Laser Induced Damage Threshold

Overview:

Developments in laser technology continue to increase output powers year-on-year, with commercially available CW power as high as 100kW (in 2023). Pulsed lasers have seen a corresponding rise in pulse energy, peak pulse power and average output power across fs-ns-µs pulsed lasers. All optical components used in conjunction with these high power CW and pulsed lasers need to have a high laser induced damage threshold (LIDT).

The LIDT of an optical component is determined by (i) the choice of glass; (ii) its purity; (iii) how it is processed from its blank or substrate state; (iv) residual surface roughness; and (v) optical coatings.

PowerPhotonic optics and assemblies use the highest grades of fused silica, have the smoothest freeform surfaces available, and are coated with specially selected coatings all to ensure the best in class LIDT performance.

The PowerPhotonic Effect:

>100kW/cm

CW Coated LIDT

>0.5J/cm^2

ps Coated LIDT

>5J/cm^2

ns Coated LIDT

CW vs Pulsed Damage:

Pulsed and Continuous Wave damage occurs due to different mechanisms. Pulsed damage occurs due to electric field (spatial) gradient of the laser pulse inducing dielectric breakdown of the substrate or coating. CW damage occurs due to thermal degradation, driven predominantly by the absorption in the bulk material and/or optical coating of the component.

Pulsed Damage Thresholds are therefore specified in terms of the maximum power or energy density incident on the surface, J/cm^2 or GW/cm^2. CW damage threshold has been shown to scale with linear power density and is specified in W/cm.

Typical Coatings:

Low Density Coating	Medium Density Coating	High Density Coating
Low density coatings such as e-beam coatings are the most commonly used in optics. E-beam coating technology has the highest deposition rate and the maturity of the technology results in a lower chamber cost.	Medium density coatings such as ion assisted deposition use a similar style of deposition as e-beam coatings with an additional ion source. This offers improved optical and environmental performance for a reduced cost compared to IBS coatings.	High Density coatings like Ion beam sputtering bombard the substrate with high energy particles. These particles are packed with a much higher packing efficiency than other coatings. This offers a more stable coating for harsher environments.

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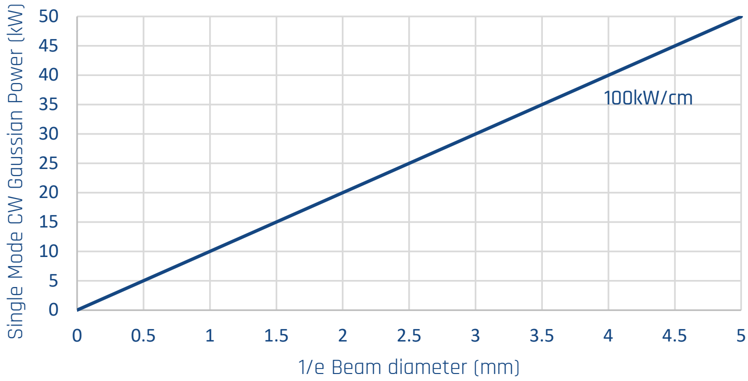
Typical Damage Thresholds:

Pulse Length	Uncoated LIDT	Coated LIDT	Coating Technology
Femtosecond	No Data	0.1-0.5J/cm^2	E-Beam / IBS
Picosecond	No Data	0.5-0.8J/cm^2	E-Beam / IBS
Nanosecond	15-100J/cm^2	5-12J/cm^2	E-Beam
Continuous Wave	No Data	>100kW/cm	IBS/MS/IP

E-Beam - Electron Beam Evaporation, IP - Ion Plating, IBS - Ion Beam Sputtering, MS - Magnetron Sputtering

Maximum Laser Power (kW)



LIDT Scaling Laws:

Both CW and Pulsed LIDT results can be scaled in wavelength and pulse length to apply to different laser systems. These scaling laws are estimates, and only apply for small changes in parameters (<10% CW wavelength and ±5% pulsed wavelength or ± a factor of 3 of pulse duration), but can be a handy tool for estimating LIDT of a system.

CW Scaling Laws:

$$\mathit{Adjusted\ LIDT} = \mathit{LIDT\ Power}\left(\frac{\mathit{New\ Wavelength}}{\mathit{LIDT\ Wavelength}}\right)$$

Pulsed Scaling Laws:

$$\mathit{Adjusted\ LIDT} = \mathit{LIDT\ Energy}\sqrt{\frac{\mathit{New\ Wavelength}}{\mathit{LIDT\ Wavelength}}}$$

or

$$\mathit{Adjusted\ LIDT} = \mathit{LIDT\ Energy}\sqrt{\frac{\mathit{New\ Pulse\ Length}}{\mathit{LIDT\ Pulse\ Length}}}$$

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PowerPhotonic
Enhancing Beam Performance