# LASER INDUCED DAMAGE THRESHOLD

Edmund Optics®
WHITEPAPER

## UNDERSTANDING AND SPECIFYING LIDT OF LASER COMPONENTS

Laser Induced Damage Threshold (LIDT) is a critical parameter when selecting or specifying laser optics. Underspecifying LIDT can lead to catastrophic component failure in the lab or field, risking the performance of critical equipment. However, over specifying LIDT can create unnecessary expense for your device or application, risking budget constraints and device profitability.

This technical note will help you understand LIDT, the parameters that affect it, and how to properly specify it to ensure a competitive advantage.

### Understanding LIDT

Laser Induced Damage Threshold (LIDT) or Laser Damage Threshold (LDT) is defined within the ISO standard as the "highest quantity of laser radiation incident upon the optical component for which the extrapolated probability of damage is zero" (ISO 21254-1:2011). The goal of this definition is to specify the maximum laser fluence (for pulsed lasers, typically in $J/cm^2$) or the maximum laser intensity (for continuous wave lasers, typically in $W/cm^2$) that a laser optic can withstand before damage occurs. Because of the statistical nature of laser induced damage and the assumptions behind the extrapolation, LIDT unfortunately cannot be considered the value below which no damage will ever occur.

An incorrect understanding of LIDT can lead to significantly higher costs than necessary, or worse, to coating failures in the field. When dealing with high power lasers, LIDT is an important specification for all types of laser optics, including reflective, transmissive, and beam shaping components.

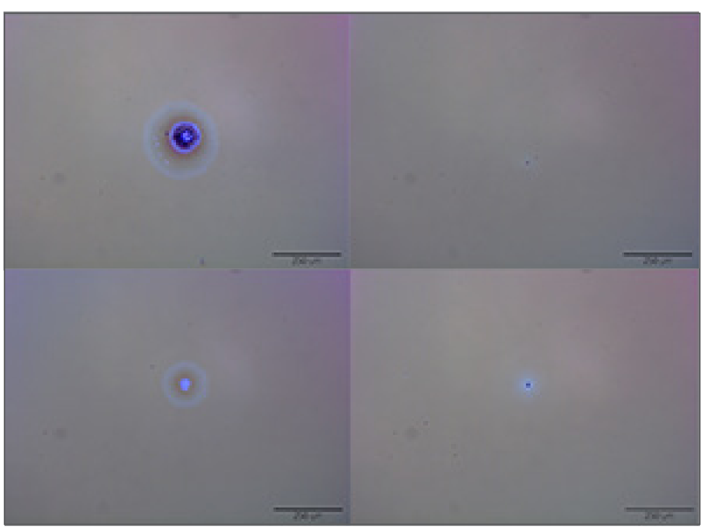

**Figure 1:** The laser induced damage in optical coatings can cause degradation in performance and often catastrophic failure. The root cause of damage creates various morphologies of damage, and identifying these morphologies is important for coating and process development. Understanding this phenomena is imperative, as over specifying will drive cost and the resultant damage will degrade laser system performance.

### Save Time by Specifying LIDT Correctly

Specifying LIDT should not be an iterative process. When the following parameters are understood and properly specified, rework and redesign are eliminated, and significant time and money are saved. In order to correctly specify LIDT, the following parameters are required:

- **Beam mode:** the axial and/or transverse modes of the laser beam used to do the testing
- **Wavelength**
- **Pulse duration** (not applicable for continuous wave lasers)
- **Repetition rate** (not applicable for continuous wave lasers)
- **Beam profile:** the beam profile on the optic under test, most often Gaussian or top-hat
- **Spot diameter:** the size of the spot on the optical surface. This affects how the distribution of defects influences the value and is an important value to specify. It is recommended to keep this value at 0,5 mm or larger to avoid significant spot-size effects on LIDT, but 0,2 mm is the minimum allowable size within the ISO specification
- **Incidence angle**
- **Polarization of the laser beam**
- **Type of test:** 1-on-1, where each spot is exposed to a single pulsed or S-on-1 where each spot is exposed to S pulses

**Figure 2**

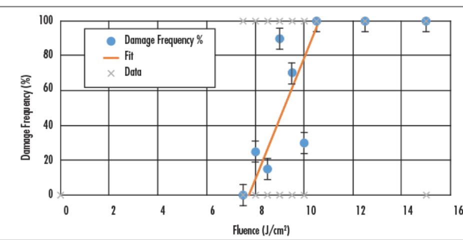


**Figure 2:** Typical LIDT tests at 1064 nm show the different fluences used during S-on-1 testing and the resulting damage frequency. In this test the damage threshold for a laser mirror is found to be 7,5 $J/cm^2$, with a clear, relatively steep slope.

### Selecting an Optic Based on LIDT and Staying within Budget

Calculating the LIDT needed to specify on your component print, or the minimum LIDT value your catalog part should meet, is a relatively simple process. First, calculate the maximum fluence, or intensity, of your laser beam at the location the beam will encounter the optical surface, ensuring to account for your beam profile. Next, verify potential back reflections, or ghost reflections, from other surfaces that exist in the system. Even if these are reflections from anti-reflection coated surfaces, when focused they can be more intense than the original incident beam. The result determines the maximum fluence any optical surface encounters.

Adding a safety factor for potential hotspots or profile and temporal anomalies in your beam is the next important step. The size of this factor depends on the type, stability, and alignment of your laser. Finally, because laser induced damage is statistical in nature, and this probabilistic nature is not included in the ISO LIDT definition, consider an additional safety factor based on the risk tolerance of your applications. Any LIDT value on an optical component larger than the product of the laser fluence and safety factors will meet your requirements; specifying an even higher LIDT will simply add cost.

Remember: you should not be required to add a safety factor due to components from your manufacturer not meeting their LIDT specification - experienced laser optics manufacturers should consistently meet their quoted LIDT on all components.

**Variables that Affect LDT/LIDT**

| Laser | Substrate | Coating |
|---|---|---|
| Output Power | Material | Deposited Material |
| Pulse Duration | Surface Quality | Deposition Process |
| Pulse Repetition Rate | Cleanliness | Pre-Coating Preparation and Cleaning |
| Beam Profile | Reactivity to the Environment | Lot-to-Lot Control |
| Beam Diameter (1/e2) | Material Absorption | Coating Design and Optimization |
| Wavelength | Material Homogeneity | Protective Layers |

### LIDT Manufacturers and Costs

Manufacturing optics that consistently meet a specific LIDT requires an additional level of attention to design and manufacturing compared to manufacturing optics for imaging or other applications. The first step is to ensure the designs of the coatings and assemblies are optimized for the required laser powers. This requires analyzing electric field distributions in coatings and adjusting coating design where necessary, as well as analyzing potential ghost reflections and adjusting optical designs in optical assemblies.

When it comes to actual manufacturing, cleanliness is paramount. From manufacturing environmental concerns to coating materials purity, ensuring cleanliness is essential. Optics and coatings acceptable for low power applications may be unsuitable for use in high power coatings due to contaminations that do not affect performance at low powers. Additionally, certain process parameters that are not as important for low power applications become important, such as the surface roughness of the polished surfaces. Optical manufacturers should be able to produce testing reports from recognized test institutes, according to the ISO 21254 standard, on request. This demonstrates performance verification of the coated optics and ideally multiple test reports demonstrate repeatable, reliable performance.

### Avoid Scaling LIDT

Scaling LIDT is a controversial topic with many different approaches. While certain scaling laws apply to some specific materials and LIDT measurement conditions, there is no generally applicable LIDT scaling formula based on experimental data that can be used to rigorously determine a new LIDT over a broad wavelength, pulse duration, or spot diameter scale without a new LIDT measurement. However, for very small shifts in wavelengths, pulse durations or spot sizes, it is often a reasonable approximation to assume a scaling of the LIDT with the square root of the pulse duration and a linear scaling with the wavelength. If the wavelength and/or pulse duration of your application are not close to the specified LIDT value, do not attempt to scale or convert it. Testing must be performed at the correct pulse duration and wavelength in order to guarantee compatibility with your application.

### Summary

The understanding of LIDT is an important prerequisite to accurately specifying laser optics. Whilst there are many factors to consider with complete understanding specifying should be relatively straightforward. Knowledge of the maximum fluence or intensity of your laser beam on the optic, taking into account all profile and hot spot considerations, leads to a required LIDT. An LIDT specified at this value or higher with the relevant beam parameters for your application will lead to an optic that meets your requirements. LIDT's specified higher than this value will add cost and should be unnecessary with an experienced laser optics manufacturer as they should consistently meet their quoted LIDT on all components.

### References

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