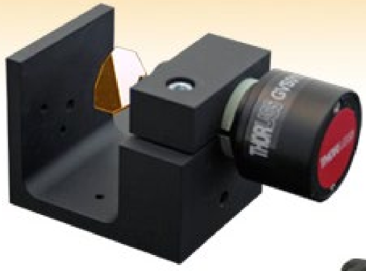
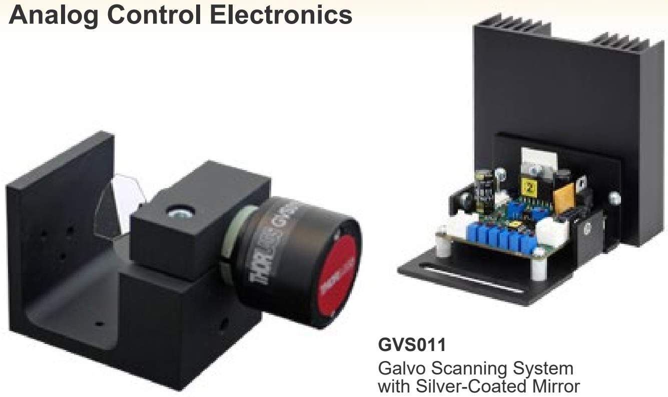
GVS411/M - February 6, 2024

Item GVS411/M was discontinued on February 6, 2024. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

LARGE BEAM DIAMETER SINGLE-AXIS SCANNING GALVO SYSTEMS

- **For Beam Diameters up to 10 mm**
- **Choice of Dielectric or Metallic Mirror Coating**
- **Easy Integration into OEM Systems**
- **Analog Control Electronics**


Single-Axis Motor/Mirror Assembly
(Shown with Gold-Coated Mirror)


GVS011
Galvo Scanning System
with Silver-Coated Mirror


GHS003
Heatsink

OVERVIEW

Features

- Moving Magnet Motor Design for Fast Response (400 µs for ±0.2°)
- High-Precision (15 µrad) Capacitive Mirror Position Detection
- Analog Control Electronics with Current Damping and Error Limiter
- Choice of Mirror Coatings Shown in the Table Below
- Custom Coatings Available upon Request (Contact Tech Sales for More Details)

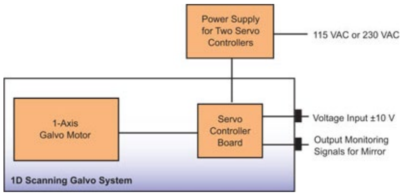
These high-speed Scanning Galvanometer Mirror Positioning Systems are designed for integration into OEM or custom laser beam steering applications with a beam diameter of <10 mm. Each system includes a single-axis galvo motor and mirror assembly, associated driver card, and driver card heatsink. Also provided is a base plate, which allows the assembly to be mounted on our TR series posts and our range of tilt platforms. A low-noise, linear power supply (Item # prefix GPS011) and a cover for the driver card (Item # GCE001) are available separately (see below for details). Upon initial setup of the system, a function generator or DAQ card will be needed for operating the servo drivers; see Chapters 3 and 4 in the manual for additional information.

Key Specifications[a,b]	
Beam Diameter	10 mm (Max)
Repeatability	15 µrad
Linearity (50% Full Travel)	99.9%
Max Mechanical Scan Angle	±20.0° (w/ 0.5 V/deg Scaling)
Bandwidth (Full Travel)	25 Hz Square Wave 35 Hz Sine Wave
Bandwidth (50% Full Travel)	65 Hz Square Wave 130 Hz Sine Wave
Small Angle (±0.2°) Bandwidth	1 kHz
Small Angle Step Response[c]	400 µs
Analog Position Signal Input Range	±10 V
Mechanical Position Signal Input Scale Factor[d]	1.0 V, 0.8 V, or 0.5 V per degree
Position Sensor Output	40 to 80 µA

a. For complete specifications, please see the *Specs* tab.
b. All specifications are valid after 60 seconds upon power on.
c. The settling time for the mirror to stop moving once the drive signal is removed.
d. See the diagram titled "JP7 Volts/Degree Scaling Factor Control" on the *Pin Diagrams* tab for more details.

The mirrors are offered with one of five coatings, as shown in the table below. Custom coatings are available upon request. Please contact Tech Sales for more details.

Galvo Motor/Mirror Assembly



The galvo consists of a galvanometer-based scanning motor with an optical mirror mounted on the shaft and a detector that provides positional feedback to the control board. The moving magnet design for the GVS series of galvanometer motors was chosen over a stationary magnet and rotating coil design in order to provide the fastest response times and the highest system resonant frequency. The position of the mirror is encoded using a capacitive sensing system located inside of the motor housing.

Due to the large angular acceleration of the rotation shaft, the size, shape, and inertia of the mirrors become significant factors in the design of high performance galvo systems. Furthermore, the mirror must remain rigid (flat) even when subjected to large accelerations. All these factors have been precisely balanced in our galvo systems in order to match the characteristics of the galvo motor and maximize performance of the system.

The galvo mirrors are secured to the motor/mirror assembly by a flexure clamp. The positions of the mirror holders are set at the factory and should not be changed by the user.

Scanning Galvo Mirror Assembly and Driver Board

All Thorlabs scanning galvo mirror systems feature a mounted single- or dual-axis mirror/motor assembly and driver card(s). Shown to the right is the silver-coated 10 mm 1D galvo mirror assembly with driver card. The mirror assembly features multiple mounting holes and a rotatable collar mount for the mirror/motor. A flying lead allows connection to the driver board. Please see below for additional mounting options and accessories.

Click to Enlarge
GVS011 Silver-Coated Galvo Mirror Assembly and Driver Board

Servo Driver Board

The Proportional Derivative (PD) servo driver circuit interprets the signals from the optical position detecting system inside the motor and then produces the drive voltage required to rotate the mirror to the desired position. The scanner uses a non-integrating, Class 0 servo that is ideal for use in applications that require vector positioning (e.g., laser marking), raster positioning (printing or scanning laser microscopy), and some step-and-hold applications. Furthermore, the proportional derivative controller gives excellent dynamic performance. The circuit includes an additional current term to ensure stability at high accelerations. The same driver board is used in all of our galvo systems.

System Operation

The servo driver must be connected to a DC power supply, the galvo motor, and an input voltage source (the monitoring connection is optional). For continuous scanning applications, a function generator with a square or sine wave output is sufficient for scanning the galvo mirror over its entire range. For more complex scanning patterns, a programmable voltage source such as a DAQ card can be used. Please note that these systems do not include a function generator or a DAQ card. The ratio between the input voltage and mirror position is switchable between 0.5 V/°, 0.8 V/°, and 1 V/°. For the GVSx11 systems, the ±10 V input produces the full angular range of ±20° with a scaling factor of 0.5. The control circuit also provides monitoring outputs that allow the user to track the position of the mirror. In addition, voltages proportional to the drive current being supplied to the motor and the difference between the command position and the actual position of the mirror are supplied by the control circuit.

Closed-Loop Mirror Positioning

The angular orientation (position) of the mirror is measured using a capacitive sensing system, which is integrated into the interior of the galvanometer housing, and allows for the closed-loop operation of the galvo mirror system.

The GVSx11 systems can be driven to scan their full ±20° range at a frequency of 65 Hz when using a square wave control input voltage and 130 Hz when using a sine wave. For a ±0.2° small angle, the step response is 400 µs. The maximum scan frequency is 1 kHz and the angular resolution is 0.0008° (15 µrad, with GPS011-xx Linear Power Supply).

SPECS

Galvanometer System Specifications[a]

Item #	GVS411(/M)	GVS211(/M)	GVS011(/M)	GVS311(/M)	GVS111(/M)
Mirror					
Maximum Beam Diameter	10 mm				
Substrate	Quartz				
Coating	UV-Enhanced Aluminum	Broadband Dielectric (-E02)	Protected Silver	Nd:YAG Fundamental and 2nd Harmonic (-K13)	Protected Gold
Wavelength Range	250 - 450 nm	400 - 750 nm	500 nm - 2.0 µm	532 nm and 1064 nm	800 nm - 20 µm
Damage Threshold	0.3 J/cm^2 at 355 nm (10 ns, 10 Hz, Ø0.381 mm)	0.25 J/cm^2 at 532 nm (10 ns, 10 Hz, Ø0.803 mm)	3 J/cm^2 at 1064 nm (10 ns, 10 Hz, Ø1.000 mm)	8 J/cm^2 at 532 nm (10 ns, 10 Hz, Ø0.491 mm) 5 J/cm^2 at 1064 nm (10 ns, 10 Hz, Ø1.010 mm)	2 J/cm^2 at 1064 nm (10 ns, 10 Hz, Ø1.000 mm)

Parallelism	<3 arcmin
Surface Quality	40-20 Scratch-Dig
Front Surface Flatness (@633 nm)	λ
Clear Aperture	>90% of Dimension
Motor and Position Sensor	
Linearity (50% Full Travel)	99.9%
Scale Drift[b]	<200 ppm/°C (Max)
Zero Drift[b]	<20 µrad/°C (Max)
Repeatability	15 µrad
Resolution (Mechanical)	With GPS011 Linear Power Supply: 0.0008° (15 µrad) With Standard Switching Mode Power Supply: 0.004° (70 µrad)
Average Current	1 A
Peak Current	10 A
Maximum Scan Angle (Mechanical Angle)	±20.0° (Input Scale Factor 0.5 V per degree)
Motor Weight (including Cables, excluding Brackets)	94 g
Operating Temperature Range	15 to 35 °C
Position Sensor Output Range	40 to 80 µA
Drive Electronics	
Full Travel Bandwidth[c]	25 Hz Square Wave, 35 Hz Sine Wave
Bandwidth (50% Full Travel)	65 Hz Square Wave, 130 Hz Sine Wave
Small Angle (±0.2°) Bandwidth	1 kHz
Small Angle Step Response[d]	400 µs
Power Supply	±15 to ±18 VDC (1.25 A rms, 10 A Peak Max)
Analog Signal Input Resistance	20 kΩ ± 1% (Differential Input)
Position Signal Output Resistance	1 kΩ ± 1%
Analog Position Signal Input Range	±10 V
Mechanical Position Signal Input Scale Factor[e]	Switchable: 1.0 V, 0.8 V or 0.5 V per degree
Mechanical Position Signal Output Scale Factor	0.5 V per degree
Operating Temperature Range	15 to 35 °C
Servo Board Size (W x D x H)	85 mm x 74 mm x 44 mm (3.35" x 2.9" x 1.73")

a. All specifications are valid after 60 seconds upon power on.
b. Measured after leaving the unit powered up for at least 8 hours (max drift is <0.8 mrad in 8 hrs upon power on).
c. The unit can operate beyond these limits with reduced performance until protections trigger (250 Hz <10 sec). For a safe operation, stay below 50 Hz 20 V_{pp} sine wave.
d. The settling time for the mirror to stop moving once the drive signal is removed.
e. See the diagram titled "JP7 Volts/Degree Scaling Factor Control" on the *Pin Diagrams* tab for more details.

Maximum Recommended Scan Angles

Input Beam Diameter	Max Optical Scan Angle (Beam Angle)	Mechanical Scan Angle (Motor Angle)
10 mm	+40° / -16°	+20° / -8°
8 mm	+40° / -32°	+20° / -16°
7 mm and Less	±40°	±20°

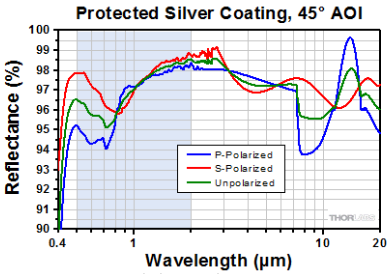
Power Supply Specifications

Item #	GPS011-US	GPS011-EC	GPS011-JP
Input Voltage	115 VAC, 60 Hz	230 VAC, 50 Hz	100 VAC, 50/60 Hz
Output Voltage	±15 VDC, 3.0 A / 0.1 A, 1.4/6.3 ms		
Fuses	T2.0 A Anti-Surge Ceramic	T1.0 A Anti-Surge Ceramic	T2.5 A Anti-Surge Ceramic
	179 mm x 274 mm (Max) x 122 mm		

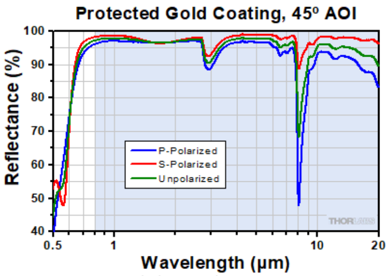
Dimensions	(7.05" x 10.79" (Max) x 4.8")
Weight	4.73 kg (10.4 lbs)

GRAPHS

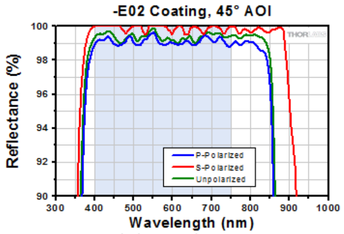
The curves below show the reflection data for the coated mirrors supplied with the GVS series galvo systems. The shaded regions denote the ranges over which we recommend using the respective coating. Please note that the reflectance outside of these bands is not as rigorously monitored in quality control, and can vary from lot to lot, especially in out-of-band regions where the reflectance is fluctuating or sloped.



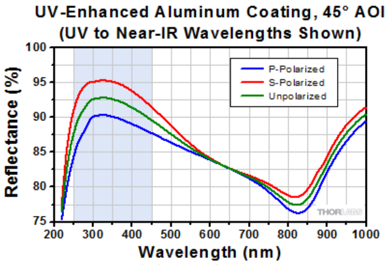
Click to Enlarge
Excel Spreadsheet with Raw Data for Protected Silver



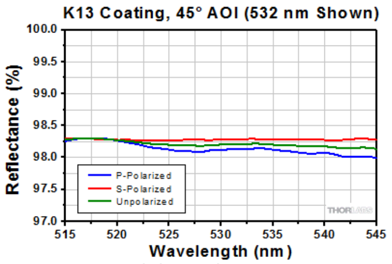
Click to Enlarge
Excel Spreadsheet with Raw Data for Protected Gold



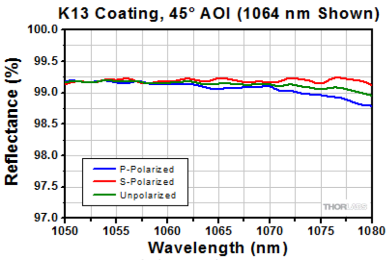
Click to Enlarge
Excel Spreadsheet with Raw Data for E02 Coating



Click to Enlarge
Excel Spreadsheet with Raw Data for UV-Enhanced Aluminum



Click to Enlarge
Excel Spreadsheet with Raw Data for K13 Coating

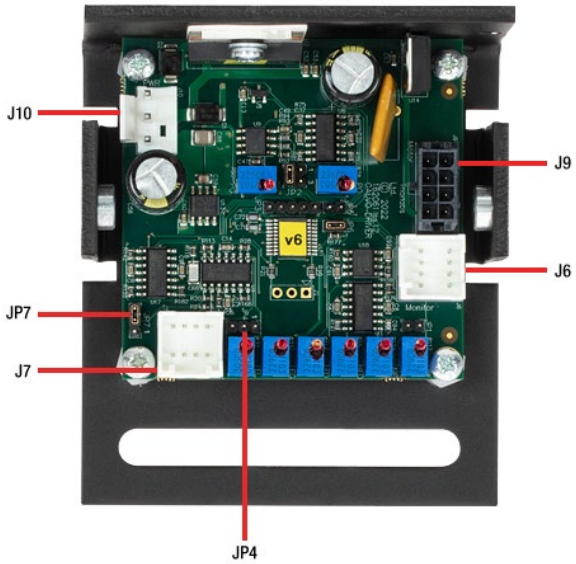


Click to Enlarge
Excel Spreadsheet with Raw Data for K13 Coating

PIN DIAGRAMS

This tab contains information regarding the power connector, diagnostics connector, motor connectors, command input connector, and degree scaling factor control on the GVS series driver boards.

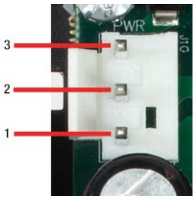
GVS Series Driver Connections



Click to Enlarge

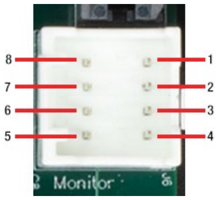
Overview of PCB connectors. Details on each connector can be found below.

J10 Power Connector



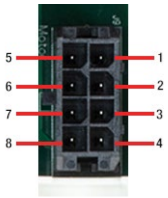
Pin	Designation
1	+ 15 V
2	Ground
3	- 15 V

J6 Diagnostics Connector



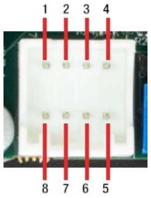
Pin	Designation
1	Scanner Position
2	Internal Command Signal
3	Positioning Error x 5
4	Motor Drive Current
5	Not Connected
6	Test Input (NC)
7	Motor + Coil Voltage / 2
8	Ground

J9 Motor Connector

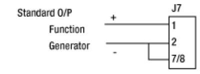


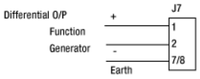
Pin	Designation
1	Position Sensor A Current
2	Position Sensor Ground
3	Position Sensor Cable Shield
4	Drive Cable Shield
5	Position Sensor B Current
6	Position Sensor Power
7	Motor + Coil
8	Motor - Coil

J7 Command Input Connector



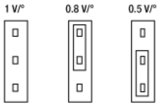
Pin	Designation
1	Command Input +ve
2	Command Input -ve
3	DRV OK
4	External Enable
5	-12 V Output (Low Impedance O/P)
6	+12 V Output (Low Impedance O/P)
7	Ground

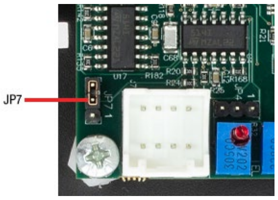




8	Ground

JP7 Volts/Degree Scaling Factor Control

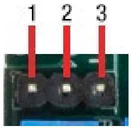




The servo driver cards have a jumper which is used to set the Volts per Degree scaling factor. The cards are shipped with the scaling set to 0.5 V/°,where the maximum mechanical scan angle is nominally ±20° for the full ±10 V input. To change the scaling factor, set the jumper on JP7 as shown above.

External Enabling of the Driver Board

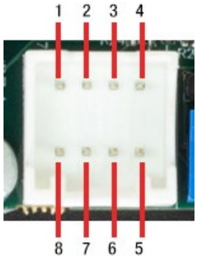
The drive electronics can be configured for external enabling by placing a jumper across pins 2 and 3 of JP4.



JP4

Once this has been done, the user can enable or disable the drive electronics by applying a 5 V CMOS signal to J7 pin 4.

If a logic high or no signal is applied, the drive electronics will be enabled. If a logic low signal is applied, then the driver will be disabled.



J7

Pin	Designation
1	Command Input +ve
2	Command Input -ve
3	No Connect
4	External Enable
5	-12 V Output
6	+12 V Output
7	Ground
8	Ground

DAMAGE THRESHOLDS

Damage Threshold Data for Thorlabs' Large Beam Diameter Scanning Galvo Systems

The specifications to the right are measured data for Thorlabs' large beam diameter scanning galvo systems. Damage threshold specifications are constant for all larger diameter scanning galvo systems.

Damage Threshold Specifications	
Item #	**Damage Threshold**
GVS011(/M)	3 J/cm^2 at 1064 nm (10 ns, 10 Hz, Ø1.000 mm)
GVS111(/M)	2 J/cm^2 at 1064 nm (10 ns, 10 Hz, Ø1.000 mm)
GVS211(/M)	0.25 J/cm^2 at 532 nm (10 ns, 10 Hz, Ø0.803 mm)
GVS311(/M)	8 J/cm^2 at 532 nm (10 ns, 10 Hz, Ø0.491 mm) 5 J/cm^2 at 1064 nm (10 ns, 10 Hz, Ø1.010 mm)
GVS411(/M)	0.3 J/cm^2 at 355 nm (10 ns, 10 Hz, Ø0.381 mm)

Laser Induced Damage Threshold Tutorial

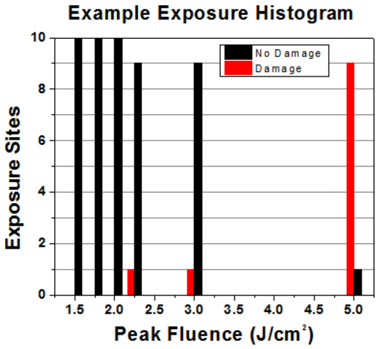
The following is a general overview of how laser induced damage thresholds are measured and how the values may be utilized in determining the appropriateness of an optic for a given application. When choosing optics, it is important to understand the Laser Induced Damage Threshold (LIDT) of the optics 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/DIS 11254 and ISO 21254 specifications.

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 30 seconds (CW) or for a 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.



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
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

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

Continuous Wave and Long-Pulse Lasers

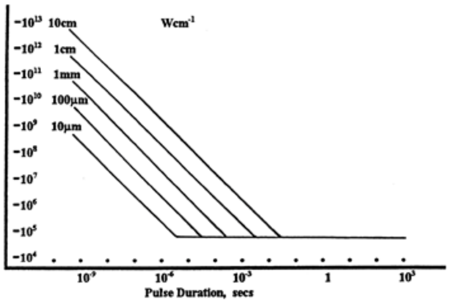
When an optic is damaged by a continuous wave (CW) laser, it is usually due to the melting of the surface as a result of absorbing the laser's energy or damage to the optical coating (antireflection) [1]. Pulsed lasers with pulse lengths longer than 1 µs can be treated as CW lasers for LIDT discussions.

When pulse lengths are between 1 ns and 1 µs, laser-induced damage can occur either because of absorption or a dielectric breakdown (therefore, a user 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 high 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. Beam diameter of your beam (1/e^2)
3. Approximate intensity profile of your beam (e.g., Gaussian)
4. Linear power density of your beam (total power divided by 1/e^2 beam diameter)

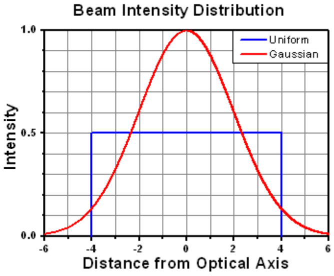


LIDT in linear power density vs. pulse length and spot size. For long pulses to CW, linear power density becomes a constant with spot size. This graph was obtained from [1].

Thorlabs expresses LIDT for CW lasers as a linear power density measured in W/cm. In this regime, the LIDT given as a linear power density can be applied to any beam diameter; one does not need to compute an adjusted LIDT to adjust for changes in spot size, as demonstrated by the graph to the right. Average linear power density can be calculated using the equation below.

$$\text{Linear Power Density} = \frac{\text{Power}}{\text{Beam Diameter}}$$

The calculation above assumes a uniform beam intensity profile. You must now consider hotspots in



the beam or other non-uniform 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

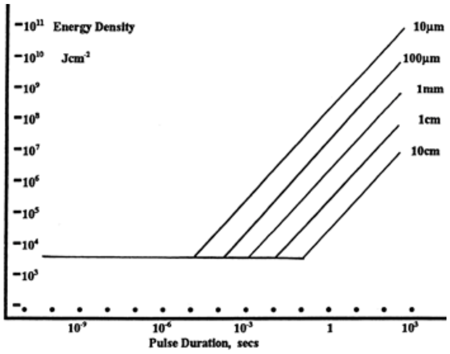
As previously stated, pulsed lasers typically induce a different type of damage to the optic than CW lasers. Pulsed lasers often do not heat the optic enough to damage it; instead, pulsed lasers produce strong electric fields capable of inducing dielectric breakdown in the material. Unfortunately, it 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	No Comparison (See Above)	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 expressing the LIDT as an energy density provides the best metric for short pulse sources. In this regime, the LIDT given as an energy density can be applied to any beam diameter; 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^{-9} 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 (1998).
[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).

LIDT CALCULATIONS

LIDT Calculator

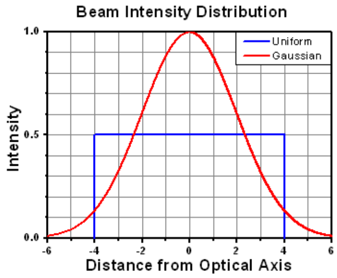
In order to illustrate the process of determining whether a given laser system will damage an optic, a number of example calculations of laser induced damage threshold are given below. For assistance with performing similar calculations, we provide a spreadsheet calculator that can be downloaded by clicking the button to the right. To use the calculator, enter the specified LIDT value of the optic under consideration and the relevant parameters of your laser system in the green boxes. The spreadsheet will then calculate a linear power density for CW and pulsed systems, as well as an energy density value for pulsed systems. These values are used to calculate adjusted, scaled LIDT values for the optics based on accepted scaling laws. This calculator assumes a Gaussian beam profile, so a correction factor must be introduced for other beam shapes (uniform, etc.). The LIDT scaling laws are determined from empirical relationships; their accuracy is not guaranteed. Remember that absorption by optics or coatings can significantly reduce LIDT in some spectral regions. These LIDT values are not valid for ultrashort pulses less than one nanosecond in duration.

CW Laser Example

Suppose that a CW laser system at 1319 nm produces a 0.5 W Gaussian beam that has a 1/e^2 diameter of 10 mm. A naive calculation of the average linear power density of this beam would yield a value of 0.5 W/cm, given by the total power divided by the beam diameter:

$$Linear\ Power\ Density = \frac{Power}{Beam\ Diameter}$$

However, the maximum power density of a Gaussian beam is about twice the maximum power density of a uniform beam, as shown in the graph to the right. Therefore, a more accurate determination of the maximum linear power density of the system is 1 W/cm.



A Gaussian beam profile has about twice the maximum intensity of a uniform beam profile.

An AC127-030-C achromatic doublet lens has a specified CW LIDT of 350 W/cm, as tested at 1550 nm. CW damage threshold values typically scale directly with the wavelength of the laser source, so this yields an adjusted LIDT value:

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

The adjusted LIDT value of 350 W/cm x (1319 nm / 1550 nm) = 298 W/cm is significantly higher than the calculated maximum linear power density of the laser system, so it would be safe to use this doublet lens for this application.

Pulsed Nanosecond Laser Example: Scaling for Different Pulse Durations
Suppose that a pulsed Nd:YAG laser system is frequency tripled to produce a 10 Hz output, consisting of 2 ns output pulses at 355 nm, each with 1 J of energy, in a Gaussian beam with a 1.9 cm beam diameter ($1/e^2$). The average energy density of each pulse is found by dividing the pulse energy by the beam area:

$$\text{Energy Density} = \frac{\text{Pulse Energy}}{\text{Beam Area}}$$

As described above, the maximum energy density of a Gaussian beam is about twice the average energy density. So, the maximum energy density of this beam is ~0.7 J/cm^2.

The energy density of the beam can be compared to the LIDT values of 1 J/cm^2 and 3.5 J/cm^2 for a BB1-E01 broadband dielectric mirror and an NB1-K08 Nd:YAG laser line mirror, respectively. Both of these LIDT values, while measured at 355 nm, were determined with a 10 ns pulsed laser at 10 Hz. Therefore, an adjustment must be applied for the shorter pulse duration of the system under consideration. As described on the previous tab, LIDT values in the nanosecond pulse regime scale with the square root of the laser pulse duration:

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

This adjustment factor results in LIDT values of 0.45 J/cm^2 for the BB1-E01 broadband mirror and 1.6 J/cm^2 for the Nd:YAG laser line mirror, which are to be compared with the 0.7 J/cm^2 maximum energy density of the beam. While the broadband mirror would likely be damaged by the laser, the more specialized laser line mirror is appropriate for use with this system.

Pulsed Nanosecond Laser Example: Scaling for Different Wavelengths
Suppose that a pulsed laser system emits 10 ns pulses at 2.5 Hz, each with 100 mJ of energy at 1064 nm in a 16 mm diameter beam ($1/e^2$) that must be attenuated with a neutral density filter. For a Gaussian output, these specifications result in a maximum energy density of 0.1 J/cm^2. The damage threshold of an NDUV10A Ø25 mm, OD 1.0, reflective neutral density filter is 0.05 J/cm^2 for 10 ns pulses at 355 nm, while the damage threshold of the similar NE10A absorptive filter is 10 J/cm^2 for 10 ns pulses at 532 nm. As described on the previous tab, the LIDT value of an optic scales with the square root of the wavelength in the nanosecond pulse regime:

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

This scaling gives adjusted LIDT values of 0.08 J/cm^2 for the reflective filter and 14 J/cm^2 for the absorptive filter. In this case, the absorptive filter is the best choice in order to avoid optical damage.

Pulsed Microsecond Laser Example
Consider a laser system that produces 1 µs pulses, each containing 150 µJ of energy at a repetition rate of 50 kHz, resulting in a relatively high duty cycle of 5%. This system falls somewhere between the regimes of CW and pulsed laser induced damage, and could potentially damage an optic by mechanisms associated with either regime. As a result, both CW and pulsed LIDT values must be compared to the properties of the laser system to ensure safe operation.

If this relatively long-pulse laser emits a Gaussian 12.7 mm diameter beam ($1/e^2$) at 980 nm, then the resulting output has a linear power density of 5.9 W/cm and an energy density of 1.2×10^{-4} J/cm^2 per pulse. This can be compared to the LIDT values for a WPQ10E-980 polymer zero-order quarter-wave plate, which are 5 W/cm for CW radiation at 810 nm and 5 J/cm^2 for a 10 ns pulse at 810 nm. As before, the CW LIDT of the optic scales linearly with the laser wavelength, resulting in an adjusted CW value of 6 W/cm at 980 nm. On the other hand, the pulsed LIDT scales with the square root of the laser wavelength and the square root of the pulse duration, resulting in an adjusted value of 55 J/cm^2 for a 1 µs pulse at 980 nm. The pulsed LIDT of the optic is significantly greater than the energy density of the laser pulse, so individual pulses will not damage the wave plate. However, the large average linear power density of the laser system may cause thermal damage to the optic, much like a high-power CW beam.

1-Axis Large Beam Diameter Scanning Galvo Systems

- 1D Large Beam Galvo Systems
- Five Wavelength Range Options from 250 nm to 20 µm

- Power Supply Sold Separately

Thorlabs 1D Galvo Mirror Systems are available in single axis configurations for large beam applications up to 10 mm. A choice of mirror coatings is available as described in the table below. Each system includes a single-axis galvo motor and mirror assembly, associated driver card, and driver card heatsink. Power supplies, driver card covers, cage system adapters, and galvo mirror heatsinks are sold separately and can be found below.

Item #	GVS411(/M)	GVS211(/M)	GVS011(/M)	GVS311(/M)	GVS111(/M)
Coating	UV-Enhanced Aluminum	Broadband Dielectric (-E02)	Protected Silver	Nd:YAG Fundamental and 2nd Harmonic (-K13)	Protected Gold
Wavelength Range[a] (R_{avg} > 95%)	250 - 450 nm	400 - 750 nm	500 nm - 2.0 µm	532 nm and 1064 nm	800 nm - 20 µm
Damage Thresholds[b]	0.3 J/cm^2 at 355 nm (10 ns, 10 Hz, Ø0.381 mm)	0.25 J/cm^2 at 532 nm (10 ns, 10 Hz, Ø0.803 mm)	3 J/cm^2 at 1064 nm (10 ns, 10 Hz, Ø1.000 mm)	8 J/cm^2 at 532 nm (10 ns, 10 Hz, Ø0.491 mm) 5 J/cm^2 at 1064 nm (10 ns, 10 Hz, Ø1.010 mm)	2 J/cm^2 at 1064 nm (10 ns, 10 Hz, Ø1.000 mm)

a. See the *Graphs* tab for reflectance curves.
b. See *Damage Thresholds* tab for more information.

Part Number	Description	Price	Availability
GVS411/M	**Customer Inspired! 1D Large Beam (10 mm) Diameter Galvo System, UV Enhanced Aluminum Mirror, Metric, Power Supply Not Included**	**$1,848.94**	**Lead Time**
GVS211/M	**Customer Inspired! 1D Large Beam (10 mm) Diameter Galvo System, Broadband Mirror (-E02), Metric, Power Supply Not Included**	**$2,070.71**	**Today**
GVS011/M	**1D Large Beam (10 mm) Diameter Galvo System, Silver-Coated Mirror, Metric, Power Supply Not Included**	**$1,750.10**	**Today**
GVS311/M	**Customer Inspired! 1D Large Beam (10 mm) Diameter Galvo System, Dual Band Mirror 532 nm/1064 nm (-K13), Metric, Power Supply Not Included**	**$2,280.43**	**Lead Time**
GVS111/M	**Customer Inspired! 1D Large Beam (10 mm) Diameter Galvo System, Gold-Coated Mirror, Metric, Power Supply Not Included**	**$1,848.94**	**Lead Time**
GVS411	**Customer Inspired! 1D Large Beam (10 mm) Diameter Galvo System, UV Enhanced Aluminum Mirror, Power Supply Not Included**	**$1,848.94**	**Today**
GVS211	**Customer Inspired! 1D Large Beam (10 mm) Diameter Galvo System, Broadband Mirror (-E02), Power Supply Not Included**	**$2,070.71**	**Today**
GVS011	**1D Large Beam (10 mm) Diameter Galvo System, Silver-Coated Mirror, Power Supply Not Included**	**$1,750.10**	**Today**
GVS311	**Customer Inspired! 1D Large Beam (10 mm) Diameter Galvo System, Dual Band Mirror 532 nm/1064 nm (-K13), Power Supply Not Included**	**$2,280.43**	**Lead Time**
GVS111	**Customer Inspired! 1D Large Beam (10 mm) Diameter Galvo System, Gold-Coated Mirror, Power Supply Not Included**	**$1,848.94**	**Today**

Galvo System Linear Power Supplies

- Compatible with Galvo Systems Above
- Low Noise, Linear Supply Minimizes Electrical Interference
- Capable of Powering Two Server Driver Cards Simultaneously
- Configured for Regional Voltage Requirements upon Shipping

These power supplies are low noise, linear supplies designed to minimize electrical interference for maximum system resolution. They deliver ±15 VDC at 3 A and are configured to accept a mains voltage of 115 VAC (for GPS011-US), 230 VAC (for GPS011-EC), or 100 VAC (for GPS011-JP). Each power supply is compatible with all of our galvo systems available above. Two 2 m (6.5') power cables are included.

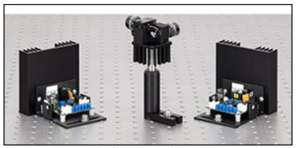
As an alternative, a standard switching mode power supply may be used for low demand applications.

Part Number	Description	Price	Availability
GPS011-EC	**Customer Inspired! 1D or 2D Galvo System Linear Power Supply, 230 VAC**	**$582.95**	**Today**
GPS011-US	**Customer Inspired! 1D or 2D Galvo System Linear Power Supply, 115 VAC**	**$582.95**	**Today**
GPS011-JP	**Customer Inspired! 1D or 2D Galvo System Linear Power Supply, 100 VAC**	**$582.95**	**7-10 Days**

Galvo Mount Heatsink and Post Mounting Adapter

- Provides Additional Cooling to Prevent Thermal Cutout
- Attaches Directly to the 1D and 2D Mirror Mounts
- Convenient Post Adapter to Thorlabs' 8-32 (M4) Threaded Posts

The GHS003 galvo mirror heatsink attaches directly to the single-axis and dual-axis mirror mounts to provide device cooling and alternate mounting options. Mounting screws are supplied with the unit.



Click to Enlarge
2D Galvo System Mounted on Heatsink on a Ø1/2" Post

Heat from the galvo mirrors is typically dissipated through the normal mounting options. However, applications involving rapidly changing drive signals can create excess heat buildup, causing the galvo motor to fail or driver board thermal cutout to trip. If the cutout occurs repeatedly, we recommend using the GHS003 Heatsink. The heatsink also serves as a post adapter, allowing the galvo mirror assembly to be mounted on our Ø1/2" 8-32 (M4) threaded posts.

Part Number	Description	Price	Availability
GHS003/M	**Galvo Heatsink and Post Mounting Adapter, Metric**	**$32.08**	**Today**
GHS003	**Galvo Heatsink and Post Mounting Adapter, Imperial**	**$32.08**	**Today**

Galvo Driver Card Cover

The GCE001 is a convenient enclosure for servo driver cards. Simply bolt it onto the servo driver bracket using the M3 screws and hex key supplied.

Note: This item is not compatible with early models of the servo driver card. Contact Tech Support for more details.

Click to Enlarge
The GCE001 can be used to cover the Galvo Systems' servo driver boards.

Part Number	Description	Price	Availability
GCE001	**Galvo Driver Card Cover**	**$69.00**	**Today**