Electro-Optics Technology, Inc.

Tornos
User Guide

Medium Power Faraday Rotators & Optical Isolators
500 nm to 1030 nm

Electro-Optics Technology, Inc. | 3340 Parkland Ct. Traverse City, MI 49686 USA
eotech.com | sales@eotech.com | 231.935.4044

Thank you for purchasing your TORNOS 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. TORNOS Optical Isolator Overview

Your TORNOS 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.

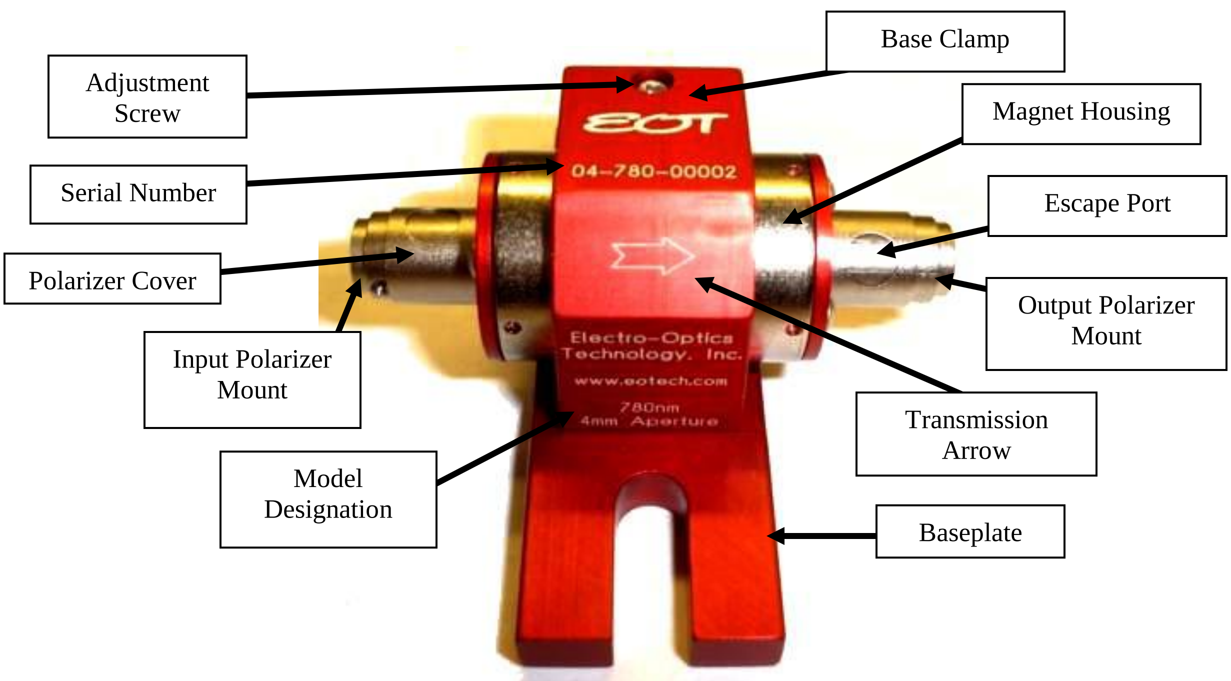


Figure 1: TORNOS Medium Power Optical Isolator

The 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. 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 TGG crystal 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 TORNOS Optical Isolator is labeled with a serial number on the base clamp of the device.

II. Safe use of your TORNOS Optical Isolator

The operational hazards presented to operating personnel by the use of your TORNOS 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 Faraday Rotator. This hazard is of most concern if such fields cause flying objects when being handled.

   Your TORNOS 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 5 cm 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 TORNOS 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/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 Faraday Rotator when laser radiation is present.

   The optical elements within the TORNOS 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.

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

5. Harm caused by external magnetic fields.

   Your TORNOS 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 TORNOS Medium Power Optical Isolator

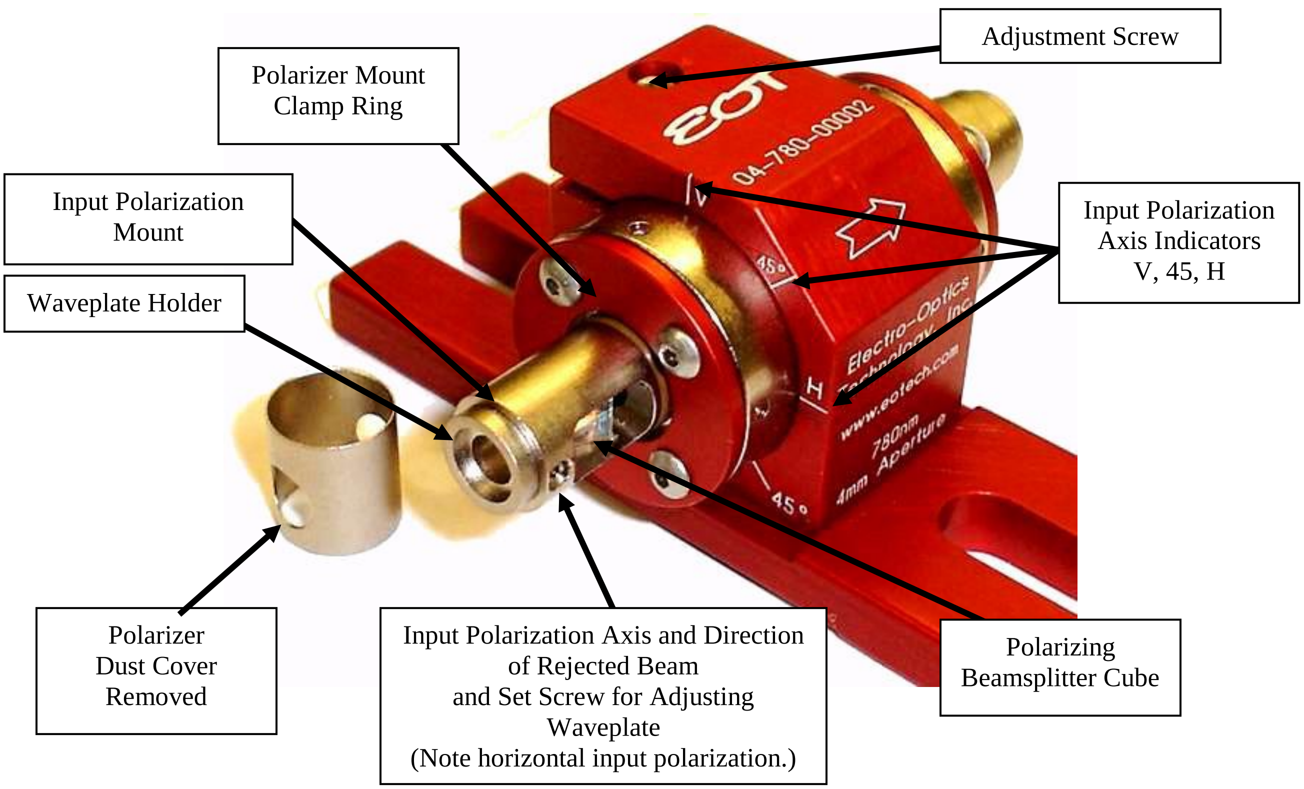


Figure 2: Overall view of a TORNOS Optical Isolator and Tuning Features

With the polarizer cover off, a polarizing beamsplitter cube (PBSC) can be seen inside the input polarization mount. The inscribed arrow on the base clamp shows the transmission direction. The output PBSC is seen to be oriented with its transmission axis rotated 45 degrees relative to the input PBSC. The input polarization shown is horizontal. The central magnet housing together with the TGG 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. Though the overall size of the device varies depending on the wavelength dependent model, the size and operation of the PBSC mounts are identical. Figures 3 and 4 below show input views of a TORNOS Medium Power Optical Isolator.

Figure 3: Horizontal Input Polarization

Figure 4: Vertical Input Polarization

Figure 3 shows a device aligned for a horizontal input polarization. The screw hole located on the side of the PBSC mount indicates the direction of polarization and the direction of the rejected beam. This is the beam that is reflected off of the input polarizer, having originating at the output of the device, traveling in the reverse direction, opposite the direction of the arrow. Figure 4 shows a device aligned for a vertical input polarization.

The second isolator available for use at 500 nm to 1030 nm is a low power version that uses dichroic polarizers. The rejected polarization is absorbed in the polarizer and therefore, there is no rejected beam and the device is shorter in length. Please consult our document *TORNOS Low Power User Guide* for further information.

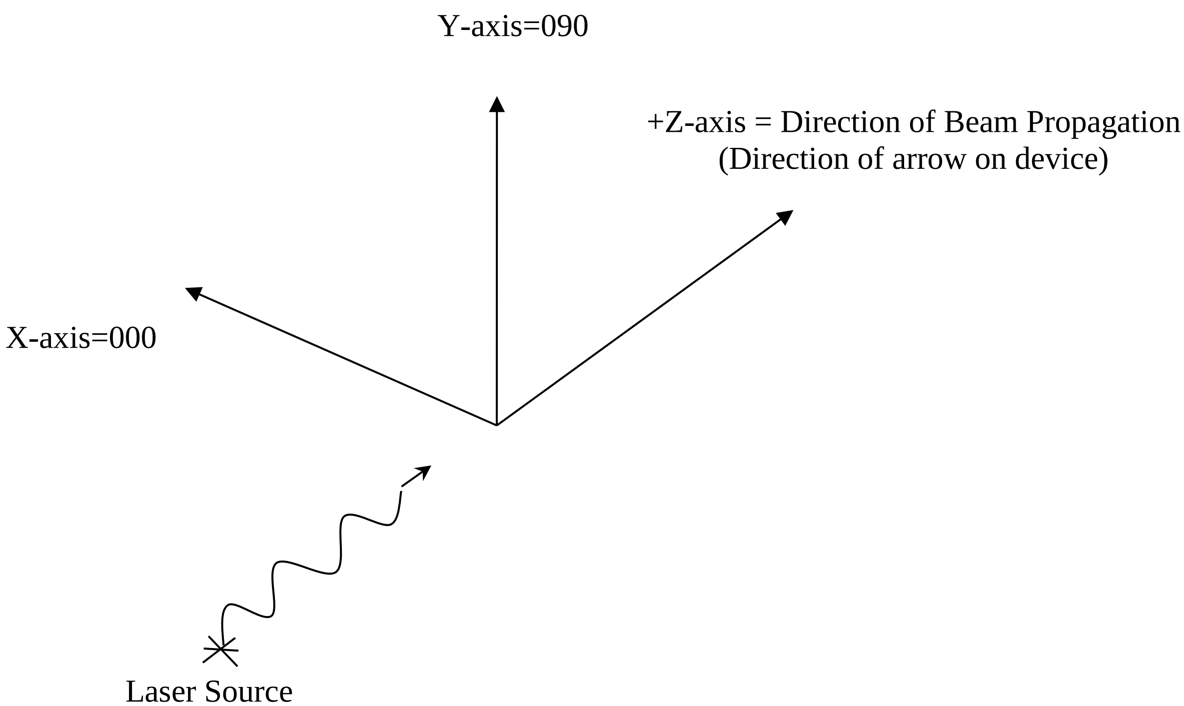
Electro–Optics Technology, Inc.

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

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

Field Description:

1. "AA" is the product type. WT=wavelength tunable rotator; MP=medium power with PBS cubes.
2. "BB" is 04 for a 4mm aperture size.
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 base clamp. The Y axis is vertical, normal to the plane of the base clamp. The XY plane forms the plane of polarization. The XZ plane forms the plane of the base clamp. 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 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 "EEE". For rotators, this field does not apply.



IV. Using your TORNOS 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, relatively dust-free 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, re-adjust 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) ¼ - 20 or M6 screws – one for each slot in the baseplate flanges. Alternatively, the baseplate may be removed from the base clamp by removing two 8-32 screws on the bottom side of the baseplate. Then, the base clamp/isolator assembly may be mounted to a standard laboratory post with an 8-32 set screw or may be conveniently mounted into laser systems, minimizing the required footprint of the device. 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 12 W transmitted or 0.5 W rejected backward propagating radiation (please consult damage threshold specifications for operating range) 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 cover. 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 termination points. In addition to high rejection (>27 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. Backward propagating rejected beams will exit from the PBSC from the side of the PBSC mount containing the screw hole (on the input polarizer). Forward transmission rejected beams will exit from the other side of the PBSC and are minimized when the input beam is polarized parallel to the input polarizer. If the Optical Isolator is used in 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 12 W transmitted or 0.5 W of backward propagating power then the polarizer covers may be kept in their factory positioned orientation – that is, 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. Note that the direction of the screw hole on the output polarizer indicates the direction of the component of rejected power from a backward propagating beam that is not parallel to the output polarizer.

V. Tuning your TORNOS Optical Isolator

A. *Adjusting Input Polarization*

The transmission axis of the input polarizer is indicated by the radial position of the screw hole located on the input polarizer mount. If the linear polarization of the laser source is geometrically known, aligning the input polarization of the Optical Isolator to that of the laser source is straightforward. Simply loosen the #2-56 socket head base clamp screw in the base clamp until the magnet housing rotates freely. Continue to rotate the magnet housing until the input polarizer transmission axis is aligned to that of your laser source. This is most easily accomplished by observing the beam exiting the escape port on the opposite side of the screw hole on the mount. Recall that the direction of a rejected beam entering in the reverse direction through the output will exit in the direction of the screw hole on the polarizer mount. As always, use caution when allowing rejected beams to escape from the polarizer covers. Confirm the direction and safe termination of these beams at low power. Wear laser safety glasses or goggles. Protect your colleagues by safely terminating beams and ensuring that they are wearing safety glasses or goggles as appropriate. At the desired operating power level minimize the power in the rejected input polarization with a power meter or other suitable power indicator. When the rejected power is minimized this corresponds to maximum transmission, retighten the baseplate clamp screw.

B. *Fine Wavelength Adjustment*

Each of the 532 nm, 650 nm, 780 nm, 850 nm, and 980 nm isolators may be tuned over a wavelength range specified within the product’s data sheet. Tuning is achieved by adjusting the relative angle between the input and output polarizers. For wavelengths longer than the central wavelength, the Faraday rotation is less than 45 degrees. For wavelengths shorter than the central wavelength, the Faraday rotation is more than 45 degrees and therefore, the device may be tuned for maximum extinction with a small transmission loss, illustrated by the wavelength tuning curves within the product’s data sheet. The 30 dB bandwidth of the isolators ranges from 26 nm at 532 nm to 46 nm at 980 nm, in increasing value. For maximum extinction, manually tune the device to the appropriate wavelength.

With the source laser operating at an average power of 0.5 W or less (attenuate the beam if necessary, to achieve such a low power level) direct the source laser beam through the Optical Isolator in the reverse direction – through the output polarizer first and then through the input polarizer. Use an IR viewer to view the transmitted radiation to ensure that it is directed onto a power meter. The power meter should be sensitive enough to detect power levels below 0.05 mW (or 40 dB of the input signal used). As a reference, 40 dB is a factor of 1:10000 and 10 dB is a factor of 1:10. If necessary, loosen the baseplate clamp screw to allow the output polarizer transmission axis to be rotated parallel to the source laser polarization axis retighten this screw when complete.
Loosen the button head input polarizer clamp ring screws just enough so that the input polarizer mount may be rotated (the input polarizer is opposite to the laser source at this point). Rotate the input polarizer mount until a minimal reading is indicated on the power meter. Retighten the input polarizer clamp ring screws. The minimal reading should be at least 27 dB of the input signal. If not, call EOT for assistance (see Section VI below). The Optical Isolator is now optimized to operate at the new laser source operating wavelength. It may now be installed for operation in transmission with the laser source as per Section IV.

C. *Changing the direction of Output Polarizer PBSC Rejected Beam Steering*

Section A above described how to orient the input PBSC to steer rejected beams as desired. If the output polarizer rejected beam steering direction needs to be changed, loosen the three output polarizer clamp screws and rotate the output polarizer mount by 180° before re-tightening the screws. Depending upon the isolation requirements, follow Procedure B from above in order to fully optimize the isolation of the device with this output polarizer orientation.

D. *Waveplate Option and Adjustment*

As described in Section III above in the *Numbering Fields and Coordinate System* description it is possible to order an Optical Isolator with a half-wave plate on the output. Should any of the above adjustments become necessary, or if the desired output polarization changes, the waveplate will need to be adjusted. To realign the waveplate loosen the radially-oriented set screw in the output polarizer mount and rotate the waveplate until the desired output polarization is achieved. Retighten the waveplate set screw. Do not over-tighten.

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.

Two-Stage Option

Optical Isolators may be used in series to obtain 60+ dB isolation, mounted on a common baseplate.

Mounting Options

Cylindrical housings are inserted into a clamping device that provides 8-32 screw holes and may be mounted onto a standard post. All devices include a baseplate for mating with ¼-20 screw holes 1" spaced breadboard. Figure 5 below shows the isolator with the baseplate removed and Figure 6 shows the isolator mounted to a standard lab post.

Figure 5: Baseplate Removed

Figure 6: Mounted to Lab Post

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.