56 Sparta Avenue • Newton, New Jersey 07860
(973) 300-3000 Sales • (973) 300-3600 Fax
www.thorlabs.com

THORLABS

# NB1-J07 - May 23, 2016

Item # NB1-J07 was removed from our e-commerce site on May, 23, 2016. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

# ARGON ION LASER MIRRORS

- **Three Wavelength Ranges Available**
- **Designed for Either 0° AOI, 45° AOI, or 0° and 45° AOI**
- **At Least 98.0% Average Reflectance over Wavelength Ranges**

**NB1-H07**
Ø1" Mirror, 0º AOI,
333 - 364 nm

**NB1-K10**
Ø1" Mirror, 0° and 45° AOI,
458 - 528 nm

**NB07-K05**
Ø19 mm Mirror, 0° and 45° AOI,
300 - 308 nm


Back Side
Engraved with Item #

Hide Overview

## OVERVIEW

### Features

- Available Wavelength Ranges
  - 300 - 308 nm
  - 333 - 364 nm
  - 458 - 528 nm
- Options for 0° and 45° AOI
- Ø19 mm and Ø1" Options

Ar-Ion laser line mirrors have a specialized coating that provides a high reflectance over wavelength ranges coincident with the emission of an Ar-Ion laser. The coating has a high damage threshold suitable for use with the output beam from large-frame high-powered CW (continuous wave) Ar-Ion lasers.

Our selection of Ø19 mm mirrors are specifically designed to fit our Polaris Fixed Optic Mounts for laser system design and other OEM applications. This diameter provides a larger clear aperture than Ø1/2" optics while allowing the mounts to maintain a Ø1" footprint.

| Common Specifications | |
|---|---|
| **Substrate Material** | Fused Silica |
| **Front Surface Flatness** | λ/10 @ 633 nm |
| **Clear Aperture** | >80% of Diameter |
| **Back Surface** | Fine Ground[a] |
| **Parallelism** | <3 arcmin |
| **Diameter Tolerance** | +0.0/-0.1 mm |
| **Thickness** | 6.0 ± 0.2 mm |
| **Surface Quality** | 10-5 Scratch-Dig |

- A fine ground back surface is frosted and will diffuse light that is not reflected by the mirror's front surface.



Hide Damage Thresholds

DAMAGE THRESHOLDS

## Damage Threshold Data for Thorlabs' Argon Ion Laser Mirrors

The specifications to the right are measured data for Thorlabs' argon ion laser mirrors. Damage threshold specifications are valid for a given reflective coating, regardless of the size of the mirror.

| Damage Threshold Specifications | | |
|---|---|---|
| Coating Designation (Item # Suffix) | Wavelength Range | Damage Threshold (CW) |
| -H07<br>-J07 | 333 - 364 nm | 1 kW/cm$^2$ |

## Laser Induced Damage Threshold Tutorial

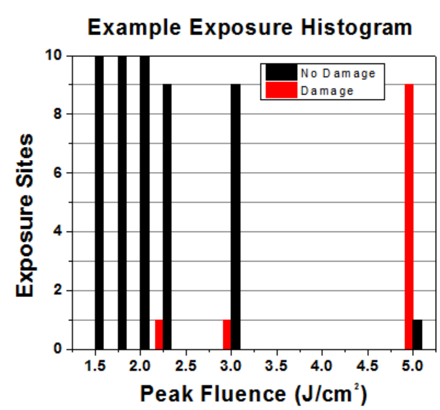
The following is a general overview of how laser induced damage thresholds are measured and how the values may be utilized in determining the appropriateness of an optic for a given application. When choosing optics, it is important to understand the Laser Induced Damage Threshold (LIDT) of the optics being used. The LIDT for an optic greatly depends on the type of laser you are using. Continuous wave (CW) lasers typically cause damage from thermal effects (absorption either in the coating or in the substrate). Pulsed lasers, on the other hand, often strip electrons from the lattice structure of an optic before causing thermal damage. Note that the guideline presented here assumes room temperature operation and optics in new condition (i.e., within scratch-dig spec, surface free of contamination, etc.). Because dust or other particles on the surface of an optic can cause damage at lower thresholds, we recommend keeping surfaces clean and free of debris. For more information on cleaning optics, please see our *Optics Cleaning* tutorial.

## Testing Method

Thorlabs' LIDT testing is done in compliance with ISO/DIS11254 specifications. A standard 1-on-1 testing regime is performed to test the damage threshold.

First, a low-power/energy beam is directed to the optic under test. The optic is exposed in 10 locations to this laser beam for a set duration of time (CW) or number of pulses (pulse repetition frequency specified). After exposure, the optic is examined by a microscope (~100X magnification) for any visible damage. The number of locations that are damaged at a particular power/energy level is recorded. Next, the power/energy is either increased or decreased and the optic is exposed at 10 new locations. This process is repeated until damage is observed. The damage threshold is then assigned to be the highest power/energy that the optic can withstand without causing damage. A histogram such as that below represents the testing of one BB1-E02 mirror.

The photograph above is a protected aluminum-coated mirror after LIDT testing. In this particular test, it handled 0.43 J/cm$^2$ (1064 nm, 10 ns pulse, 10 Hz, Ø1.000 mm) before damage.




According to the test, the damage threshold of the mirror was 2.00 J/cm$^2$ (532 nm, 10 ns pulse, 10 Hz, Ø0.803 mm). Please keep in mind that these tests are performed on clean optics, as dirt and contamination can significantly lower the damage threshold of a component. While the test results are only representative

| Example Test Data | | | |
|---|---|---|---|
| Fluence | # of Tested Locations | Locations with Damage | Locations Without Damage |
| 1.50 J/cm$^2$ | 10 | 0 | 10 |
| 1.75 J/cm$^2$ | 10 | 0 | 10 |

of one coating run, Thorlabs specifies damage threshold values that account for coating variances.

| | | | |
|---|---|---|---|
| 2.00 J/cm$^2$ | 10 | 0 | 10 |
| 2.25 J/cm$^2$ | 10 | 1 | 9 |
| 3.00 J/cm$^2$ | 10 | 1 | 9 |
| 5.00 J/cm$^2$ | 10 | 9 | 1 |

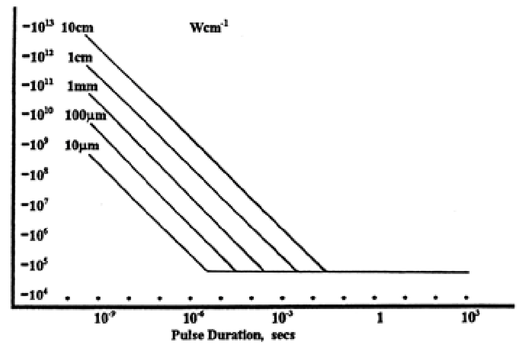
## Continuous Wave and Long-Pulse Lasers

When an optic is damaged by a continuous wave (CW) laser, it is usually due to the melting of the surface as a result of absorbing the laser's energy or damage to the optical coating (antireflection) [1]. Pulsed lasers with pulse lengths longer than 1 µs can be treated as CW lasers for LIDT discussions. Additionally, when pulse lengths are between 1 ns and 1 µs, LIDT can occur either because of absorption or a dielectric breakdown (must check both CW and pulsed LIDT). Absorption is either due to an intrinsic property of the optic or due to surface irregularities; thus LIDT values are only valid for optics meeting or exceeding the surface quality specifications given by a manufacturer. While many optics can handle high power CW lasers, cemented (e.g., achromatic doublets) or highly absorptive (e.g., ND filters) optics tend to have lower CW damage thresholds. These lower thresholds are due to absorption or scattering in the cement or metal coating.

Pulsed lasers with high pulse repetition frequencies (PRF) may behave similarly to CW beams. Unfortunately, this is highly dependent on factors such as absorption and thermal diffusivity, so there is no reliable method for determining when a high PRF laser will damage an optic due to thermal effects. For beams with a large PRF both the average and peak powers must be compared to the equivalent CW power. Additionally, for highly transparent materials, there is little to no drop in the LIDT with increasing PRF.

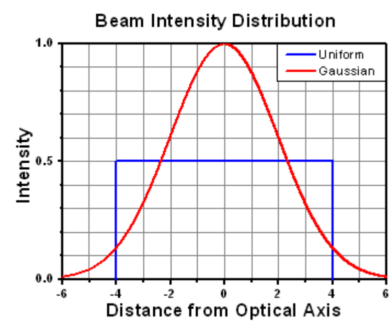
In order to use the specified CW damage threshold of an optic, it is necessary to know the following:

1. Wavelength of your laser
2. Linear power density of your beam (total power divided by 1/e$^2$ spot size)
3. Beam diameter of your beam (1/e$^2$)
4. Approximate intensity profile of your beam (e.g., Gaussian)




LIDT in linear power density vs. pulse length and spot size. For long pulses to CW, linear power density becomes a constant with spot size. This graph was obtained from [1].

The power density of your beam should be calculated in terms of W/cm. The graph to the right shows why the linear power density provides the best metric for long pulse and CW sources. Under these conditions, linear power density scales independently of spot size; one does not need to compute an adjusted LIDT to adjust for changes in spot size. This calculation assumes a uniform beam intensity profile. You must now consider hotspots in the beam or other nonuniform intensity profiles and roughly calculate a maximum power density. For reference, a Gaussian beam typically has a maximum power density that is twice that of the uniform beam (see lower right).




Now compare the maximum power density to that which is specified as the LIDT for the optic. If the optic was tested at a wavelength other than your operating wavelength, the damage threshold must be scaled appropriately. A good rule of thumb is that the damage threshold has a linear relationship with wavelength such that as you move to shorter wavelengths, the damage threshold decreases (i.e., a LIDT of 10 W/cm at 1310 nm scales to 5 W/cm at 655 nm):

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

While this rule of thumb provides a general trend, it is not a quantitative analysis of LIDT vs wavelength. In CW applications, for instance, damage scales more strongly with absorption in the coating and substrate, which does not necessarily scale well with wavelength. While the above procedure provides a good rule of thumb for LIDT values, please contact Tech Support if your wavelength is different from the specified LIDT wavelength. If your power density is less than the adjusted LIDT of the optic, then the optic should work for your application.

Please note that we have a buffer built in between the specified damage thresholds online and the tests which we have done, which accommodates variation between batches. Upon request, we can provide individual test information and a testing certificate. The damage analysis will be carried out on a similar optic (customer's optic will not be damaged). Testing may result in additional costs or lead times. Contact Tech Support for more information.

## Pulsed Lasers

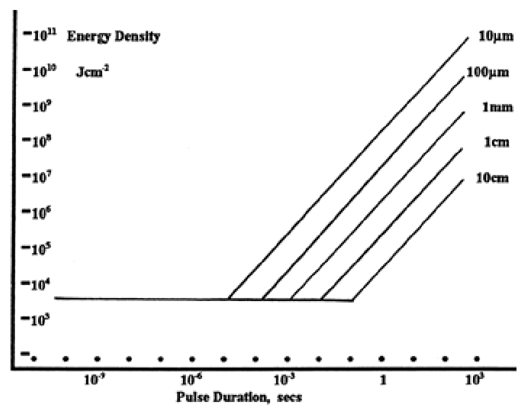
As previously stated, pulsed lasers typically induce a different type of damage to the optic than CW lasers. Pulsed lasers often do not heat the optic enough to damage it; instead, pulsed lasers produce strong electric fields capable of inducing dielectric breakdown in the material. Unfortunately, it can be very difficult to compare the LIDT specification of an optic to your laser. There are multiple regimes in which a pulsed laser can damage an optic and this is based on the laser's pulse length. The highlighted columns in the table below outline the relevant pulse lengths for our specified LIDT values.

Pulses shorter than $10^{-9}$ s cannot be compared to our specified LIDT values with much reliability. In this ultra-short-pulse regime various mechanics, such as multiphoton-avalanche ionization, take over as the predominate damage mechanism [2]. In contrast, pulses between $10^{-7}$ s and $10^{-4}$ s may cause damage to an optic either because of dielectric breakdown or thermal effects. This means that both CW and pulsed damage thresholds must be compared to the laser beam to determine whether the optic is suitable for your application.

| **Pulse Duration** | $t < 10^{-9}$ s | $10^{-9} < t < 10^{-7}$ s | $10^{-7} < t < 10^{-4}$ s | $t > 10^{-4}$ s |
|---|---|---|---|---|
| **Damage Mechanism** | Avalanche Ionization | Dielectric Breakdown | Dielectric Breakdown or Thermal | Thermal |
| **Relevant Damage Specification** | N/A | Pulsed | Pulsed and CW | CW |

When comparing an LIDT specified for a pulsed laser to your laser, it is essential to know the following:

1. Wavelength of your laser
2. Energy density of your beam (total energy divided by $1/e^2$ area)
3. Pulse length of your laser
4. Pulse repetition frequency (prf) of your laser
5. Beam diameter of your laser ($1/e^2$ )
6. Approximate intensity profile of your beam (e.g., Gaussian)




LIDT in energy density vs. pulse length and spot size. For short pulses, energy density becomes a constant with spot size. This graph was obtained from [1].

The energy density of your beam should be calculated in terms of J/cm$^2$. The graph to the right shows why the energy density provides the best metric for short pulse sources. Under these conditions, energy density scales independently of spot size, one does not need to compute an adjusted LIDT to adjust for changes in spot size. This calculation assumes a uniform beam intensity profile. You must now adjust this energy density to account for hotspots or other nonuniform intensity profiles and roughly calculate a maximum energy density. For reference a Gaussian beam typically has a maximum energy density that is twice that of the $1/e^2$ beam.

Now compare the maximum energy density to that which is specified as the LIDT for the optic. If the optic was tested at a wavelength other than your operating wavelength, the damage threshold must be scaled appropriately [3]. A good rule of thumb is that the damage threshold has an inverse square root relationship with wavelength such that as you move to shorter wavelengths, the damage threshold decreases (i.e., a LIDT of 1 J/cm$^2$ at 1064 nm scales to 0.7 J/cm$^2$ at 532 nm):

$$Adjusted\ LIDT = LIDT\ Energy\sqrt{\frac{Your\ Wavelength}{LIDT\ Wavelength}}$$

You now have a wavelength-adjusted energy density, which you will use in the following step.

Beam diameter is also important to know when comparing damage thresholds. While the LIDT, when expressed in units of J/cm², scales independently of spot size; large beam sizes are more likely to illuminate a larger number of defects which can lead to greater variances in the LIDT [4]. For data presented here, a <1 mm beam size was used to measure the LIDT. For beams sizes greater than 5 mm, the LIDT (J/cm2) will not scale independently of beam diameter due to the larger size beam exposing more defects.

The pulse length must now be compensated for. The longer the pulse duration, the more energy the optic can handle. For pulse widths between 1 - 100 ns, an approximation is as follows:

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

Use this formula to calculate the Adjusted LIDT for an optic based on your pulse length. If your maximum energy density is less than this adjusted LIDT maximum energy density, then the optic should be suitable for your application. Keep in mind that this calculation is only used for pulses between 10 s and $10^{-7}$ s. For pulses between $10^{-7}$ s and $10^{-4}$ s, the CW LIDT must also be checked before deeming the optic appropriate for your application.

Please note that we have a buffer built in between the specified damage thresholds online and the tests which we have done, which accommodates variation between batches. Upon request, we can provide individual test information and a testing certificate. Contact Tech Support for more information.

---

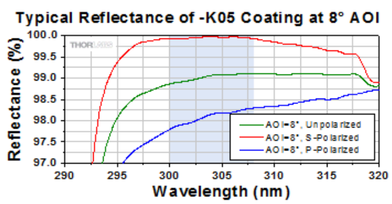

[1] R. M. Wood, Optics and Laser Tech. **29**, 517 (1997).
[2] Roger M. Wood, *Laser-Induced Damage of Optical Materials* (Institute of Physics Publishing, Philadelphia, PA, 2003).
[3] C. W. Carr *et al*., Phys. Rev. Lett. **91**, 127402 (2003).
[4] N. Bloembergen, Appl. Opt. **12**, 661 (1973).


Hide Ar-Ion Laser Line Mirror: 300 - 308 nm

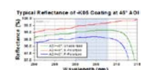
## Ar-Ion Laser Line Mirror: 300 - 308 nm


### Specifications at 0° and 45°

- S-Polarization: $R_{avg}$ > 99.5% (300 - 308 nm)
- P-Polarization: $R_{avg}$ > 98.0% (300 - 308 nm)



Click to Enlarge
Click Here for Raw Data


Click to Enlarge
Click Here for Raw Data

| Part Number | Description | Price | Availability |
|---|---|---|---|
| NB07-K05 | NEW! Ø19 mm Ar-Ion Laser Line Mirror, 300 - 308 nm, 0° and 45° AOI | $116.00 | Today |
| NB1-K05 | NEW! Ø1" Ar-Ion Laser Line Mirror, 300 - 308 nm, 0° and 45° AOI | $133.00 | Today |

Hide Ar-Ion Laser Line Mirrors: 333 - 364 nm

## Ar-Ion Laser Line Mirrors: 333 - 364 nm

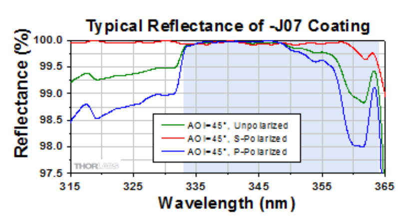

### NB1-H07 Specifications at 0°

- Unpolarized: $R_{avg}$ > 99.5% (333 - 364 nm)
- Damage Threshold: 1 kW/cm$^2$ @ 333 - 364 nm

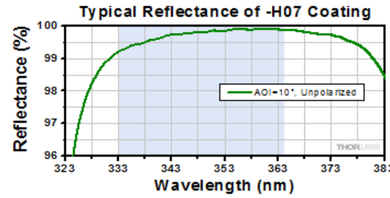
Please note that reflectance does not depend on polarization as the angle of incidence (AOI) approaches 0°.

### NB1-J07 Specifications at 45°

- S-Polarization: $R_{avg}$ > 99.5% (333 - 364 nm)
- P-Polarization: $R_{avg}$ > 99.5% (333 - 364 nm)
- Damage Threshold: 1 kW/cm$^2$ @ 333 - 364 nm



Click to Enlarge
Click Here for Raw Data

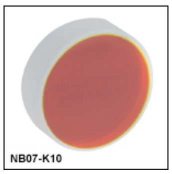



Click to Enlarge
Click Here for Raw Data

| Part Number | Description | Price | Availability |
|---|---|---|---|
| NB1-H07 | Ø1" Ar-Ion Laser Mirror, 333 - 364 nm, 0° AOI | $126.00 | Today |
| NB07-J07 | Ø19 mm Ar-Ion Laser Mirror, 333 - 364 nm, 45° AOI | $114.00 | Today |
| NB1-J07 | Ø1" Ar-Ion Laser Mirror, 333 - 364 nm, 45° AOI | $130.00 | Today |

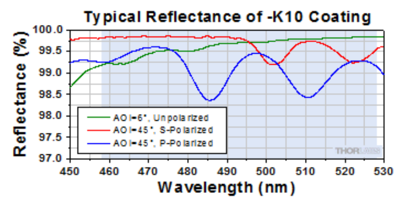
Hide Ar-Ion Laser Line Mirrors: 458 - 528 nm

## Ar-Ion Laser Line Mirrors: 458 - 528 nm




### Specifications at 0° and 45°

- S-Polarization: $R_{avg}$ > 99.0% (458 - 528 nm)
- P-Polarization: $R_{avg}$ > 99.0% (458 - 528 nm)




Click to Enlarge
Click Here for Raw Data

| Part Number | Description | Price | Availability |
|---|---|---|---|
| NB07-K10 | NEW! Ø19 mm Ar-Ion Laser Mirror, 458 - 528 nm, 0° and 45° AOI | $116.00 | Today |
| NB1-K10 | NEW! Ø1" Ar-Ion Laser Mirror, 458 - 528 nm, 0° and 45° AOI | $133.00 | Today |

Visit the *Argon Ion Laser Mirrors* page for pricing and availability information:
https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=806