

# MAKROS

## User Guide



Faraday Rotators & Optical Isolators  
1900 nm to 2100 nm

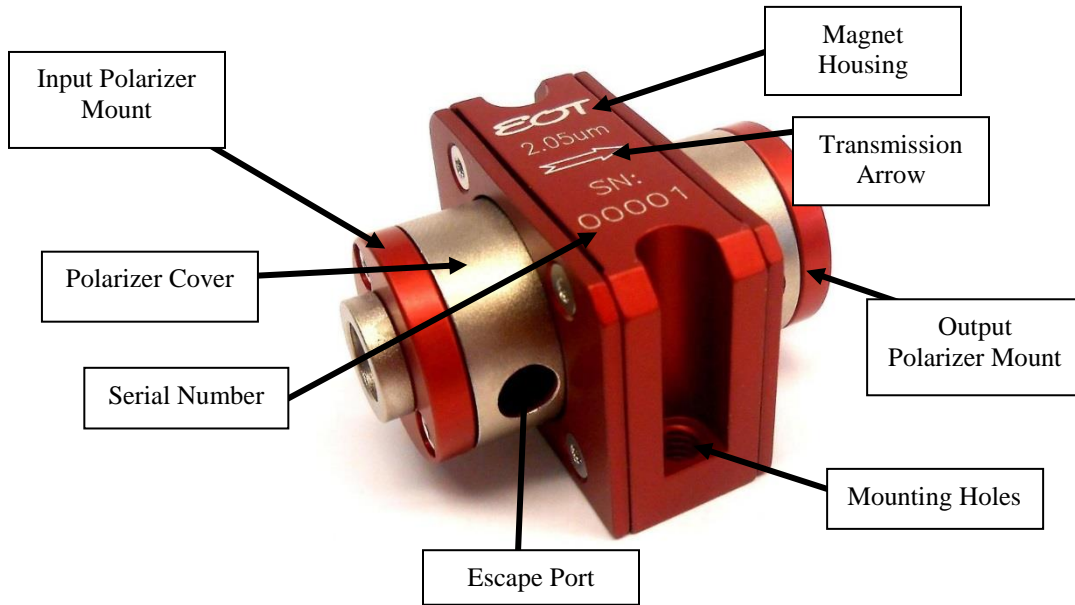
Thank you for purchasing your MAKROS Faraday Rotator or Optical Isolator from EOT. This user guide will help answer questions you may have regarding the safe use and optimal operation of your Faraday Rotator or Isolator.

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### I. MAKROS Optical Isolator Overview

Your MAKROS Optical Isolator is essentially a unidirectional light valve. It is used to protect a laser source from destabilizing feedback or actual damage from back-reflected light. Figure 1 below identifies the main elements of your Optical Isolator.



**Figure 1: MAKROS Optical Isolator**

The Optical Isolator is a cylindrically-shaped magneto-optic device in which strong permanent magnets are used to generate axially-oriented fields within the magnet housing. The strong longitudinal field causes 45 degrees of non-reciprocal polarization rotation for propagating light via the Faraday Effect in the crystal located within the magnet housing. In operation the magnet housing is sandwiched between input and output polarizers that have their transmission axis oriented 45 degrees relative to each other to account for the 45 degrees of Faraday rotation in the forward (transmission)

direction. In the reverse (isolation) direction the non-reciprocal Faraday rotation and the 45 degree polarizer transmission axis angle add so that the polarization transmitted by the output polarizer is rejected at the input polarizer.

Your MAKROS Optical Isolator is labeled with a serial number on the baseplate of the device.

## II. Safe use of your MAKROS Optical Isolator

The operational hazards presented to operating personnel by the use of your MAKROS Optical Isolator are listed below. An explanation of how the Optical Isolator is designed together with procedures users can employ to eliminate or minimize these hazards is presented.

1. Danger of sharp ferromagnetic objects being attracted to the residual permanent magnet fields outside of the isolator. This hazard is of most concern if such fields cause flying objects when being handled.

Your MAKROS Optical Isolator requires strong internal magnetic fields to operate properly. Efforts have been made to minimize external fields from the device while still maintaining a relatively small and cost-effective package. The external fields are designed to be well within federal safety guidelines which limit external fields from magnetic devices to be less than 2 K Gauss at a radial distance of 5cm from the outside of the device. However, such fields can be sufficient to attract nearby objects such as knives and razor blades. Should attraction of such objects begin to occur, there would be a strong attractive force directing these objects towards the interior of the magnet housing. This could be particularly likely to result in injury (e.g. a cut or puncture wound) if such attraction occurred while the device was being handled - particularly if a body part of the operating personnel is near a beam aperture (i.e. end) of the device.

To minimize the above risks, remove all loose ferromagnetic objects from the path over which your MAKROS Optical Isolator is to be moved prior to attempting to move it. **Do not** pick up the isolator by its ends (i.e. apertures) where the attractive magnetic fields are strongest. Always pick the isolator up along its sides.

2. Never attempt to disassemble the magnetic housing of your Faraday Rotator/Isolator. Serious injury could result.
3. Reflection of rejected beams from the input and output polarizer.

The polarizer covers have been rotated at the factory to block all beams rejected from the polarizers. In the event that your Optical Isolator will be used with transmitted average powers in excess of 25 W, or will block backward propagating light in excess of 0.5 W average power, these polarizer covers must be rotated to allow rejected beams to exit through the escape ports (see Figure 1) onto user-supplied beam dumps.

**These rejected beams can represent a hazard to users and/or their colleagues. Care must be exercised to ensure that all rejected beams (both transmission and isolation directions) are accounted for and terminated into functional beam dumps.** Wherever possible keep the strongest rejected beams in the horizontal plane of the table or otherwise safest direction (typically down into the table). **Always wear laser safety glasses or goggles consistent with all laser frequencies and power levels present.** See Sections III and IV for further details.

4. Failure of operating personnel to observe standard laser safety by trying to sight down through the Isolator or not controlling the direction of the rejected beams when laser radiation is present.

It is never appropriate to view through the device in the transmission, isolation, or rejected beam direction when laser radiation is present – even with laser safety goggles.

**Never sight through your Optical Isolator in either direction when there is any possibility of laser radiation being present.**

5. Harm caused by external magnetic fields.

Your MAKROS Optical Isolator has been designed to meet existing federal safety guidelines for external fields as noted previously. Such guidelines could change in the future as more information becomes known or reviewed regarding the interaction between magnetic fields and human health. Since various claims exist regarding the potential harmful (and beneficial!) effects of magnetic fields on humans it is prudent to limit interaction with these fields as much as possible.

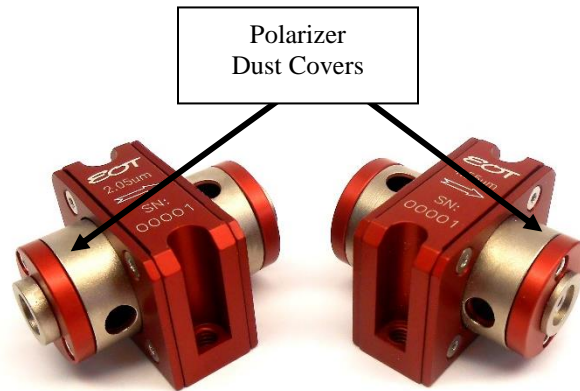
Personnel with any magnetically-sensitive implants such as pacemakers should present a copy of this report and consult their medical doctor regarding any potential complications which could arise from the isolator external magnetic fields.

6. Other non-health related hazards.

The Optical Isolator external magnetic fields can draw ferromagnetic objects into the magnet housing which can damage the optical elements within the device. Keep a suitable area from the Optical Isolator in all directions clear of any loose ferromagnetic objects. Ideally, use non-magnetic tools (such as stainless steel or titanium) and hardware to secure the Optical Isolator. If only ferromagnetic tools are available use extreme care when using them around the Optical Isolator. It is always helpful to bring such tools towards an aperture (or end) radially rather than along the optical beam path. Doing this ensures that the fields will tend to pull such objects into the magnet housing endplate rather than into the optical aperture. Where possible use two hands, one to hold the tool and the other to guide it to the desired destination.

Another concern regarding external magnetic fields is their effect on magnetically-sensitive devices. The external fields are strong enough to induce a pulse of current in electronic devices (such as digital watches) that can destroy them. The fields can also disrupt the operation of other mechanical devices with ferromagnetic parts in them. Finally, the external fields can erase information from magnetic strips such as those found on credit and ID cards. Remove all magnetically-sensitive materials and devices such as watches, computer hard drives, and magnetic strips from operators prior to working in the proximity of an isolator.

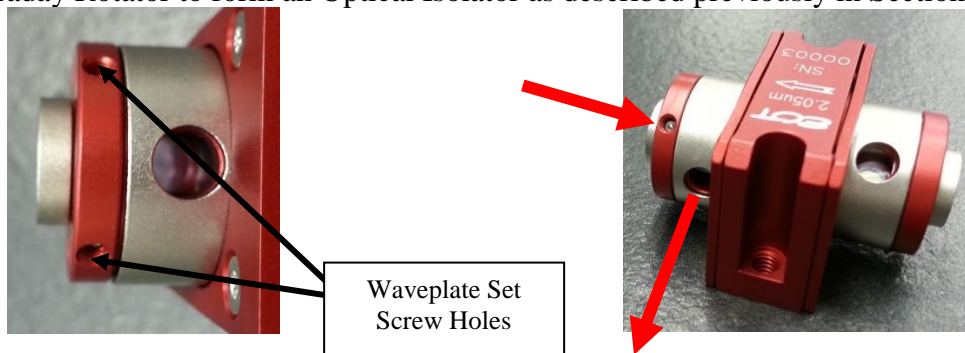
### III. The MAKROS Optical Isolator



**Figure 2: Overall view of a MAKROS Optical Isolator**

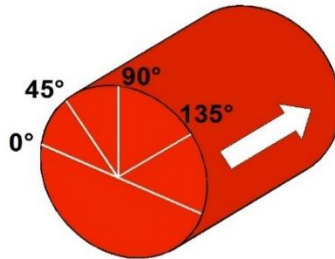
With the polarizer covers open, a polarizing beamsplitter cube (PBSC) can be seen at each end of the device. The output PBSC is oriented with its transmission axis rotated 45 degrees relative to the input PBSC. The input polarization shown is horizontal on the left and vertical on the right for a 2.05  $\mu\text{m}$  device. The polarization always follows the orientation of the escape ports.

The central magnet housing together with the crystal residing in its center forms a Faraday Rotator. The Faraday Rotator rotates the input horizontal transmission axis by 45 degrees so that transmitted light has a polarization aligned with the output transmission axis. The input and output PBSCs work in conjunction with the central Faraday Rotator to form an Optical Isolator as described previously in Section I.



**Figure 3: Rejected beam direction**

Figure 3 shows the waveplate set screw holes. The rejected beam port that is between these set screw holes is the direction that a backward propagating beam (i.e. a beam going the opposite direction of the arrow on the isolator body) will be rejected.



**Figure 4: Polarization Orientation Diagram**

Figure 4 shows the coordinate system for the Optical Isolators. A horizontal orientation is referred to as  $0^\circ$  while a vertical orientation is  $90^\circ$ . While looking in the direction of the transmitted beam, rotating clockwise from  $0^\circ$  gives an increasing orientation value, going toward  $45^\circ$ , then  $90^\circ$ , and finally  $135^\circ$  before coming around again to  $0^\circ$ .

$45^\circ$  of rotation can be achieved in either direction (e.g.  $0^\circ$  to  $45^\circ$  or  $45^\circ$  to  $0^\circ$ ) without the use of a waveplate. If the output polarization needs to be the same as or  $90^\circ$  off from the input polarization, a waveplate will be needed. Waveplates are installed on the input side of the device unless otherwise specified.

Figure 5 shows a  $2.05\ \mu\text{m}$  device with a horizontal input polarization.



**Figure 5:  $2.05\ \mu\text{m}$ , Horizontal Polarization**

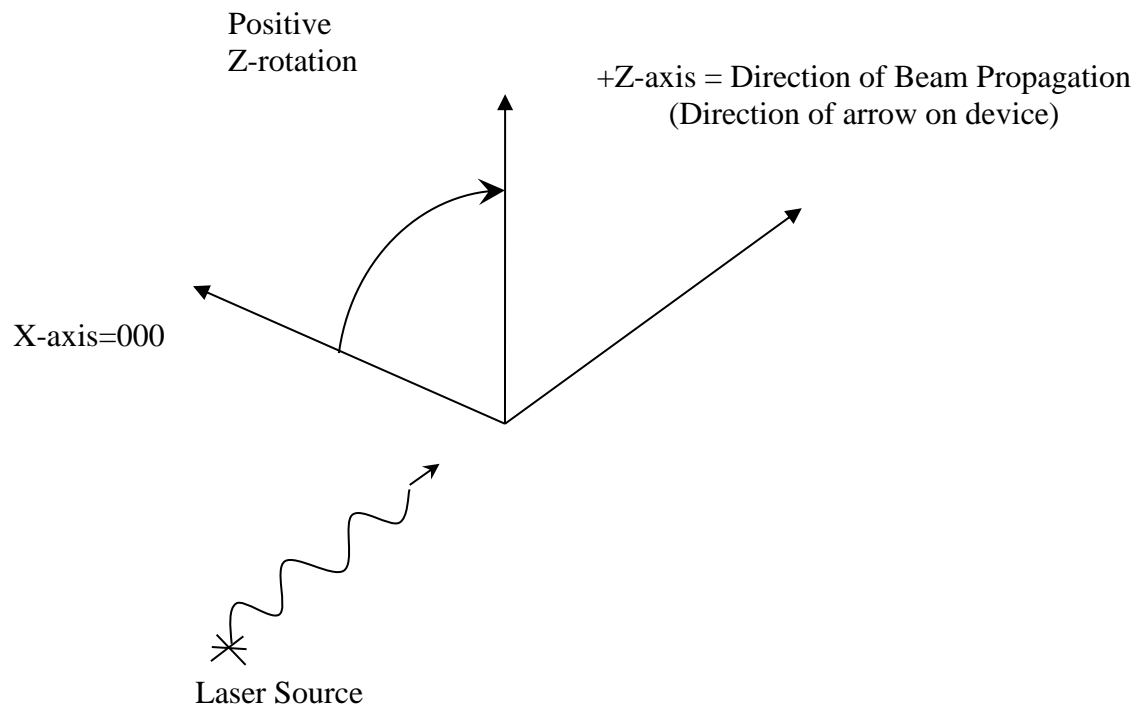
**Numbering Fields & Coordinate System for MAKROS Faraday Rotators & Optical Isolators**

General Format for Numbering Field: AA-B-CCCC-DDD-EEE

**Field Description:**

1. “AA” is the aperture size, e.g. 04=4 mm.
2. “B” is the device type. I=isolator; R=rotator.
3. “CCCC” is the operating wavelength in nm.
4. “DDD” is the input polarization axis angle. A right hand X, Y, Z Cartesian coordinate system is used, in which the direction of beam propagation away from the laser source is along the positive Z axis. The X axis is in the plane of the baseplate. The Y axis is vertical, normal to the plane of the baseplate. The XY plane forms the plane of polarization. The XZ plane forms the plane of the baseplate. As an example, a horizontal input polarization is 000 or 0 degrees. A vertical polarization is 090, or 90 degrees. If no polarization is selected by the customer, 000 will be assigned. For rotators, this field does not apply.
5. “EEE” is the output polarization, which is 45 degrees from the input polarization if no waveplate is used. If a waveplate is used and no output polarization is specified, the default setting is the input polarization plus 90 degrees. The angle convention is the same as described for “DDD”. For rotators, this field does not apply.

Y-axis=090



#### IV. Using your MAKROS Optical Isolator

Observe the guidelines for safe use of your Optical Isolator found in Section II above when removing your isolator from its shipping container. Do not remove the protective dust cover end caps from the polarizers until the device is in a clean, dust-free environment.



**Figure 6: Remove the protective dust cover end caps in a clean environment**

Save the protective end caps, packaging material, and containers in the event that the device should ever need to be returned to EOT.

Verify that the input and output polarization states are consistent with the intended mode of operation as described by the purchase order model number. If not, either send the device back to EOT (see Section VI) or, if desired, readjust the isolator as required (see Section V).

With the source laser off, or running at very low power (less than 250 mW), position the Optical Isolator such that the source laser beam can be directed through the input aperture. Critical alignment of the Optical Isolator should be done at low power (less than 250 mW) in order to prevent optical damage to your isolator or laser source.

Use IR cards, IR viewers, or heat-sensitive film to ensure that the source laser beam is centered on the input and output apertures. It is also preferable to use an IR viewer to ensure that weak reflections from AR coated optical surfaces in the Optical Isolator are not being directed back into the source laser. The optical surfaces in the Optical Isolator are angled slightly to reduce these reflections. However, if any such reflections exist the device may typically be tilted by a small amount to ensure that such back-reflections are not coaxially aligned with the source laser beam. Increasing the distance between the Optical Isolator and the source laser can also help ensure that no reflections couple back into the source laser if necessary.

Two (2) #4 or M3 screws can be used to mount the isolator. Alternatively, the holes are also tapped for two (2) 8-32 screws. Steel (ferromagnetic) ball drivers or other such



wrenches will be attracted to the external magnetic field surrounding the device. If possible use anti-magnetic stainless steel or titanium tools. If ferromagnetic tools are used it is desirable to introduce them slowly towards the device from the sides along the direction of the mounting holes.

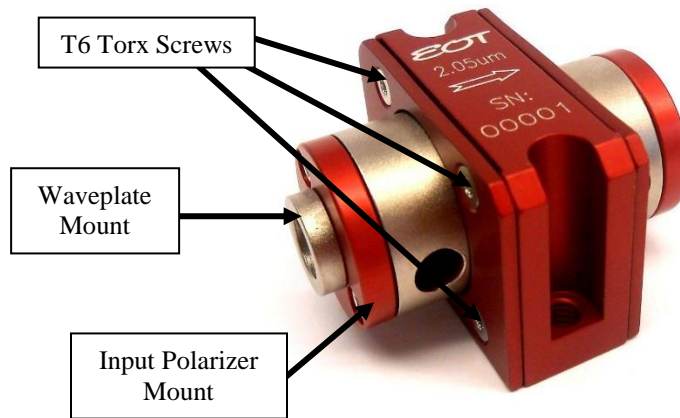
If the Optical Isolator will be used with average powers in excess of 25 W transmitted or 0.5 W rejected backward propagating radiation the polarizer covers will need to be rotated so that the escape ports allow rejected polarization light to be safely dumped onto a beam dump. Failure to allow these rejected polarizations to escape can cause the device to heat up. Such heat can degrade the performance of the Optical Isolator, or in severe cases, cause damage to optical components in the isolator. While working with low alignment level power and wearing safety glasses physically grasp the polarizer cover and rotate it by 90 degrees. Any rejected polarized beams (in either the forward or backward propagating directions) can now exit the polarizer assembly. Use an IR viewer or IR card to locate these beams. Ensure that they are terminated on beam dumps consistent with the maximum amount of power that may be in such beams. In addition to high rejection (>30 dB) of any undesired linear polarization component in transmission, the input and output PBSC may reflect as much as 3% of the desired transmitted polarization. If the Optical Isolator is used in an application where strong reflections and/or optical gain elements (amplifiers) exist there may be very high power rejected beams for backward propagating light at the input polarizer. If the average power levels used do not exceed 25 W transmitted or 0.5 W of backward propagating power then the polarizer covers may be kept in their factory positioned orientation – all rejected beams will then be blocked by the polarizer cover. However, if the Optical Isolator is to be used with very high peak intensities it is prudent to allow rejected beams to escape on to external beam dumps to prevent any ablation damage to the polarizer covers. Follow the same procedure above as for high average powers in order to safely terminate all rejected beams.

## V. Tuning your MAKROS Optical Isolator

### A. *Maximizing Isolation*

If it becomes necessary to operate the isolator at a different wavelength or temperature than it was aligned at in the factory the isolator can be tuned to maximize isolation at your operating conditions. Isolation of the device will change with wavelength used and the temperature of the device. Loosen the four (4) T6 torx screws on the input side of the isolator enough to allow the input polarizer mount to rotate as shown in Figure 7. **Only** loosen the screws enough to let the mount rotate. Loosening too much or completely removing the screws may damage the isolator. To tune the isolator to your specific conditions, place it in the beam path in the reverse direction – the arrow on the isolator body will point back toward the laser source. Ensure that the polarization going into the isolator matches the output polarization of the isolator, which is now the end facing the laser. Make sure all rejected beams are going in a safe direction. Turn the loosened polarizer until the laser power going through the device is minimized.

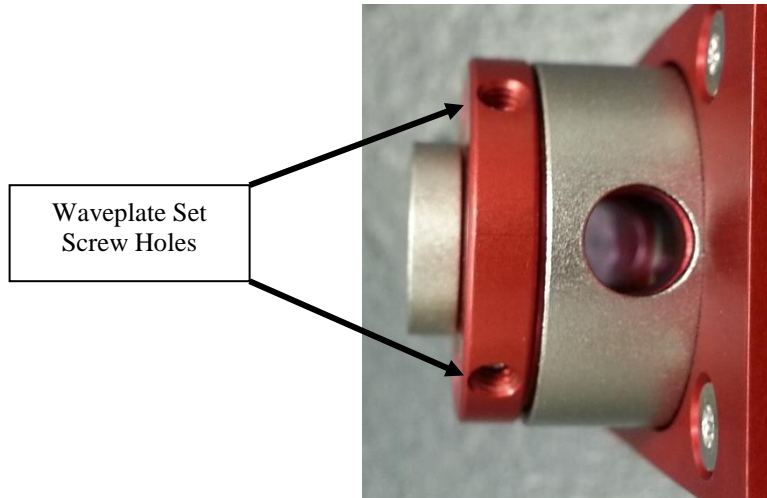
Carefully retighten the four (4) T6 torx screws to a torque of 3 in\*lbs. Retighten the screws slowly in a star pattern to help ensure the alignment of the mount stays true.



**Figure 7: Rotating Input Polarizer**

### *B. Aligning Input Polarization*

If the device was purchased with a waveplate, the input polarization can be adjusted. This allows transmission to be maximized. This should be adjusted any time the isolation of the device is tuned. To do so, remove the two backing screws shown in Figure 8 with a 0.035" hex driver. Loosen the revealed set screws to allow the waveplate mount to rotate freely. If these set screws are loosened too much, the entire waveplate mount may fall out. To align the input polarization, insert the device in the forward direction – the arrow on the isolator body will point in the direction of the beam propagation. Ensure that the polarization going into the isolator matches the desired input polarization of the isolator. Make sure all rejected beams are going in a safe direction. Rotate the waveplate mount until the transmitted power is maximized, or the power rejected off the first polarizer is minimized. Retighten the set screws using 0.7 in\*lbs. and replace the backing screws, also tightening to 0.7 in\*lbs.



**Figure 8: Waveplate Set Screw Location**

## **VI. Warranty Statement and Repair**

EOT warrants its products to be free from defects in material and workmanship and complies with all specifications. EOT will at its option, repair or replace any product or component found to be defective during the warranty period. This warranty applies only to the original purchaser and is not transferrable for a period of one year after date of original shipment. The foregoing warranties shall not apply, and EOT reserves the right to refuse warranty service, should malfunction or failure result from:

- a. Damage caused by improper installation, handling or use.
- b. Unauthorized product modification or repair.
- c. Operation outside the environmental or damage specifications of the product.
- d. Contamination not reported to EOT within 30 days of the original ship date.
- e. EOT's output isolators contain a "spacer" at the end of the isolator. Under certain conditions, an off-axis back-reflection from the workpiece could focus down onto the output displacer or polarizer inside the isolator. The purpose of the spacer is to eliminate the conditions under which this could happen. Should EOT's output isolators be purchased without the spacer, or should the spacer be removed, damage to the output displacer or polarizer will not be covered under warranty and the customer will be responsible for all costs associated with such an occurrence.

This warranty is exclusive in lieu of all other warranties whether written, oral, or implied. EOT specifically disclaims the implied warranties of merchantability and fitness for a particular purpose. In no event shall EOT be liable for an indirect, incidental, or consequential damages in connection with its products.

If the customer believes there is a problem with the rotator/isolator, they should immediately contact EOT's Sales/Customer department at 231-935-4044 or [customerservice@eotech.com](mailto:customerservice@eotech.com). EOT's Customer Service department will either issue an RMA for the device, or provide the customer with a procedure and authorize the



Electro-Optics Technology, Inc.

customer to modify the device. All returns should reference the RMA number on the outside of the shipping container and should be sent to:

Electro-Optics Technology, Inc.  
Attn: Sales/Customer Service  
3340 Parkland Ct.  
Traverse City, MI 49866 USA

EOT reserves the right to inspect rotators/isolators returned under warranty to assess if the problem was caused by a manufacturer defect. If EOT determines the problem is not due to a manufacturer defect (an example would be damage to an optical element caused by impact from a loose ball driver or exceeding the damage threshold of the device), repairs will be done at the customer's expense. EOT will always provide a written quote for repair prior to performing repairs at the customer's expense. **Never attempt to disassemble the magnetic housing of your Faraday Rotator/Isolator. Injury could result.** Any indications that an attempt to disassemble the magnetic housing was made will render the warranty null and void.

#### Notes:

1. **Operating Temperature:** Performance of EOT's Faraday Rotators/Isolators is related to operating temperature. For information on the effect of operating temperature on EOT's Faraday Rotators/Isolators, please review our application note, *Thermal Lensing Analysis of TGG*.
2. **For higher incident powers or aperture sizes other than those specified, or other custom requirements, please consult EOT.** You may either contact EOT's sales department at sales@eotech.com or view our *Custom Solutions* page on our website, eotech.com. EOT has a designated Custom Solutions department with the expertise and capability of manufacturing custom Faraday Rotators and Isolators.
3. **Pulsed Damage Threshold:** The pulsed damage threshold of your free space Faraday Rotator or Isolator can be determined at pulsewidths other than 10 ns by using the "Root T" scaling method.