SO0001

# LASER-INDUCED DAMAGE THRESHOLD (LIDT) MEASUREMENT REPORT

## CLASSICAL LIFETIME TEST BASED ON S-ON-1 (INTERVALS) PROCEDURE

### SAMPLE: SAMPLE

### Request from

| | |
|---|---|
| Address | Company<br>Address Line 1<br>Address Line 2<br>Country |
| Contact person | Name Surname |
| Inquiry ID | 0001 |
| Purchase order | - |

### Testing institute

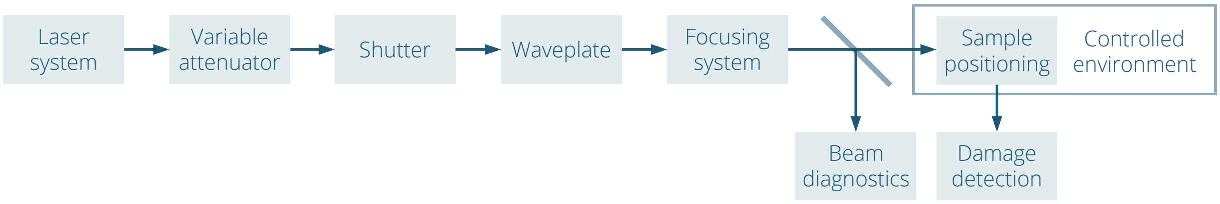
| | |
|---|---|
| Address | UAB Lidaris<br>Saulėtekio al. 10<br>10223 Vilnius<br>Lithuania |
| Tester | Name Surname |
| Test date | 01/01/2026 |
| Sale order | SO0001 |
| Test ID | - |

### Specimen

| | |
|---|---|
| Name | Sample |
| Type | HR Dielectric Coating |
| Dimensions | Ø20.0 x 5.0 mm |
| Packaging | Plastic box |

# TEST EQUIPMENT

## Test setup

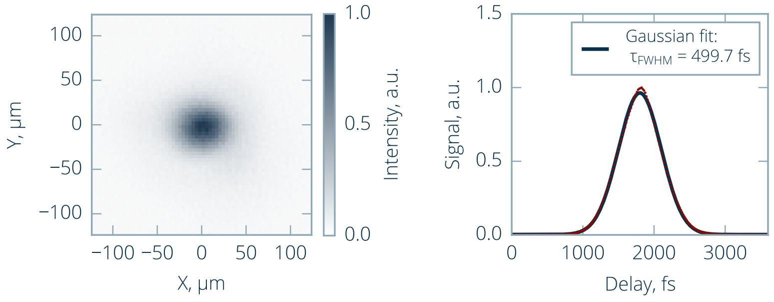


## Laser and its parameters

| | |
|---|---|
| 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 | 20 kHz |
| Spatial beam profile in target plane | TEM00 |
| Beam diameter in target plane ($1/e^2$) | ($93.8 \pm 1.0$) μm |
| Longitudinal pulse profile | Kerr-lens mode-locked |
| Pulse duration (FWHM) | 499.7 fs (assuming Gaussian pulse shape) |
| Pulse to pulse energy stability (SD) | 0.4 % |

## Energy/power meter

| | |
|---|---|
| Manufacturer | Ophir |
| Model | 12A-P |
| Calibration due date | 2027-12-31 |



(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 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.

## Test sites

| | |
|---|---|
| Number of sites | 350 |
| Arrangement of sites | Hexagonal |
| Minimum distance between sites | 390 µm |
| Maximum pulses per site | 1000000 |

## Analysis information

| | |
|---|---|
| Online detection | Scattered light diode |
| Offline detection | Nomarski microscope |
| Software version | b9b713f1 |

## Test environment

| | |
|---|---|
| Environment | Air |
| Cleanroom class (ISO 14644-1) | ISO7 |
| Pressure | 1 bar |
| Temperature | 22.2 - 22.3 C |
| Humidity | 36.9 - 37.1 % |

## Sample preparation

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

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[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)

# LIDT TEST RESULTS

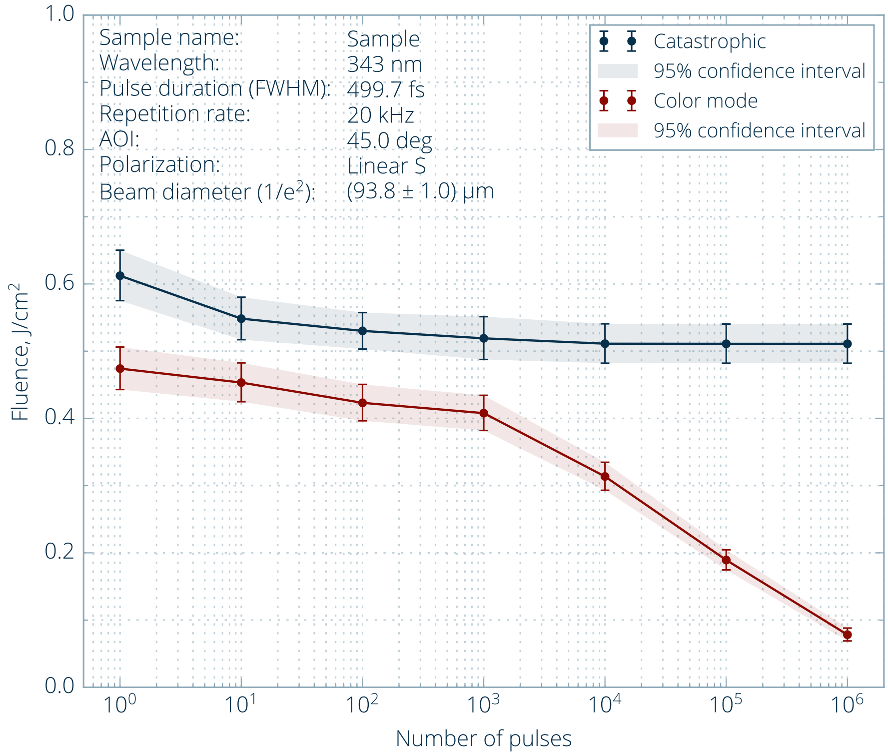
## LIDT VALUE

| | |
|---|---|
| $10^6$-on-1 | $0.0782\,^{+0.0098}_{-0.0093}$ J/cm$^2$ |

## CHARACTERISTIC DAMAGE CURVE

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

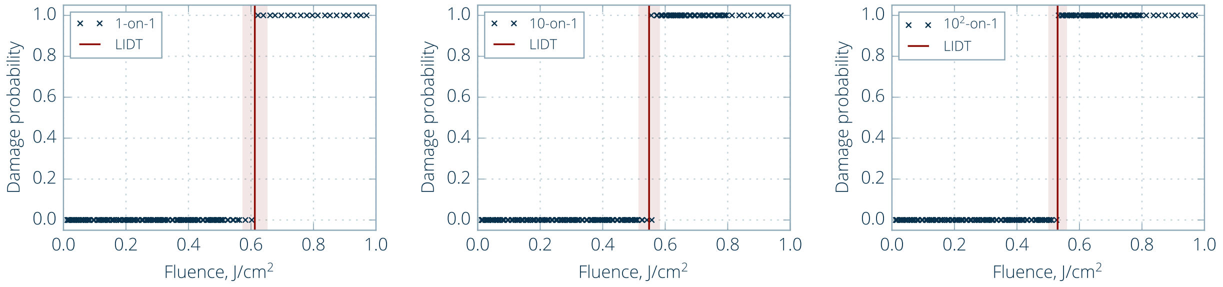
| Test mode | Threshold (Catastrophic) | Threshold (Color mode) |
|---|---|---|
| 1-on-1 | $0.612\,^{+0.038}_{-0.037}$ J/cm$^2$ | $0.4741\,^{+0.0321}_{-0.0311}$ J/cm$^2$ |
| 10-on-1 | $0.548\,^{+0.032}_{-0.031}$ J/cm$^2$ | $0.4533\,^{+0.0293}_{-0.0285}$ J/cm$^2$ |
| $10^2$-on-1 | $0.530\,^{+0.027}_{-0.027}$ J/cm$^2$ | $0.4231\,^{+0.0274}_{-0.0267}$ J/cm$^2$ |
| $10^3$-on-1 | $0.519\,^{+0.032}_{-0.032}$ J/cm$^2$ | $0.4078\,^{+0.0265}_{-0.0258}$ J/cm$^2$ |
| $10^4$-on-1 | $0.511\,^{+0.030}_{-0.029}$ J/cm$^2$ | $0.3136\,^{+0.0211}_{-0.0205}$ J/cm$^2$ |
| $10^5$-on-1 | $0.511\,^{+0.029}_{-0.029}$ J/cm$^2$ | $0.1893\,^{+0.0153}_{-0.0147}$ J/cm$^2$ |
| $10^6$-on-1 | $0.511\,^{+0.029}_{-0.029}$ J/cm$^2$ | $0.0782\,^{+0.0098}_{-0.0093}$ J/cm$^2$ |



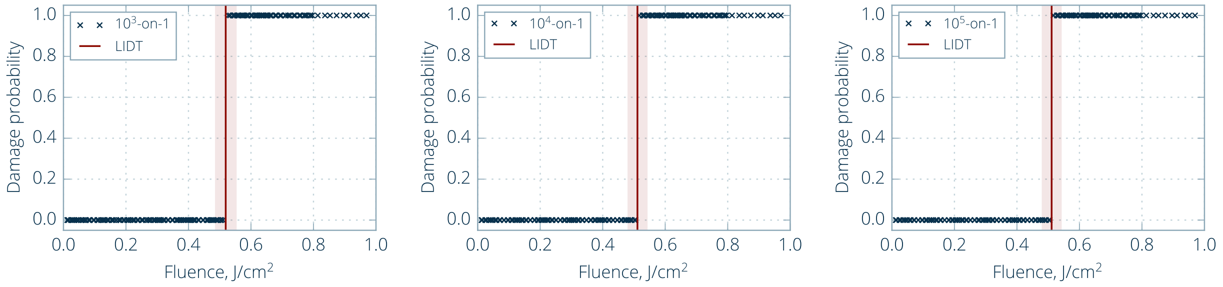
| | |
|---|---|
| Sample name: | Sample |
| Wavelength: | 343 nm |
| Pulse duration (FWHM): | 499.7 fs |
| Repetition rate: | 20 kHz |
| AOI: | 45.0 deg |
| Polarization: | Linear S |
| Beam diameter (1/e$^2$): | (93.8 ± 1.0) μm |

Figure 2. Characteristic damage curve.

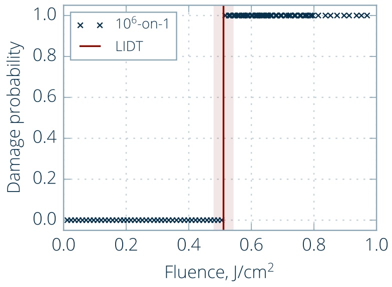
# DAMAGE PROBABILITY (CATASTROPHIC)



(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

Figure 3. Damage probability plots.

# TYPICAL DAMAGE MORPHOLOGY (CATASTROPHIC)

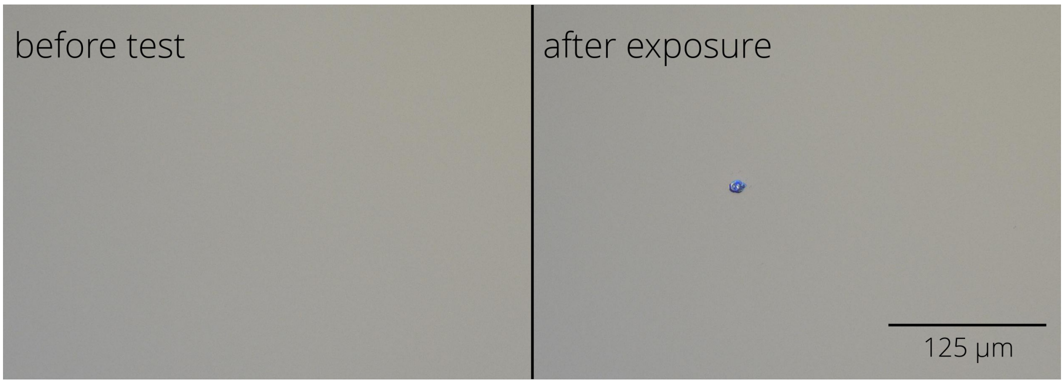


Figure 4. Typical damage morphology: fluence 0.753 J/cm$^2$, damage after 11 pulse(s).

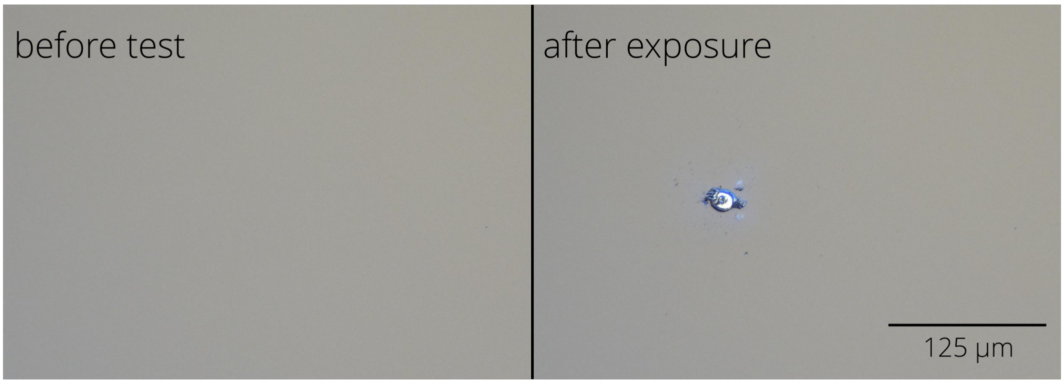
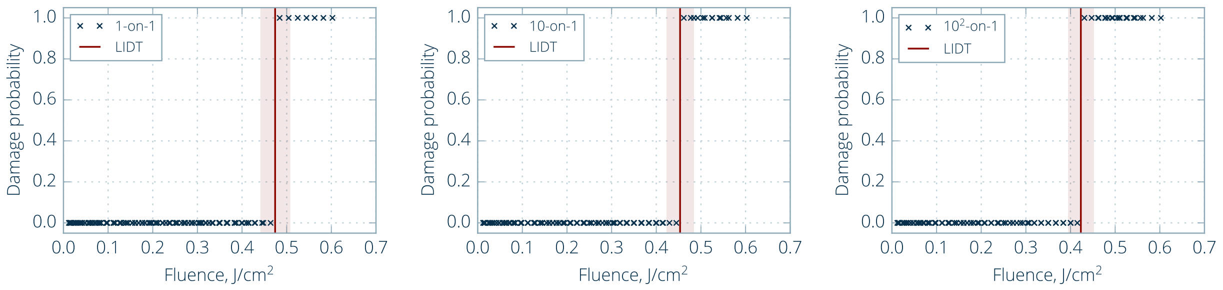
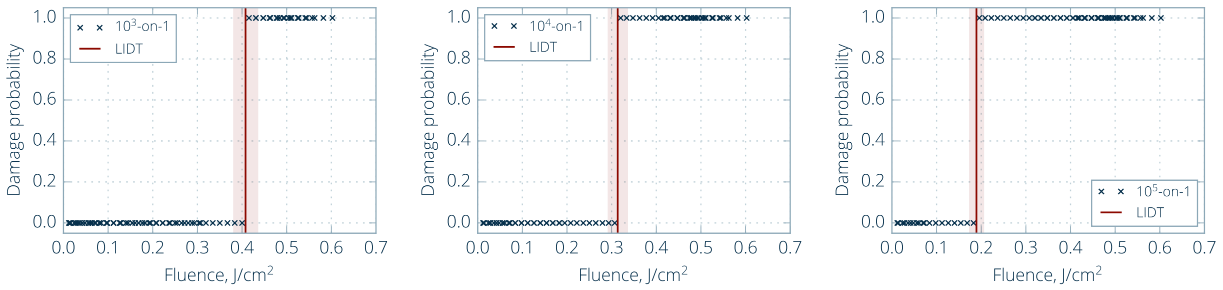


Figure 5. Typical damage morphology: fluence 0.802 J/cm$^2$, damage after 3 pulse(s).

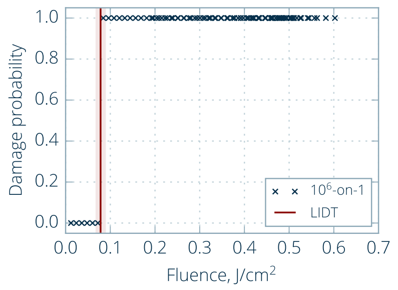
# DAMAGE PROBABILITY (COLOR MODE)



(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

Figure 6. Damage probability plots.

# TYPICAL DAMAGE MORPHOLOGY (COLOR MODE)

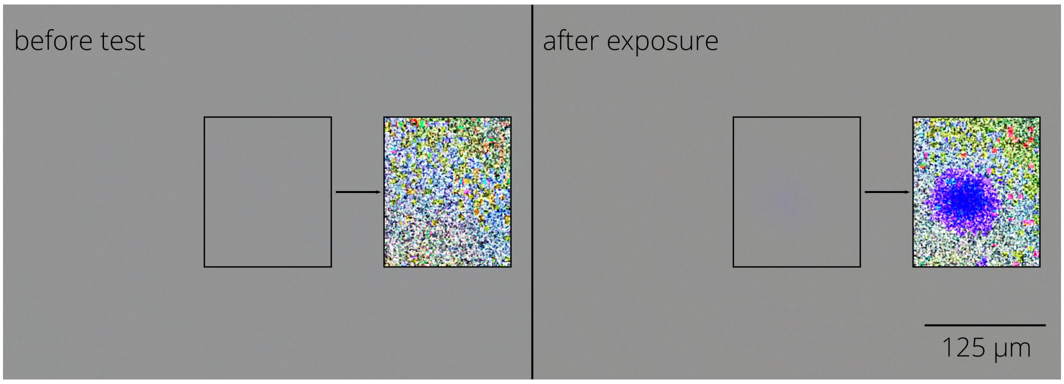


Figure 7. Typical damage morphology: fluence 0.141 J/cm$^2$, damage after 1000000 pulse(s). High contrast image.

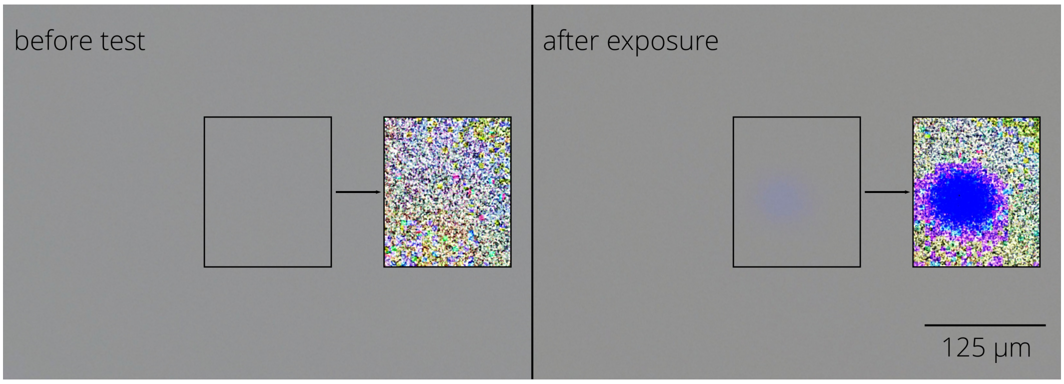


Figure 8. Typical damage morphology: fluence 0.220 J/cm$^2$, damage after 1000000 pulse(s). High contrast image.

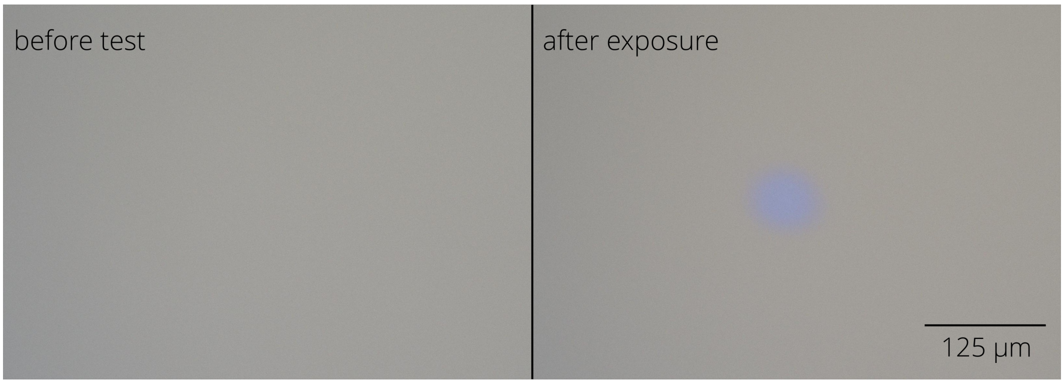


Figure 9. Typical damage morphology: fluence 0.402 J/cm$^2$, damage after 1000000 pulse(s).

# LIFETIME EXTRAPOLATION

Lifetime of optical component is estimated by constructing a model that combines a stress-life relationship (fatigue relationship) together with lifetime distribution at a single stress (fluence – *F*) level [3]. Point estimate of the model is evaluated by performing maximum a posteriori probability estimation while the credible intervals for each of the parameters are determined using Markov chain Monte Carlo (MCMC) technique.

Lifetime distribution is assumed to follow log-normal distribution. Probability density function $\Phi$ of log-normal distribution is expressed as:

$$\Phi(t, \mu, \sigma) = \frac{1}{\sigma t}\frac{1}{\sqrt{2\pi}}\exp\left(-\frac{\left(\frac{\log(t)-\mu}{\sigma}\right)^2}{2}\right)$$

where $t$ – irradiation time, $\mu$ – log-location parameter, $\sigma$ – log-scale parameter.

## SUMMARY OF LIFETIME EVALUATION

| | |
|---|---|
| Catastrophic fatigue limit ($F_0$) | $0.5130\,^{+0.0039}_{-0.0193}\,J/cm^2$ |

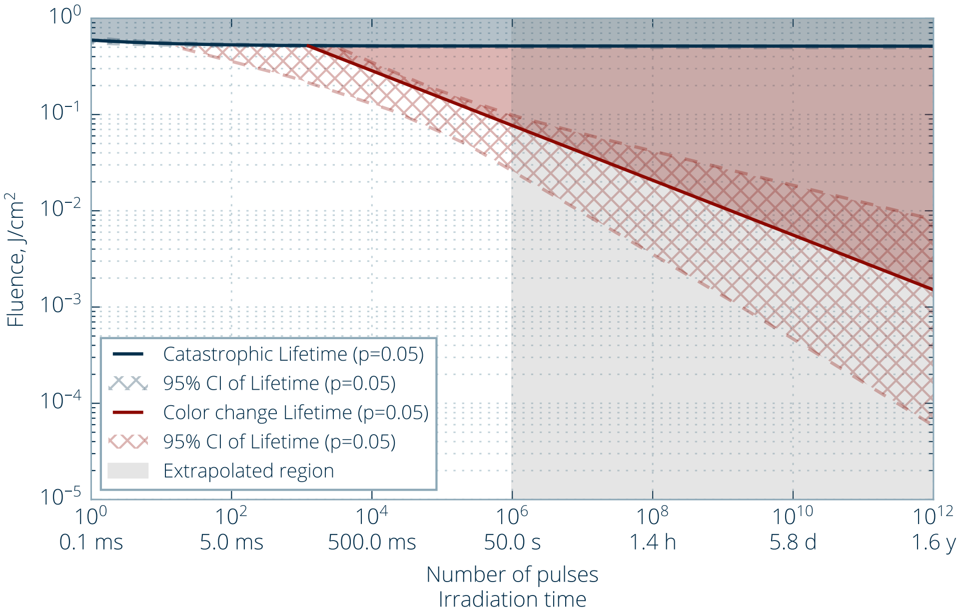


Figure 10. Summary of lifetime evaluation.

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

# CATASTROPHIC LIFETIME EVALUATION

Stress-life relationship (fatigue relationship) for Catastrophic damages is assumed to follow an inverse power relationship (parameters $y_{0,\mu}$ and $y_{1,\mu}$) with fatigue limit $F_0$ while the log-scale parameter of log-normal distribution is assumed to be constant (parameter $y_{0,\sigma}$):

$$\mu(F) = y_{0,\mu} - y_{1,\mu}\log(F - F_0)$$

$$\sigma(F) = y_{0,\sigma}$$

| | |
|---|---|
| Catastrophic fatigue limit ($F_0$) | $0.5130\,^{+0.0039}_{-0.0193}\,J/cm^2$ |

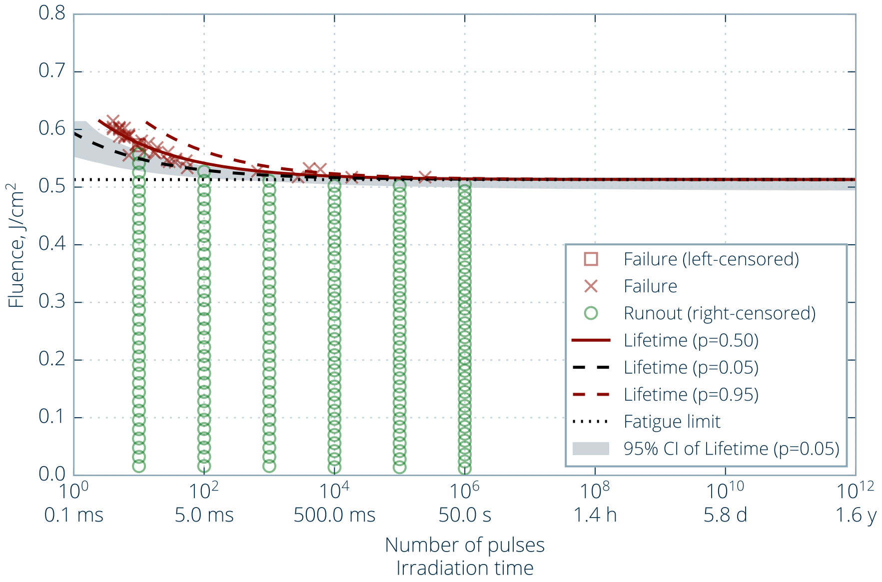

Figure 11. Lifetime extrapolation for Catastrophic damages.

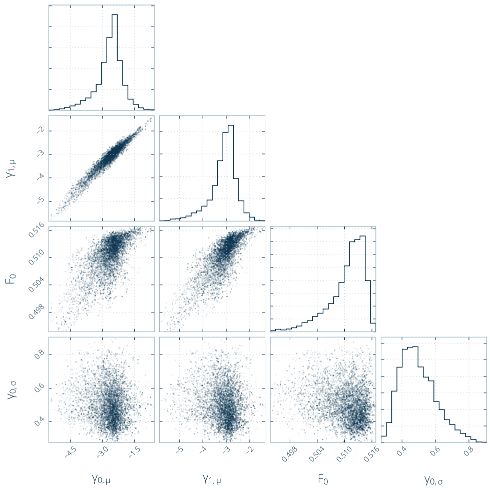

Figure 12. Corner plot of MCMC samples for Catastrophic damages.

# COLOR MODE LIFETIME EVALUATION

Stress-life relationship (fatigue relationship) for Color mode damages is assumed to follow an inverse power relationship (parameters $y_{0,\mu}$ and $y_{1,\mu}$) while the log-scale parameter of log-normal distribution is assumed to be constant (parameter $y_{0,\sigma}$):

$$\mu(F) = y_{0,\mu} - y_{1,\mu}\log(F)$$

$$\sigma(F) = y_{0,\sigma}$$

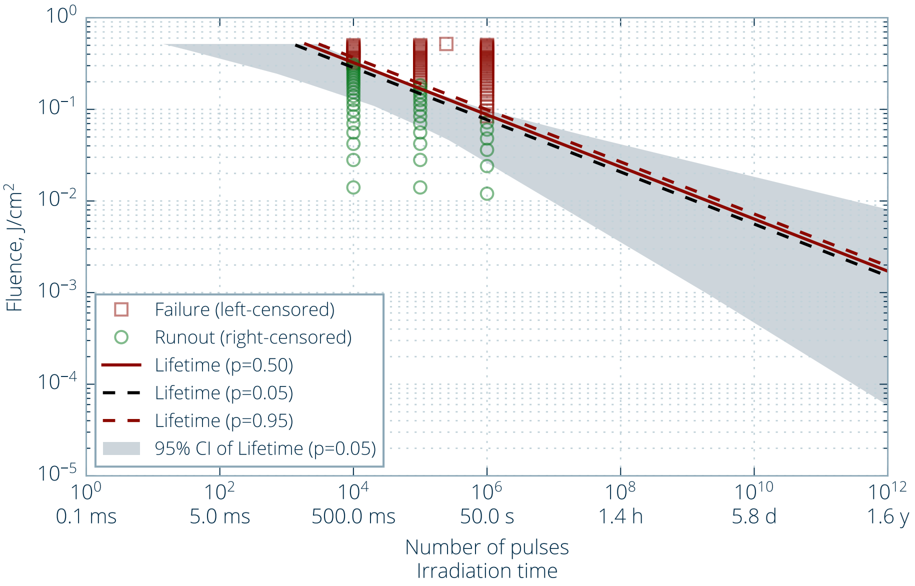

Figure 13. Lifetime extrapolation for Color mode damages.

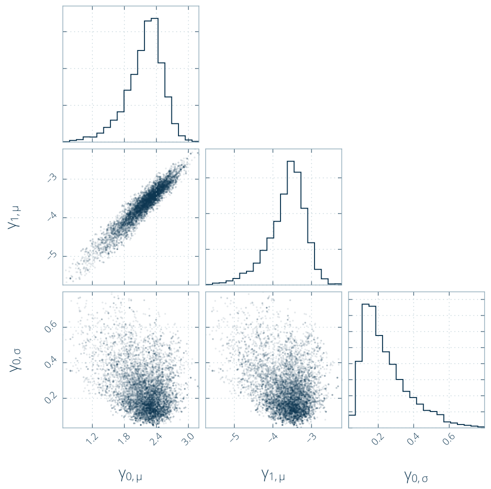

Figure 14. Corner plot of MCMC samples for Color mode damages.

# 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 15).

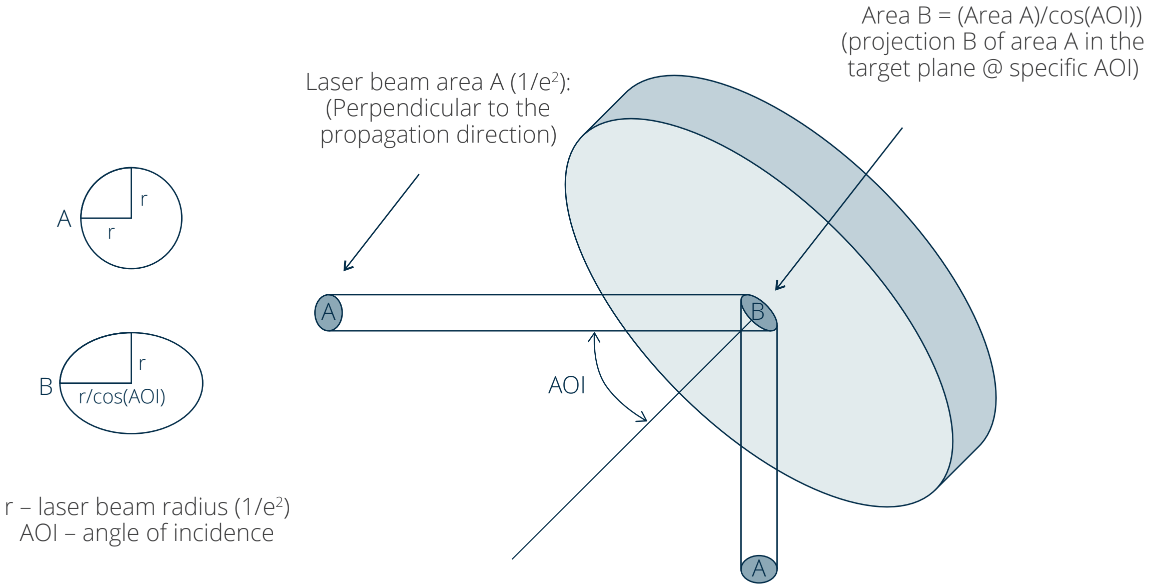

Figure 15. Oblique incidence.