

LIFETIME EXTRAPOLATION (COLOR MODE)

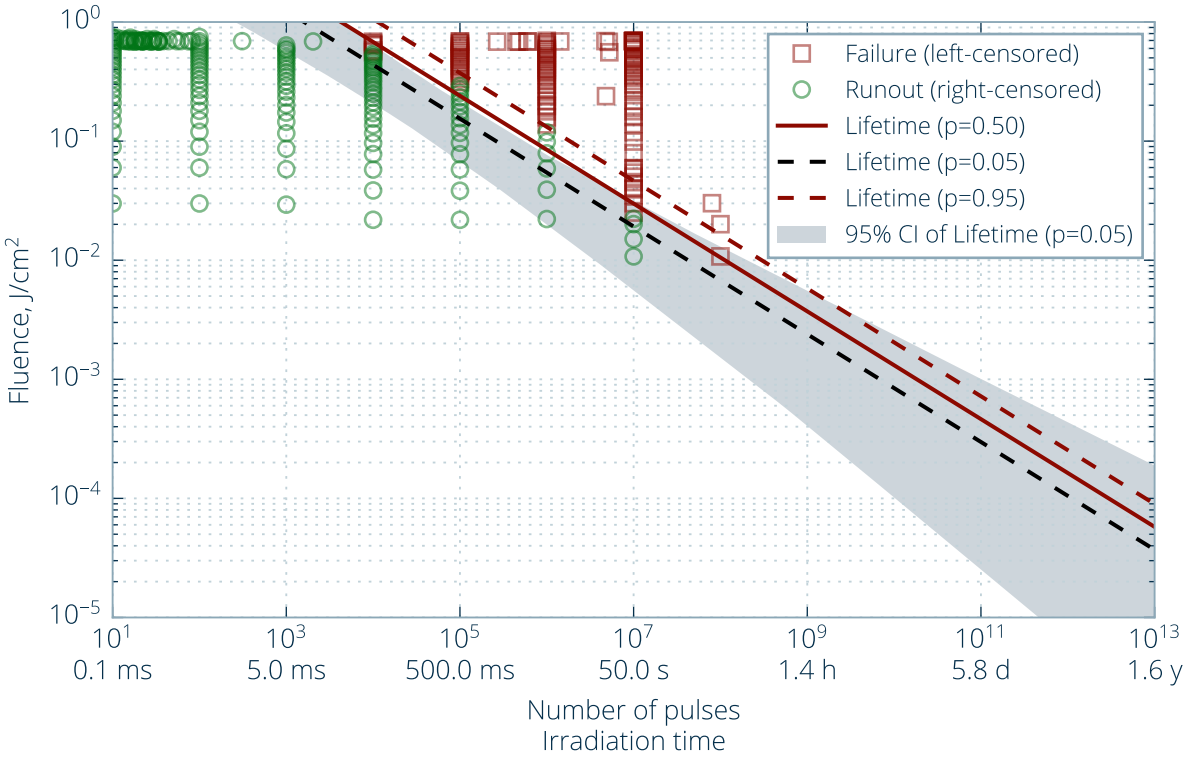


Figure 11. Lifetime extrapolation for Color mode damages.

TECHNICAL NOTES

TECHNICAL NOTE 1: 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 12).

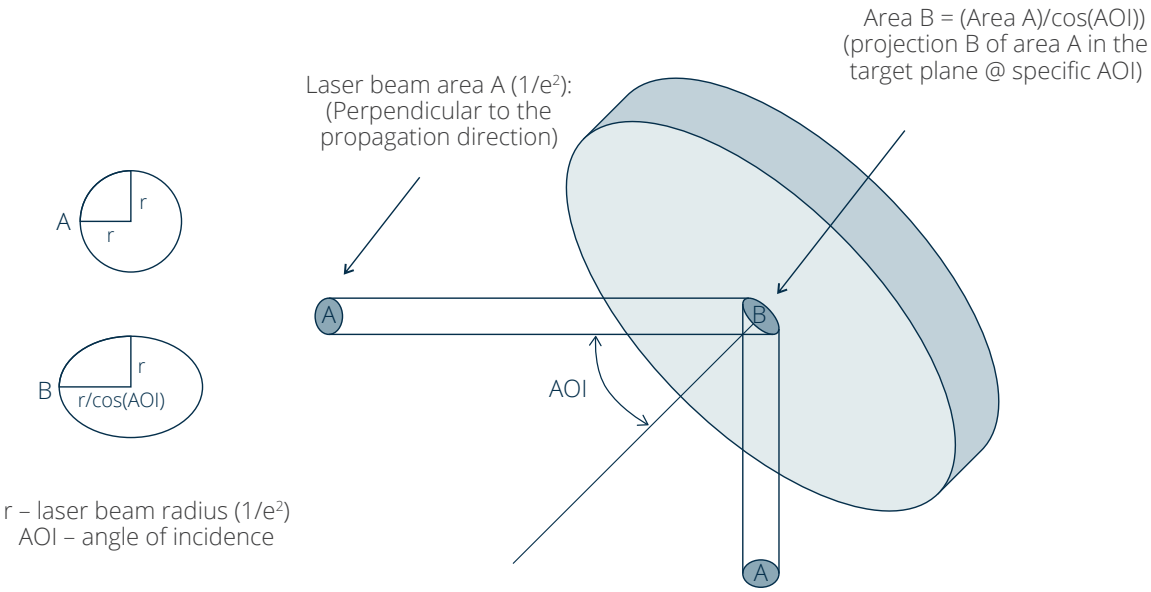


Figure 12. Oblique incidence.