EOT BROADBAND FARADAY ROTATOR/ISOLATOR
USER'S GUIDE

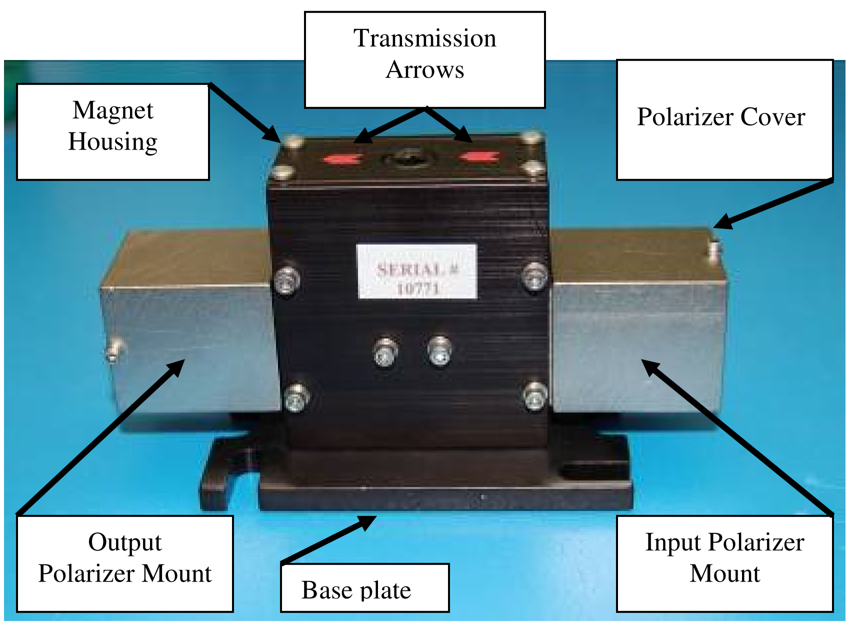
Thank you for purchasing your Faraday Isolator from EOT. This user's guide will help answer questions you may have regarding the safe use and optimal operation of your Faraday Isolator or Rotator.

TABLE OF CONTENTS

I. Faraday Rotator and Isolator Overview

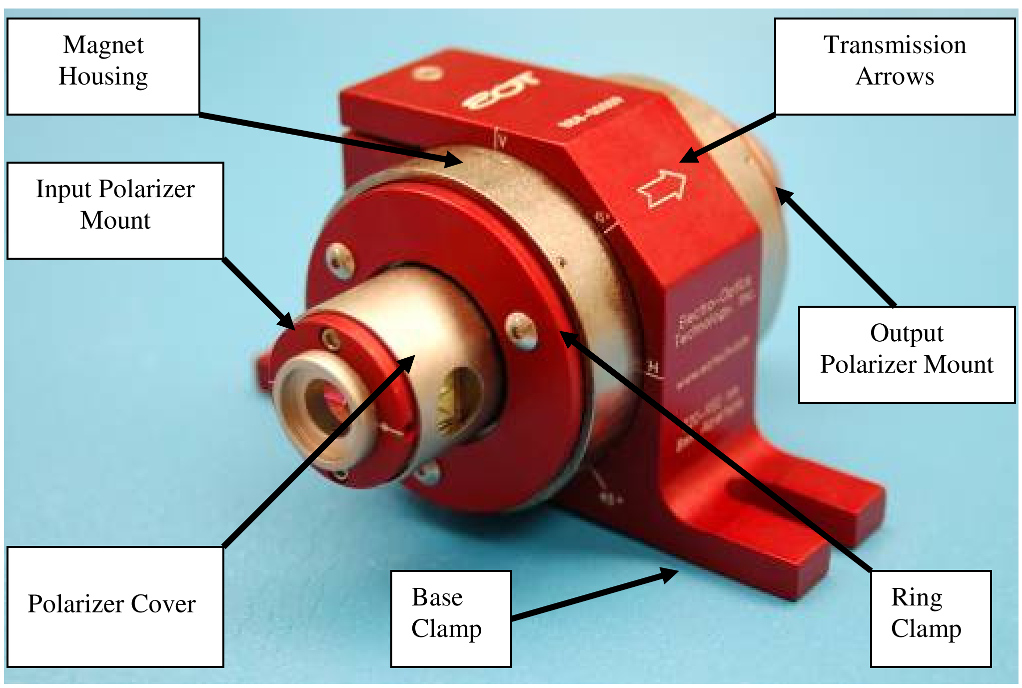
Your EOT Faraday Isolator is essentially a uni-directional light valve or spectrally selective one-way mirror. It is used to protect a laser source from destabilizing feedback or actual damage from back-reflected light. Figure 1 below identifies the main elements of your Faraday Isolator.

Figure 1: EOT Broadband, 5mm Aperture Faraday Isolator



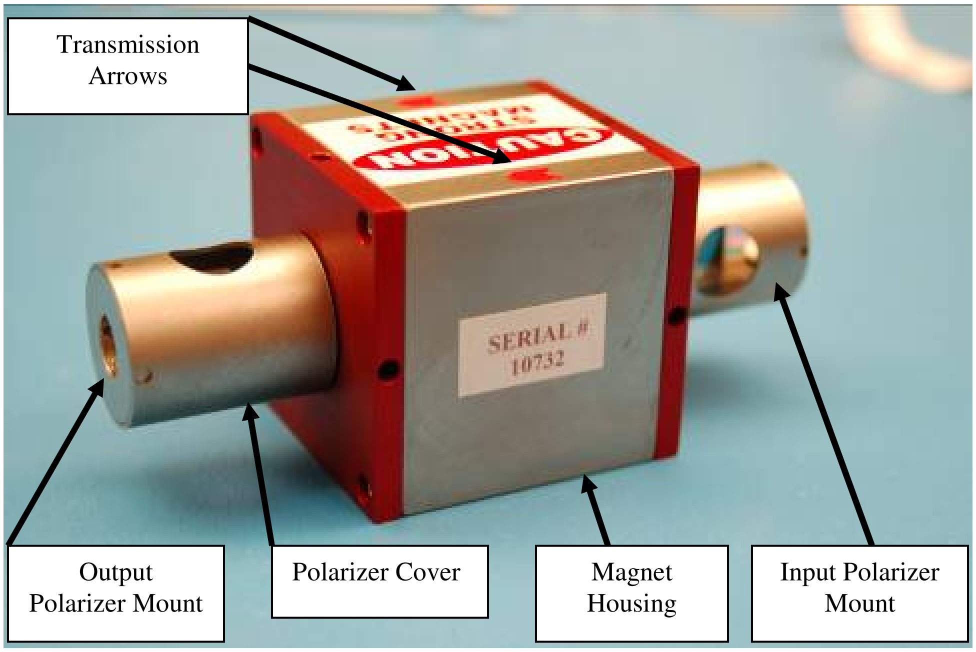
The 5mm aperture Faraday isolator is a rectangular shaped magneto-optic device. Strong Neodymium Iron Boron permanent magnets are used to generate high (>10,000 Gauss) axially oriented fields within the magnet housing. The strong longitudinal field causes 45 degrees of non-reciprocal polarization rotation 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 deg. rotation. In the forward direction, the two rotations add up, resulting in 90 deg. of rotation. In the reverse direction, the two rotations are opposite and result in 0 deg. 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.

Figure 2: EOT Broadband, 8mm Aperture Faraday Isolator



The 8mm aperture Faraday isolator is a cylindrically shaped magneto-optic device. The device operates similarly to the 5mm aperture device. However, the magnet body is cylindrical and the polarizers and mounts are different.

Figure 3: EOT Broadband, 10mm Aperture Faraday Isolator



The 10mm aperture Faraday isolator is a rectangular shaped magneto-optic device. The device operates similarly to the 5mm aperture device. However, the magnet body is rectangular and the polarizers and mounts are different.

II. Safe use of your EOT Faraday Isolator

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

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 EOT Faraday 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 2KGauss 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 EOT Faraday 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. 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 Faraday Isolator will be used with transmitted average powers in excess of 25W, or will block backward propagating light in excess of 0.5W 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/goggles consistent with all laser frequencies and power levels present.*** *See Sections III and IV for further details.*

3. 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 EOT Faraday 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 EOT Faraday Isolator in either direction when there is <u>any possibility</u> of laser radiation being present.

4. Harm caused by external magnetic fields.

Your EOT Faraday 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 there exist various claims 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.

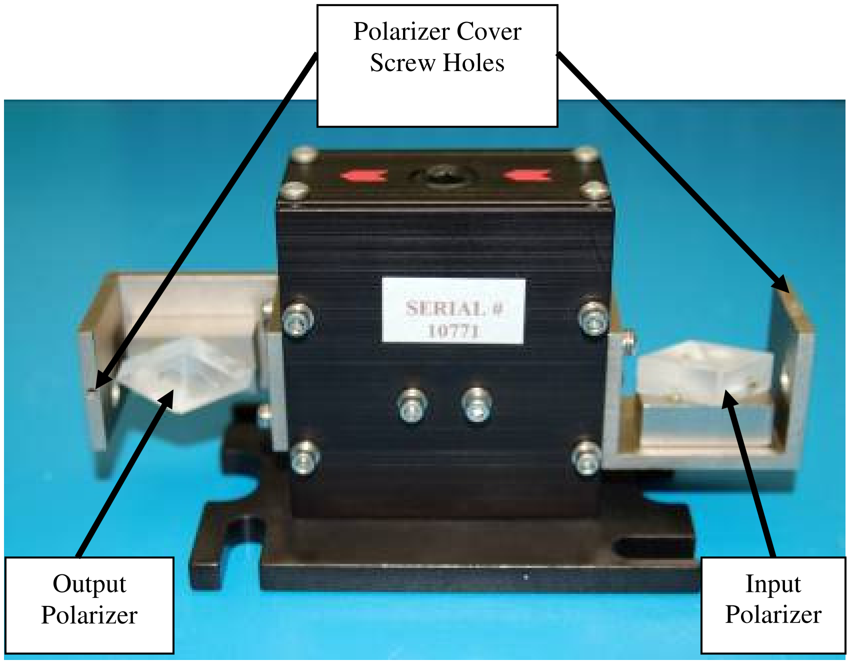
5. Other non-health related hazards.

The Faraday 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 Faraday 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 Faraday Isolator. If only ferromagnetic tools are available use extreme care when using them around the Faraday 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 are 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 EOT Broadband Faraday Isolator and Rotator

Figure 4: View of a 5mm aperture, EOT Broadband Faraday Isolator with polarizer covers removed.



With the polarizer covers off, a polarizer can be seen at each end of the device. For the 5mm aperture devices, glan laser calcite polarizers are used. The arrow stickers on the top indicate 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. The input and output polarizers work in conjunction with the central Faraday rotator to form a Faraday Isolator as described previously in Section I.

Figures 5 shows the input view of the isolator, note that the aperture is displaced to one side. This is due to the displacement of the beam after transmission through the glan laser calcite input polarizer. The output polarizer creates a similar magnitude of displacement. However, the beam is shifted vertically rather than horizontally. This is apparent in figure 2. A more detailed illustration of the aperture locations is in figure 4.

Figure 5: Input View of 5mm Aperture Broadband Faraday Isolator

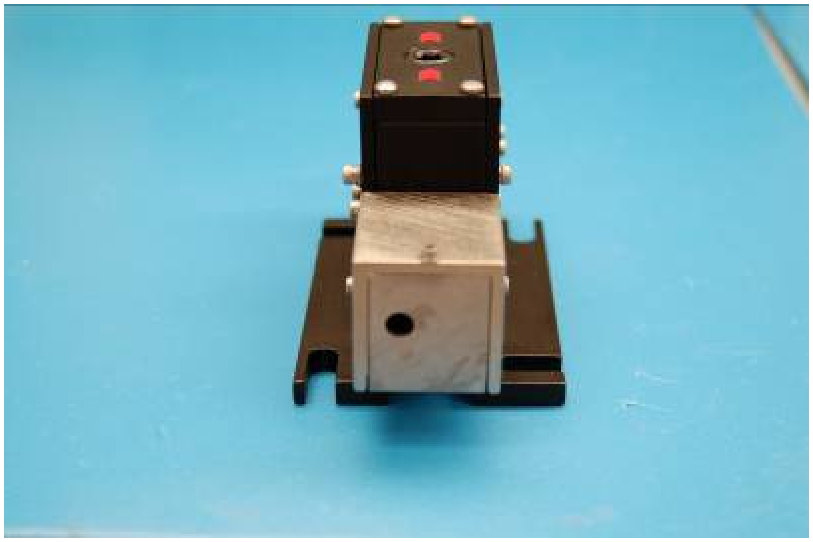
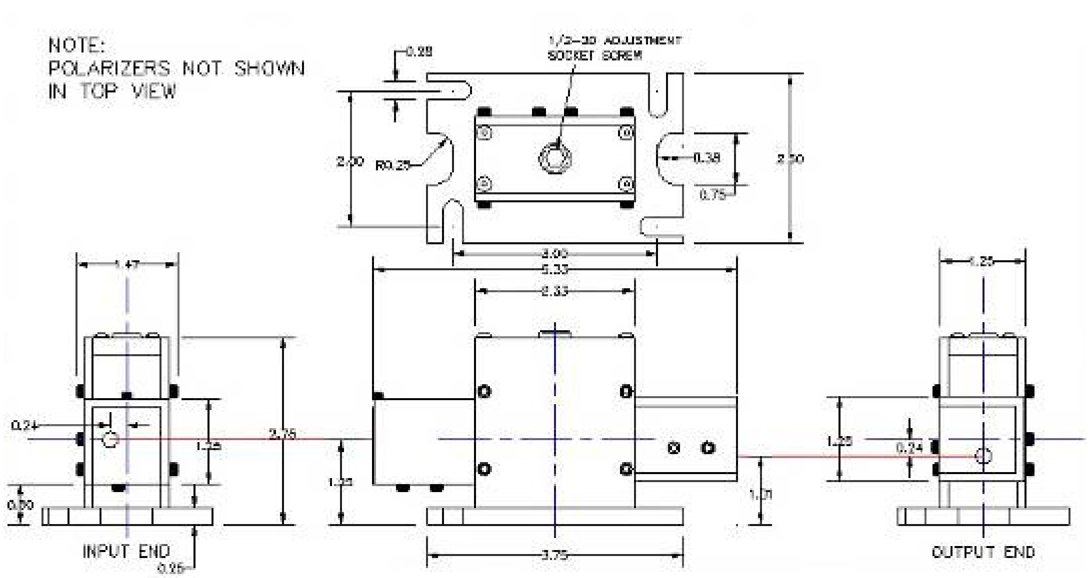


Figure 6 shows a diagram with multiple views of the 5mm aperture broadband Faraday isolator.

Figure 6: Diagram View of 5mm Aperture Broadband Isolator



Another option is to use a Broadband Faraday Rotator. Optically, this device is composed of a Faraday rotator and a quartz rotator. Figure 7 shows a view of the device. 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. Figure 8 shows a detailed diagram of the rotator.

Figure 7: View of 5mm Aperture Broadband Rotator

Figure 8: Diagram View of 5mm Aperture Broadband Rotator

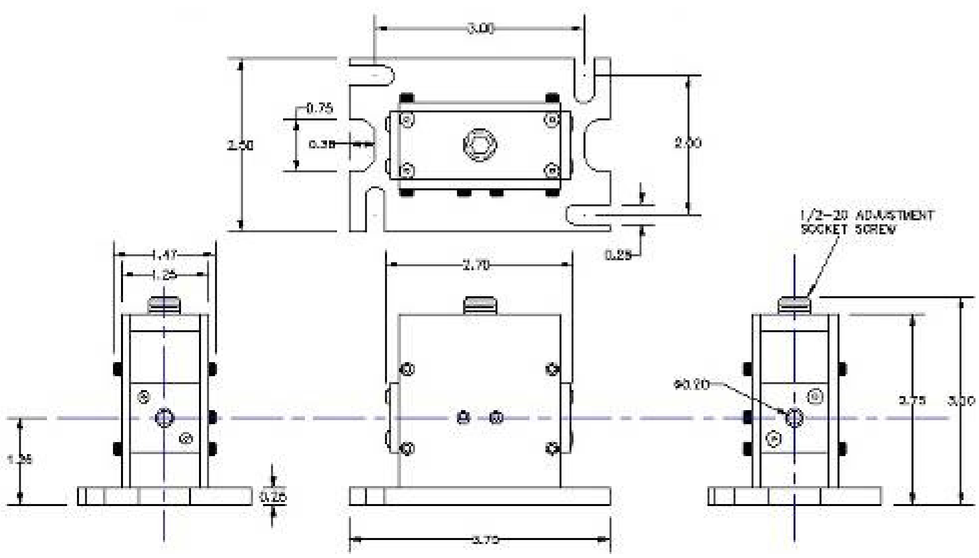
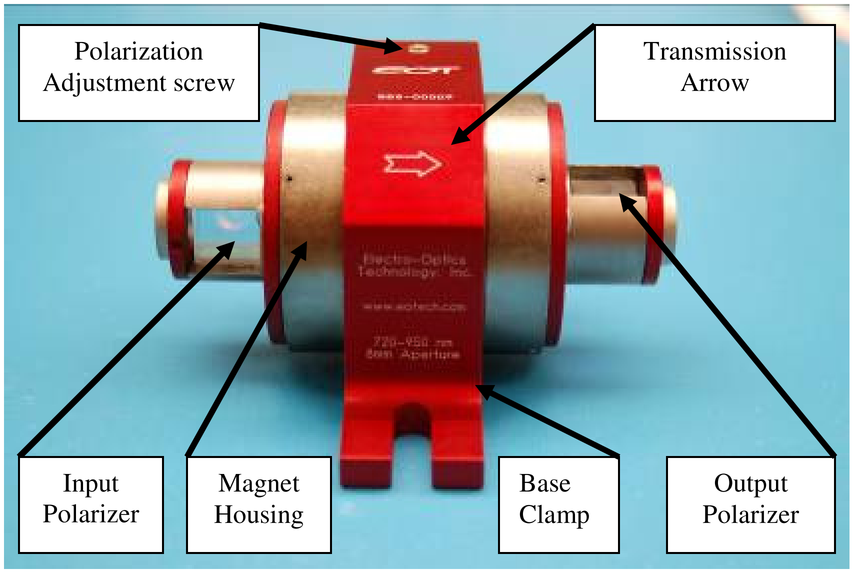


Figure 9: View of 8mm Aperture Broadband Isolator without polarizer covers



Referring to figure 9, with the polarizer covers off, a polarizer can be seen at each end of the device. For the 8mm aperture devices, polarizing beam splitter cubes are used. The arrow on the side indicates the transmission direction. The input polarization shown is horizontal and the output is vertical. The central magnet housing together with the TGG and quartz crystals residing in its center form a broadband Faraday rotator. The input and output polarizers work in conjunction with the central Faraday rotator to form a Faraday isolator as described previously in Section I. Figure 10 shows a more detailed, diagram view of the device. Note that unlike the 5mm aperture isolator, the input and output apertures are in-line and centered on the magnet body. Unlike the 5mm and 10mm models, this device may be adjusted readily for any input polarization. The polarization adjustment screw shown in figure 9 may be loosened and the entire magnet housing along with input and output polarizers will rotate freely in the base clamp 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.

The input view is observed in figure 2. Note that the polarizer covers are in the open position here, allowing rejected beams to exit the device. The user may close these ports by simply rotating the polarizer cover, shown in figure 2, until the port is in the closed position. This cover is held in place by an o-ring located between its inner surface and the polarizer mount.

Figure 10: Diagram View of 8mm Aperture Broadband Isolator

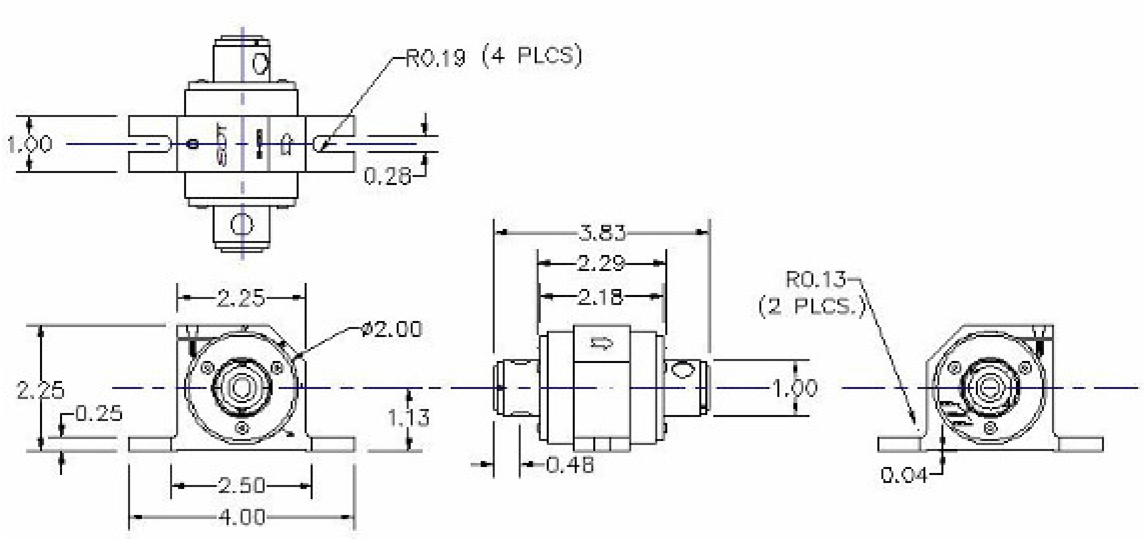


Figure 11 provides a detailed diagram of the 8mm aperture broadband rotator. Note the in-line configuration and square cross-section. Note the mounting holes located on the bottom of the device.

Figure 11: Diagram View of 8mm Aperture Broadband Rotator

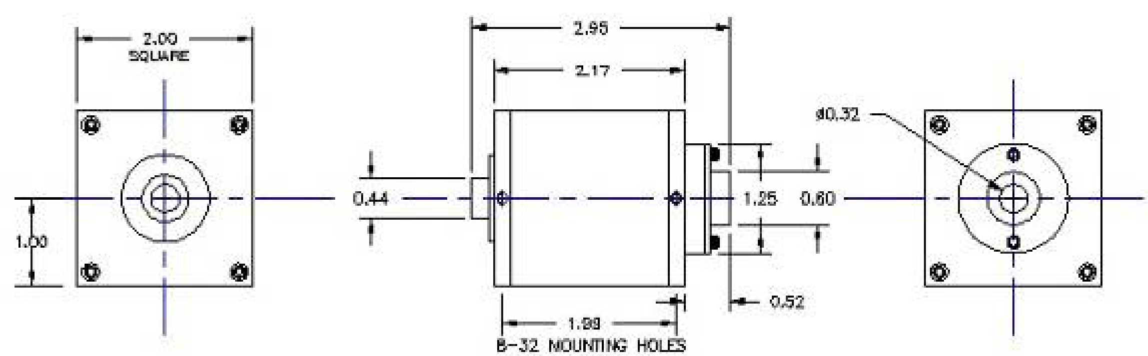


Figure 12: View of 10mm Aperture Broadband Isolator without polarizer covers

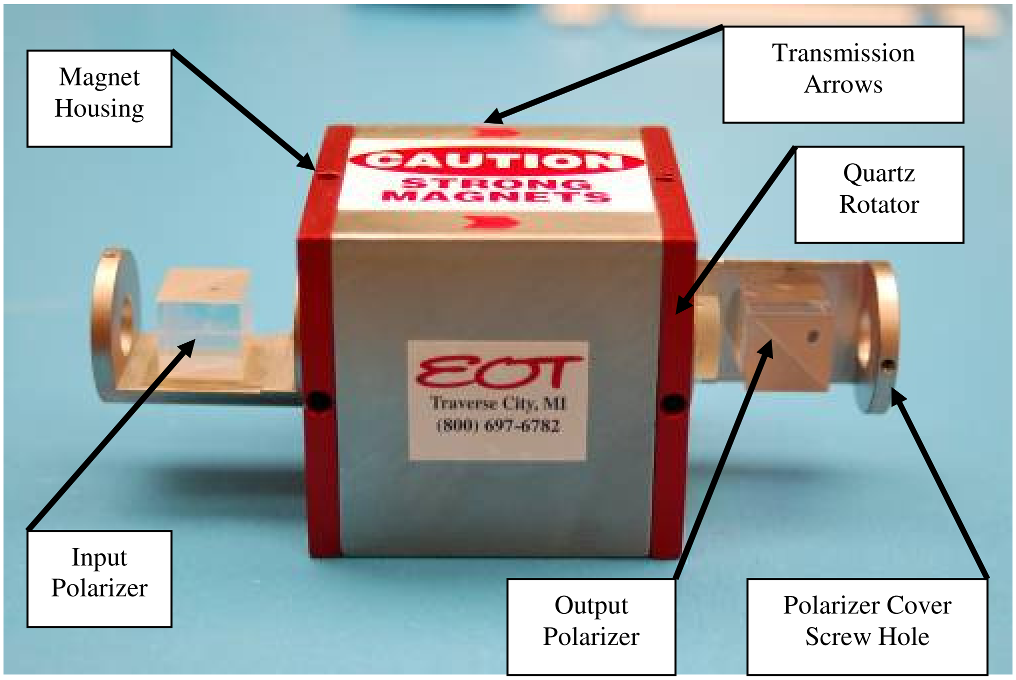


Figure 12 shows the 10mm aperture broadband isolator without polarizer covers. Note that the device uses pbs cubes for polarizers and the apertures are located in-line through the device. As in the previous models, the arrows on top indicate the transmission direction. The quartz rotator may be observed mounted to the output polarizer mount on the output end of the Faraday rotator assembly (magnet housing).

Figure 13 shows a reverse view of the 10mm aperture broadband isolator with polarizer covers in place. They may be rotated between the open position (shown) and the closed position (with the covers rotated 90 deg.). Unlike the 8mm 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 12.

Figure 13: View of 10mm Aperture Broadband Isolator with polarizer covers

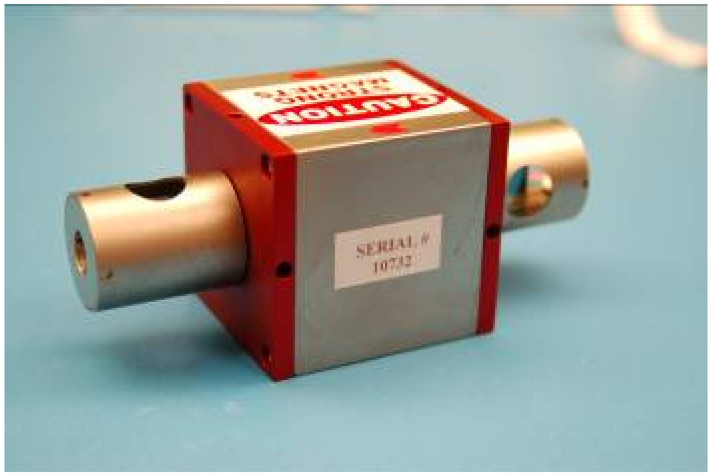
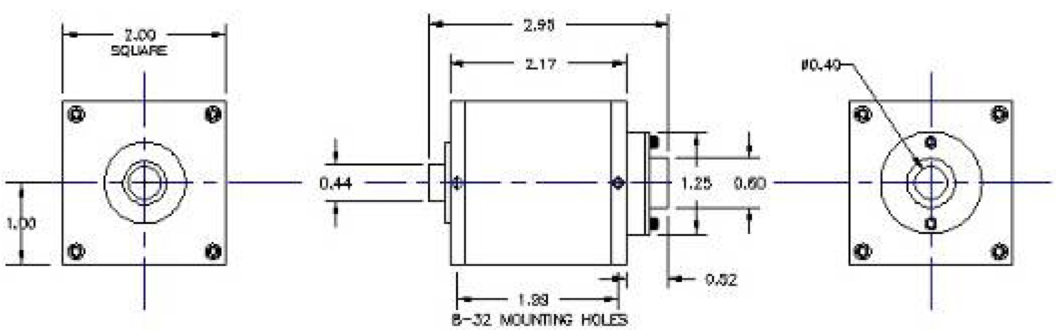


Figure 14 shows a diagram view of the 10mm aperture broadband faraday rotator. Note its very similar construction to the 8mm aperture device. Note the mounting screw holes located on the endplates of the device.

Figure 14: Diagram View of 10mm Aperture Broadband Faraday Rotator



The polarization of EOT Faraday Isolators are 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.

<u>Numbering Fields and Coordinate System for EOT Broadband Faraday Isolators/Rotators</u>

General Format for Numbering Field: BB-A-CC-D-EEE

Field Description:
1. "BB" designates the device as a broadband and is common for all broadband units.
2. "A" is "8" for 800nm center wavelength and "9" is for 900nm center wavelength.
3. "CC" designates the aperture size: 05,08,09 correspond to 5,8, and 9mm diameters, respectively.
4. "D" designates whether the device is a rotator, "R" or an isolator, "I".
5. "EEE" designates the input polarization, "000" for horizontal, "090" for vertical. This applies only to isolators. For rotators, this field does not apply.

IV. Using your Faraday Isolator

Observe the guidelines for safe use of your Faraday 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, re-adjust the isolator as required (see Section V).

With the source laser off, or running at very low power (less than 250mW), position the Faraday Isolator such that the source laser beam can be directed through the Input Aperture.

Critical alignment of the Faraday Isolator should be done at low power (less than 250mW) in order to prevent optical damage to your isolator or laser source.

Use IR cards or viewers 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 Faraday Isolator are not being directed back into the source laser. The Optical surfaces in the Faraday Isolator are angled slightly to reduce these reflections. Increasing the distance between the Faraday Isolator and the source laser can also help ensure that no reflections couple back into the source laser if necessary.

At this point the Faraday Isolator should be secured to the work surface with two to four 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 the slowly towards the device from the sides along the direction of the baseplate flange slots.

If the Faraday Isolator will be used with average powers in excess of 25W transmitted or 0.5W 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 Faraday 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 Faraday Isolator is used in applications 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 25W transmitted or 0.5W 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 Faraday 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 Faraday Isolator

A. 5mm Aperture Model.

For the 5mm aperture device, there are only two configurations for the input polarization. In order to switch between the two, the input and output polarizer dust covers must be removed, then the polarizer mounts must be removed and rotated 90 deg. Caution must be taken during this operation to avoid attraction of a screwdriver to the aperture of the device and the potential damage to the optics. For more details, please contact the sales department at EOT at sales@eotech.com.

B. 8mm Aperture Model.

For the 8mm aperture device, the cylindrical magnet body is clamped into the base 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.

C. 10mm Aperture Model.

The 10mm 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 deg. rotation of the device.

VI. Warranty Statement and Repair

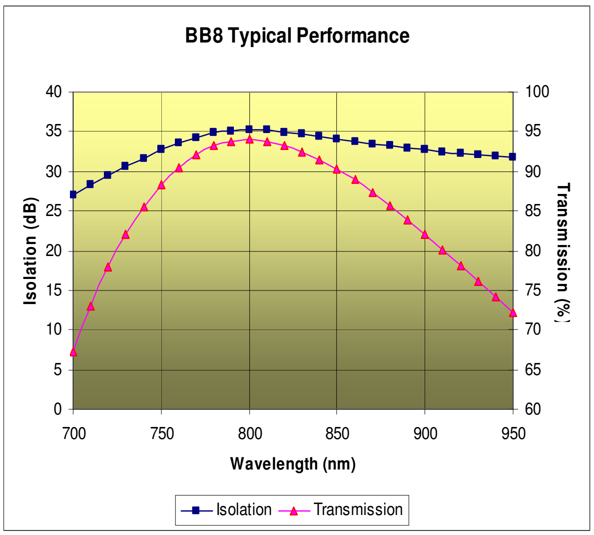
EOT warrants its Faraday rotators/isolators to be free of defects in materials and workmanship for a period of one year after date of shipment. Any unauthorized modifications made by the customer to EOT's Faraday rotators/isolators will render the warranty null and void. If the customer believes there is a problem with the rotator/isolator, they should immediately contact EOT's Sales/Customer department at 231-935-4044 or sales@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 do modify the device. All returns reference the RMA No. on the outside of the shipping container and should be sent to:

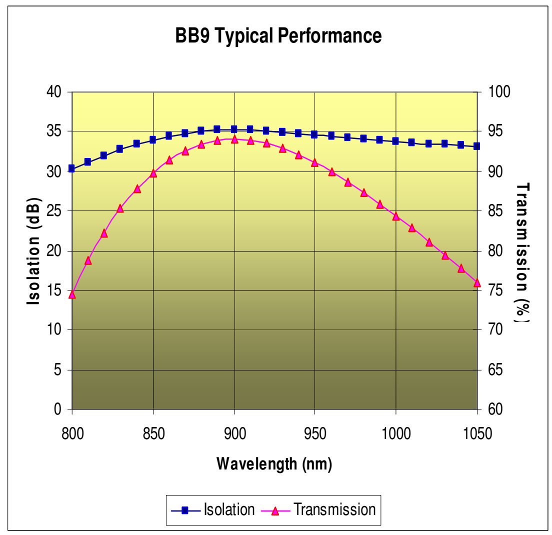
Electro-Optics Technology, Inc.
Attn: Sales/Customer Service
5835 Shugart Lane
Traverse City, MI. 46984 USA

EOT reserves the right to inspect rotators/isolators returned under for warranty to assess if the problem was caused by a manufacturer defect. If EOT determines the problem is not due to a manufactuer defect (an example would be damage to an optical element caused by impact from a loose balldriver or exceeding the damage threshold of the device), repairs will be done at customer expense. EOT will always provide a written or verbal quote prior to peroforming repairs at customer 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.

VII. Specifications: Broadband Faraday Isolators and Rotators

Model No.	Spectral Bandwidth (nm)	Center Wavelength (nm)	Optical Pathlength	Pulsed Damage Threshold @10ns	Polarizer Type
BB8-5X	720-950	800	42mm	300MW/cm^2	Glan Laser Calcite
BB8-8X	"	"	15mm	100MW/cm^2	Cemented PBS Cube
BB8-10X	"	"	28mm	"	"
BB9-5X	800-1050	900	43mm	300MW/cm^2	Glan Laser Calcite
BB9-8X	"	"	15mm	100MW/cm^2	Cemented PBS Cube
BB9-10X	"	"	28mm	"	"





Model Number: For X enter R for rotator or I for Isolator

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 technical bulletin, **Effects of Temperature on EOT's Faraday Rotators/Isolators**.

2. **For incident powers ≥50W, please consult EOT.** You may either contact EOT's sales department at sales@eotech.com or view our **Custom Rotators** page on our website (www.eotech.com).

3. **For apertures** other than those specified, please contact our sales department at sales@eotech.com. EOT has a custom solutions department and has the capability of manufacturing custom faraday isolators and rotators.

4. **Pulsed Damage Threshold:** The pulsed damage threshold of your free space Faraday rotator or isolator can be determined at pulsewidths other than 10nsec by using the "Root T" scaling method. Please visit our **Calculators** page on our website.