Electro–Optics Technology, Inc.

EURYS
User Guide

Broadband Faraday Rotators & Optical Isolators
720 nm to 950 nm
Large Aperture (>5 mm)

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Thank you for purchasing your 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 Optical Isolator.

TABLE OF CONTENTS

I. EURYS Optical Isolator Overview 2
II. Safe use of your EURYS Optical Isolator 3
III. The EURYS Broadband Optical Isolator 6
IV. Using your EURYS Optical Isolator 9
V. Tuning your EURYS Optical Isolator 10
VI. Warranty Statement and Repair 10

I. EURYS Optical Isolator Overview

Your EURYS Optical Isolator is essentially a unidirectional light valve or spectrally selective one-way mirror. 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.

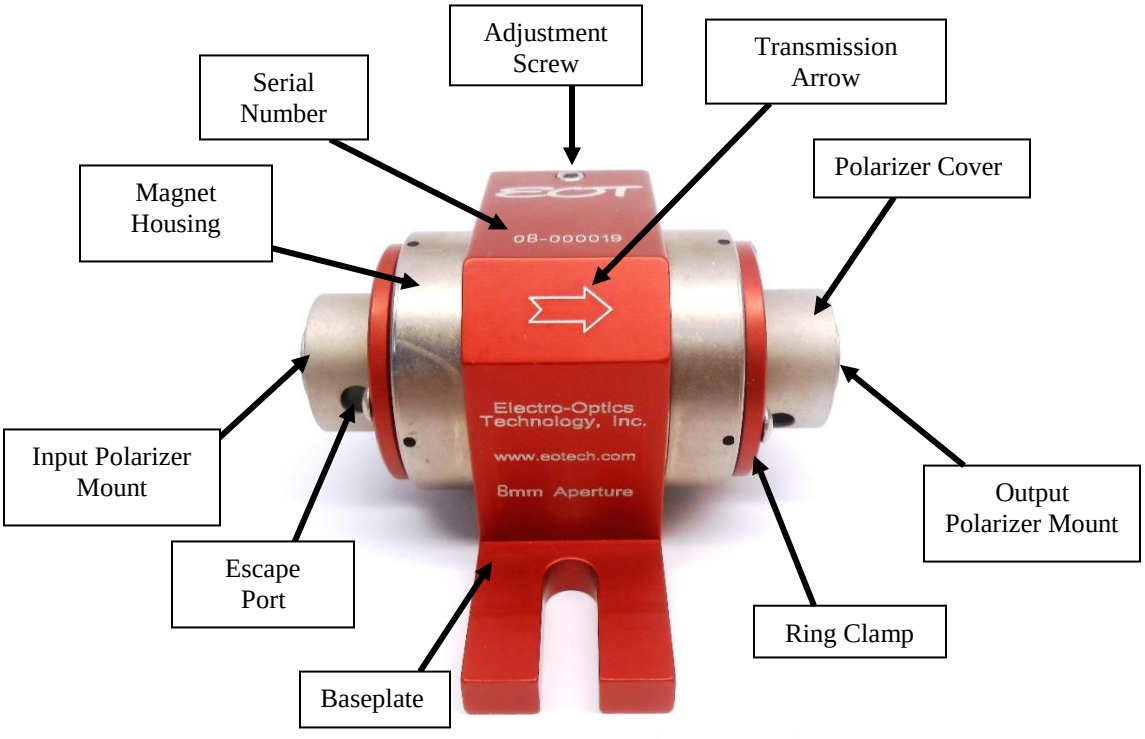


Figure 1: EURYS 8 mm Broadband Optical Isolator

The 8 mm aperture Optical Isolator is a cylindrically-shaped magneto-optic device. Strong Neodymium Iron Boron permanent magnets are used to generate high (>10,000

Gauss) 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 terbium gallium garnet ("TGG") crystal located within the magnet housing. Following the TGG crystal is a quartz reciprocal rotator with 45 degrees of rotation. In the forward direction, the two rotations add up, resulting in 90 degrees of rotation. In the reverse direction, the two rotations are opposite and result in 0 degrees of rotation. The change in rotation as the wavelength shifts from the central wavelength is similar for both TGG and quartz, resulting in broadband operation. In operation, the magnet housing is sandwiched between input and output polarizers that have their transmission axis oriented 90 degrees relative to each other. In the reverse direction the backward traveling beam has a polarization orthogonal to the input polarizer and is therefore crossed with it, resulting in a rejected beam exiting the input polarizer.

The 10 mm aperture Optical Isolator is a rectangular shaped magneto-optic device. The device operates similarly to the 8mm aperture device. However, the magnet body is rectangular and the polarizers and mounts are different. Figure 2 below identifies the main elements of a 10 mm Optical Isolator.

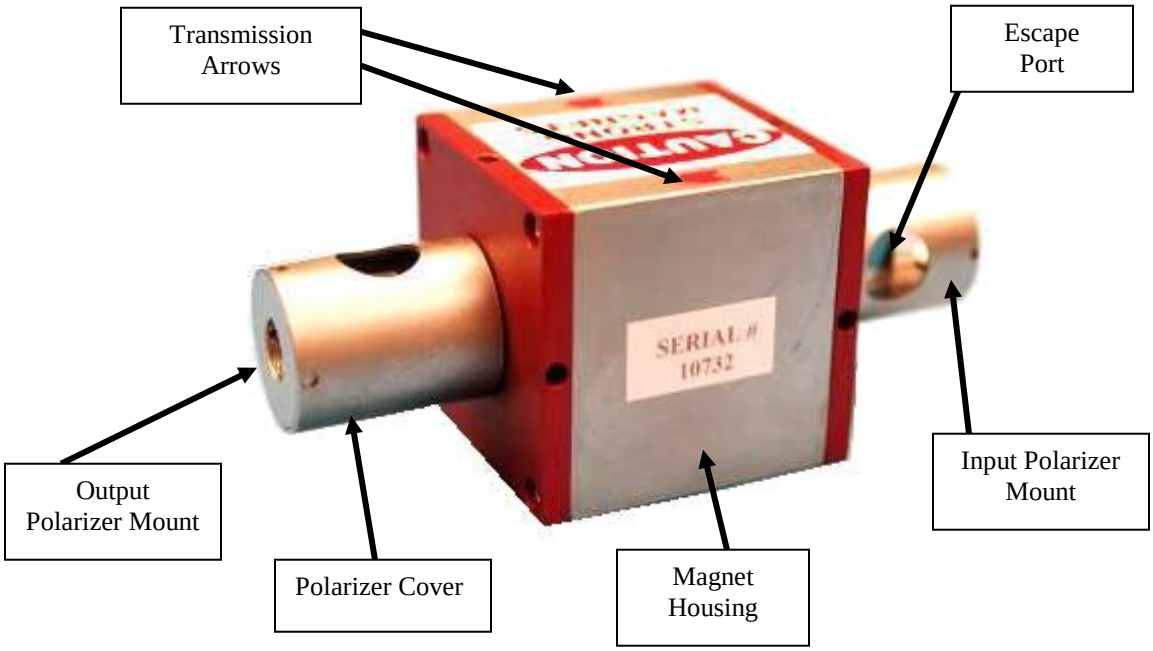


Figure 2: EURYS Broadband 10 mm Aperture Optical Isolator

II. Safe use of your EURYS Optical Isolator

The operational hazards presented to operating personnel by the use of your EURYS 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 EURYS 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 EURYS 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 positioned 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 removed to allow rejected beams to exit (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 sighting down through the isolator when laser radiation is present.

   The optical elements within the EURYS Optical Isolators can be transmissive throughout the visible and near infrared. Consequently, it is never appropriate to

view through the device in either the transmission or isolation 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 EURYS 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 EURYS Optical Isolator

Figure 3: Overall view of a EURYS 8 mm aperture Broadband Optical Isolator

With the polarizer covers off, a polarizer can be seen at each end of the device. The arrow on the top indicates the transmission direction. The input polarization shown is horizontal. The central magnet housing together with the TGG and quartz crystals residing in its center form a broadband Faraday Rotator. For the 8 mm aperture device, polarizing beam splitter cubes (PBSC) are used. The input and output polarizers work in conjunction with the central Faraday Rotator to form an Optical Isolator as described previously in Section I.

The 8 mm aperture broadband Optical Isolator input and output apertures are in-line and centered on the magnet body. These devices may be adjusted readily for any input polarization. The polarization adjustment screw shown in Figure 1 may be loosened and the entire magnet housing along with input and output polarizers will rotate freely in the baseplate as a single assembly. Once the device is oriented for optimal input polarization, the screw is tightened again. Further details for this procedure are provided in section V.

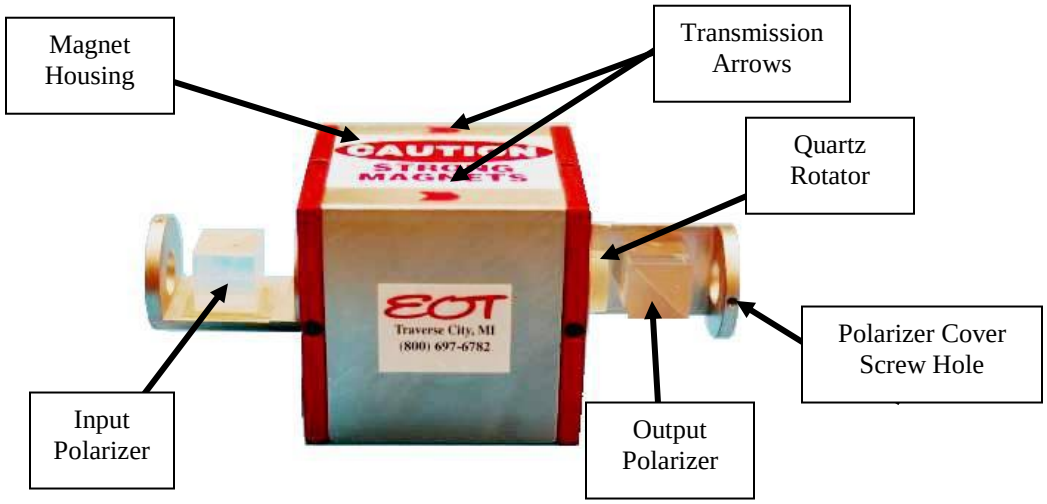


Figure 4: Overall view of a EURYS 10 mm aperture Broadband Optical Isolator

Figure 4 shows the 10 mm aperture broadband Optical Isolator without polarizer covers. Note that the device also uses polarizing beamsplitter cubes for polarizers and the

apertures are located in-line through the device. As in the previous models, the arrows on top indicate the transmission direction. The quartz rotator may be observed mounted to the output polarizer mount on the output end of the Faraday Rotator assembly (magnet housing).

The polarizer covers may be rotated between the open position and the closed position (with the covers rotated 90 degrees). Unlike the 8 mm aperture isolator, the polarizer cover is fixed in position by a single screw that is tightened into the polarizer cover screw hole shown in Figure 4.

Another option is to use a broadband Faraday Rotator. Optically, this device is composed of a Faraday Rotator and a quartz rotator. Rather than polarizer mounts, this device has a set of trim pieces with a central aperture. The quartz is mounted to the interior of the output trim piece.

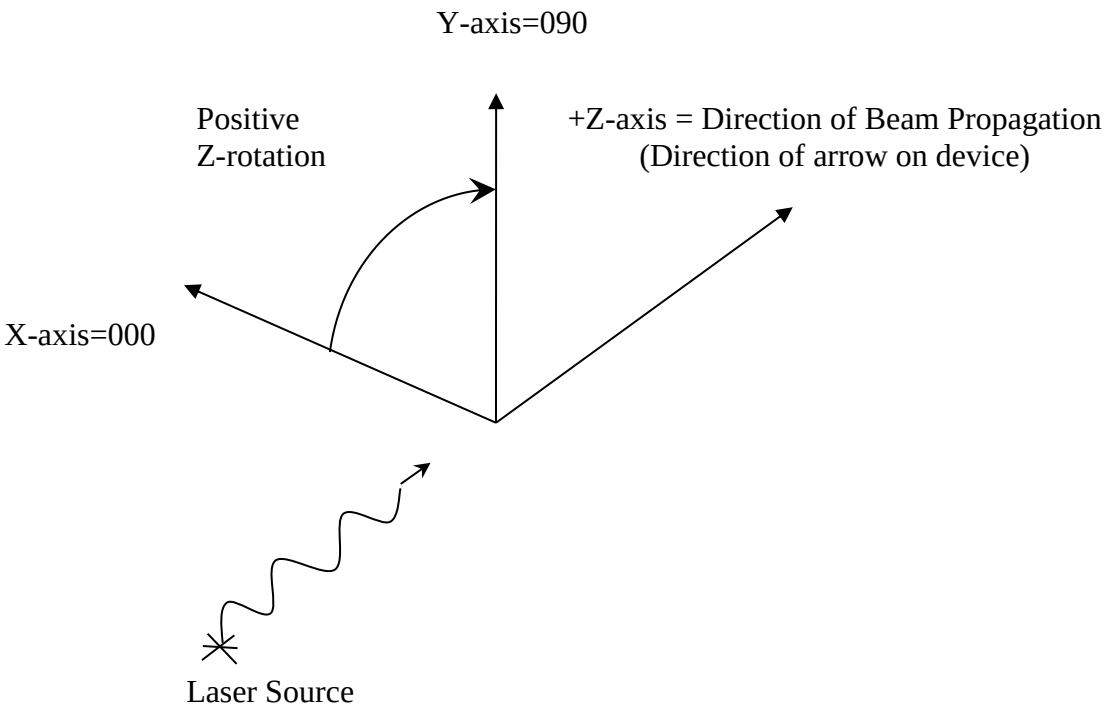
The polarization of EURYS Optical Isolators is factory set as per the model number specified in a purchase order. The information below shows the range for each field in the model number. EOT provides an online build-your-own service for ordering standard devices that will produce a model number based on the following system. A horizontal input polarization combined with a vertical output polarization is default in the event it is not specified by the customer. However, a customer may specify a vertical input polarization and a horizontal output polarization instead.

Numbering Fields & Coordinate System for EURYS Faraday Rotators & Optical Isolators

General Format for Numbering Field: AA-BB-C-DDD-EEE-FFF

Field Description:

1. "AA" is the product type. BB = broadband.
2. "BB" is the aperture size, e.g. 08=8 mm.
3. "C" is the device type. I = isolator; R = rotator.
4. "DDD" is the operating wavelength in nm.
5. "EEE" 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.
6. "FFF" is the output polarization, which is 90 degrees from the input polarization. The angle convention is the same as described for "EEE." For rotators, this field does not apply.



IV. Using your EURYS 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 covers from the polarizer mounts until the device is in a clean, relatively dust-free environment.

Save the 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. 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.

At this point the Optical Isolator should be secured to the work surface with two (2) to four (4) ¼ - 20 or M6 screws – one for each slot in the baseplate flanges. 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 baseplate flange slots.

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 removed 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, remove the screw holding the dust cover in place for both the input and output. 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. 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 – that it with all rejected beams 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 nickel-plated polarizer covers. Follow the same procedure above as for high average powers in order to safely terminate all rejected beams.

V. Tuning your EURYS Optical Isolator

A. 8 mm Aperture Model

For the 8 mm aperture devices, the cylindrical magnet body is clamped into the baseplate clamp structure. The polarization adjustment screw may be loosened and the cylindrical isolator structure rotates freely inside the clamp. The preferred method for alignment is to use an external polarizer mounted to a fine rotation stage with known directional axes and a waveplate to rotate the polarization before entering the test polarizer. By crossing this polarizer with the input polarizer of the device, a precise input polarization may be realized to a known reference orientation.

B. 10 mm Aperture Model

The 10 mm aperture model has a square cross-section and has mounting screw holes located orthogonal to the propagation direction. The input polarization may be tuned to only two positions by physically picking the device up and setting it back down on its side in the same position. The apertures are centered on the cross-section. Therefore, no alignment is needed following the 90 degrees rotation of the device.

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. EOT's Customer Service department will either issue an RMA for the device, or provide the customer with a procedure and authorize the 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 46986 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.