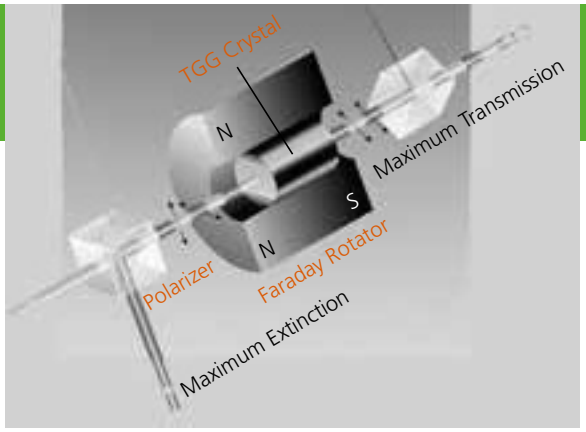


Characteristics

Principle of Operation

Faraday isolators are optical components which allow light travel in only one direction. Their mode of operation is based on the Faraday effect (linear magneto-optical effect). In principle, the function of an optical isolator is analogue to that of an electrical diode.

Faraday isolators are composed of three elements:

- Entrance Polarizer
- Faraday Rotator
- Exit Polarizer

Thin film polarizers are commonly used as entrance and exit polarizers, typically in form of a special polarizing beam splitter cube. These polarizers have an extremely high extinction ratio and are designed for use with high power lasers. The polarizer entrance and exit surfaces are coated with an antireflective coating for the specified wavelength range. The key element of the Faraday isolator is the Faraday rotator. The rotator consists of a strong permanent magnet containing a crystal with a high Verdet constant.

Light of any polarization entering the entrance polarizer exits it as horizontally or vertically linearly polarized light. Since laser light is usually linearly polarized, one can match the orientation of the entrance polarizer and the polarization of the laser by simply rotating the isolator. Light then passes through the Faraday rotator. For most wavelengths the crystal is a Terbium Gallium Garnet (TGG) crystal which is placed in a strong homogeneous magnetic field. Crystal length and magnetic field strength are adjusted so that the light polarization is rotated by 45° on exiting the crystal. In the figure above, the light is rotated counter clockwise when viewed in the north/south direction of the magnetic field (±45°) and the exit polarizer is also oriented at ±45°, so that the maximum beam intensity is transmitted.

If light of any polarization, but with a reversed direction of propagation, meets the exit polarizer, it leaves at ±45°, passes through the Faraday rotator and is again rotated by ±45°. The non-reciprocal nature of the Faraday effect results in the direction of rotation once again being counter clockwise as viewed in the north/south direction of the magnetic field. Upon leaving the Faraday rotator, the polarization has gone through two ±45° rotations resulting in a total rotation of ±90°. In this polarization direction the light is deflected laterally by the entrance polarizer.

Increased Isolation

The maximum isolation of the Faraday isolator is limited by inhomogenities of the TGG crystal and the magnetic field. However, it is possible to square the extinction ratio by placing two isolators in series and by arranging the polarity of the two magnets to be opposite to each other. This way the polarization direction of the transmitted light remains unchanged in the transmission direction and the effect of both magnetic fields is enhanced. This arrangement also leads to a more compact isolator. The strength of this effect depends on the distance between the two magnets and can be used to tune the isolator to different wavelengths. The adjustment is necessary because the rotational angle of the TGG crystal is wavelength and temperature dependent. Please see section “Two Stage Isolators” (page 20) for more information.

Advantages

High Isolation

The properties of the LINOS Faraday isolators are determined by the quality of the optical elements and the uniformity of the magnetic field. The entrance and exit polarizers exhibit a very high extinction ratio, so that the isolation is mainly limited by inhomogenities in the crystal material. Specially selected crystal materials with a high Verdet constant combined with permanent magnets with a high remanence enable Qioptiq to use shorter crystals and obtain an isolation > 30 dB.

The radiation blocked by the entrance and exit polarizers is not absorbed internally, but is deflected by 90° with respect to the beam direction. This ensures a stable thermal operation even at higher laser power levels. The blocked radiation can be used for other applications. All optical surfaces are slightly tilted relative to the beam axis.

Low Insertion Loss

The high transmission, typically > 90%, is achieved by using materials with low absorption and anti-reflective coatings with low residual reflectivity on all entrance and exit surfaces.

Large Aperture, Compact Design

All optical elements have been aligned to eliminate beam shading and allow for easy adjustment. Focusing is not necessary. The compact design is achieved by using rare earth magnets with the highest remanent magnetism and TGG crystal material with a high Verdet constant. The isolator is suitable for divergent beams or in setups with limited space. A minimal optical path length in the isolator results in the lowest possible influence on the image.

Three sides of the entrance and exit polarizers are usable and readily accessible for easy cleaning. The degree of isolation can be adjusted over a wide range.

Mounting Flexibility

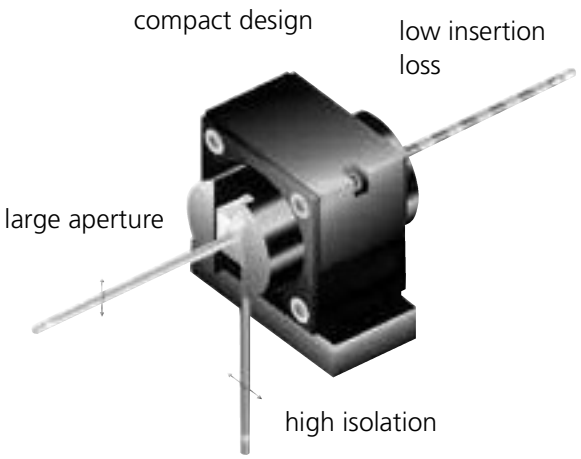
The LINOS Faraday isolators can be mounted directly via threaded holes in the housing or via additional base plates or angle brackets. New rotatable Faraday isolators are available.

Applications

The ongoing development and refinement of laser technology have created a need for optical components that shield the laser resonator from back reflections. LINOS Faraday isolators provide an efficient method of suppressing instabilities and intensity fluctuations in laser devices.

Typical Applications are:

- Protection of the resonator in solid state and gas lasers from back reflections
- Prevention of parasitic oscillation in multistage solid state amplifiers
- Protection of diode lasers against back scatter and extraneous light



Two Stage Faraday Isolators

Technical Overview

Diode lasers are extremely sensitive to reflected radiation. Standard Faraday isolators typically achieve between 30 dB and 40 dB isolation, which in some cases is not sufficient to suppress undesirable feedback.

Our two stage LINOS Faraday isolators were developed for the special requirements of diode lasers and square the standard isolation of single stage Faraday isolators. At the heart of this development is the use of two coupled isolator stages together with the best polarizers available on the market.

This configuration combines the exit polarizer of the first stage with the entry polarizer of the second stage to form one central polarizer.

Arranging the polarity of the two magnets to be opposite to each other results in two benefits: The polarization direction of the transmitted light remains unchanged in the transmission direction and the effect of both magnetic fields is enhanced. Therefore this configuration also leads to a more compact isolator and a reduction of the optical path length which in turn enhances the optical quality of the LINOS Faraday isolators.

All optical surfaces are antireflection coated and the surfaces normal to the beam axis are tilted. The polarizers are mounted in a way that allows easy cleaning of the external optical surfaces. This guarantees that the isolation is not reduced by residual reflections and scattering from the isolator. Based on this special design a guaranteed 60 dB isolation at the design wavelength, respectively within the adjustment range, makes Linos two stage Faraday isolators the best on the market.

Applications

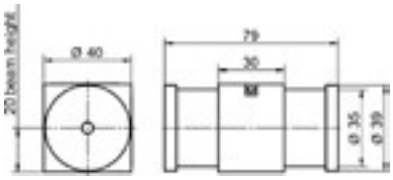
All two stage LINOS Faraday isolators are typically used to improve the power and frequency stability of diode lasers used in spectroscopy, interferometry, metrology, and precision control systems as well as in alignment applications. Since the output polarization and the beam position are conserved for all two stage LINOS Faraday isolators, the influence of the smallest feedback effects on the laser can be quantitatively examined.

Two-Stage Faraday Isolators, Tunable, TVC/TIC Series

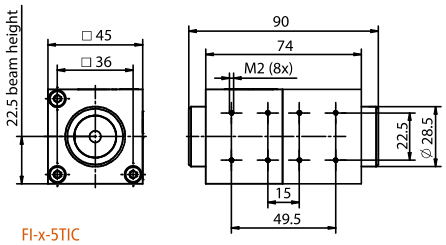
FI-x-TV / FI-x-TI

- Tunable with maximum isolation over the complete wavelength range
- Two coupled isolator stages in series
- Especially high isolation > 60 dB
- TGG crystal
- Customized central wavelength on request

- Mounting TVC-Version: via two M4 threaded holes on the bottom side, 30 mm separation
- Mounting TIC-Version: via 8 M2 threaded holes on the bottom side and on the back side, 22.5 mm separation



FI-x-5TVC



FI-x-5TIC

Single stage is not sufficient?

Some lasers are extremely sensitive to back reflection. The two stage Faraday Isolators provide extreme isolation of 60dB to keep the power of such lasers stable. Additional, some Isolator designs can be used for injection locking.

Two-Stage Faraday Isolators, tunable, TVC/TIC Series

Product	Isolation, guaranteed (dB)	Transmission at design wavelength (%)	Tuning range typical (nm)	Aperture Ø (mm)	Dimensions (mm)	Damage threshold @ 1.2 ps pulses (J/cm²)	Damage threshold @ 8 ns pulses (J/cm²)	Part No.
FI-650-5TVC	≥ 60	≥ 80	630 - 680	5	40x40x79	0.1 @ 650 nm	0.7 @ 650 nm	845110100200
FI-670-5TVC	≥ 60	≥ 80	650 - 700	5	40x40x79	0.1 @ 670 nm	0.7 @ 670 nm	845110100201
FI-710-5TVC	≥ 60	≥ 80	700 - 740	5	40x40x79	0.2 @ 710 nm	0.7 @ 710 nm	845110100202
FI-760-5TVC	≥ 60	≥ 80	735 - 790	5	40x40x79	0.2 @ 760 nm	0.8 @ 760 nm	845110100203
FI-780-5TVC	≥ 60	≥ 80	750 - 800	5	40x40x79	0.2 @ 780 nm	0.8 @ 780 nm	845110100059
FI-810-5TVC	≥ 60	≥ 80	780 - 840	5	40x40x79	0.2 @ 810 nm	0.8 @ 810 nm	845110100075
FI-850-5TVC	≥ 60	≥ 80	815 - 870	5	40x40x79	0.2 @ 850 nm	0.9 @ 850 nm	845110100080
FI-880-5TVC	≥ 60	≥ 80	850 - 910	5	40x40x79	0.2 @ 880 nm	0.9 @ 880 nm	845110100204
FI-920-5TIC	≥ 60	≥ 80	905 - 965	5	45x45x90	0.2 @ 920 nm	0.9 @ 920 nm	845110100205
FI-950-5TIC	≥ 60	≥ 80	930 - 990	5	45x45x90	0.2 @ 950 nm	1.0 @ 950 nm	845110100206
FI-980-5TIC	≥ 60	≥ 80	950 - 1025	5	45x45x90	0.2 @ 980 nm	1.0 @ 980 nm	845110100207
FI-1060-5TIC	≥ 60	≥ 80	1025 - 1080	5	45x45x90	0.2 @ 1060 nm	1.1 @ 1060 nm	845110100173

Subject to technical changes

Two Stage Faraday Isolators, Tunable

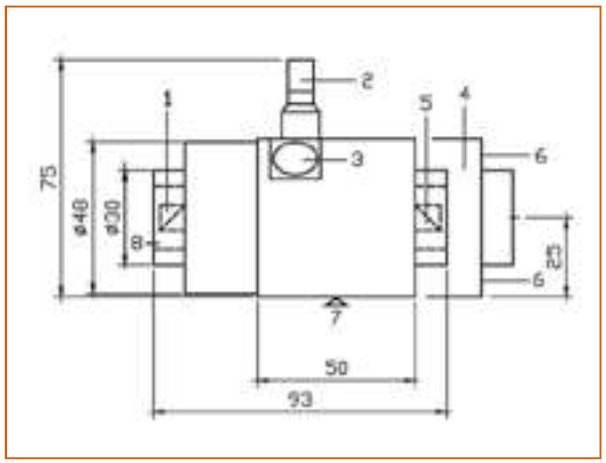
Technical Overview

The tunable isolators of the DLI series were developed for the special requirements of diode lasers in the visible spectrum and combine the outstanding isolation of a two stage isolator with the flexibility of a tunable isolator.

The DLI isolators are easily integrated into an existing setup and can be adjusted to match any wavelength without changing the laser polarization or displacing the laser beam. The isolators can be coarsely tuned by altering the effective magnetic field in the two isolator stages. A precise wavelength adjustment is possible by rotating the central polarizer with a micrometer set screw. The blocked radiation is deflected out of the isolator at 90° with respect to the beam axis. It is not absorbed by the interior of the isolator, but is available at the side surfaces of the polarizer and the exit window.

Injection Locking

The DLI injection version inverts this operating mode and uses the exit window for in-coupling of the seed laser for injection locking while decoupling efficiently the master and the slave laser from each other at the same time. With this setup stable mode locking (e.g. of Ti:Sapphire lasers) is simplified.



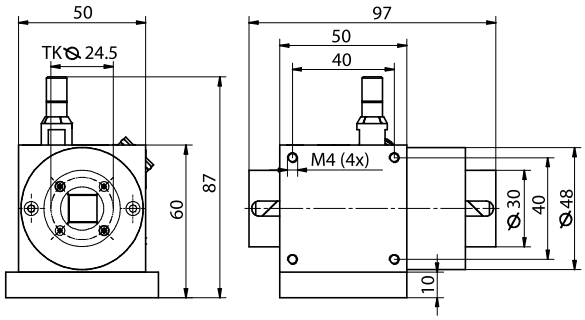
1 Entrance polarizer
2 Tuning micrometer screw
3 Exit window
4 Waveband adjuster
5 Exit polarizer
6 Adjusting screw
7 Mounting surface
8 Protective ring

Two-Stage Faraday Isolators, Tunable, DLI Series

- Tunable with maximum isolation and maximum transmittance over the complete wavelength range
- Two coupled isolator stages in series
- Especially high isolation ≥ 60 dB
- TGG crystal
- Rare earth magnet
- Input polarization = output polarization
- Individually calibrated adjustment curve supplied with each isolator
- Simple integration of DLI isolators is possible. They can be adjusted easily without changing laser polarization or beam position.
- Mounting: via four M4 threaded holes at the bottom side and at the back side, 40x40 mm separation, or via base plate
- Base plate included
- Access to blocked beam via window
- DLI injection locking versions available

A closer look

Injection locking versions use exit window for incoupling of seed laser for injection locking. This enables stable mode locking.



Two-Stage Faraday Isolators, tunable, DLI Series

Product	Isolation, guaranteed (dB)	Transmission at design wavelength (%)	Tuning range typical (nm)	Aperture Ø (mm)	Dimen-sions (mm)	Dimensions base pate (LxWxH) (mm)	Damage threshold @ 1.2 ps pulses (J/cm²)	Damage threshold @ 8 ns pulses (J/cm²)	Part No.
DLI 1	≥ 60	≥ 80	745 - 890	5	50x50x97	50x60x10	0.2 @ 890 nm	0.9 @ 890 nm	84501003000
DLI 2	≥ 60	≥ 80	610 - 700	5	50x50x97	50x60x10	0.1 @ 700 nm	0.7 @ 700 nm	84501002000
DLI 3	≥ 60	≥ 80	650 - 760	5	50x50x97	50x60x10	0.2 @ 760 nm	0.8 @ 760 nm	84501001000

Subject to technical changes