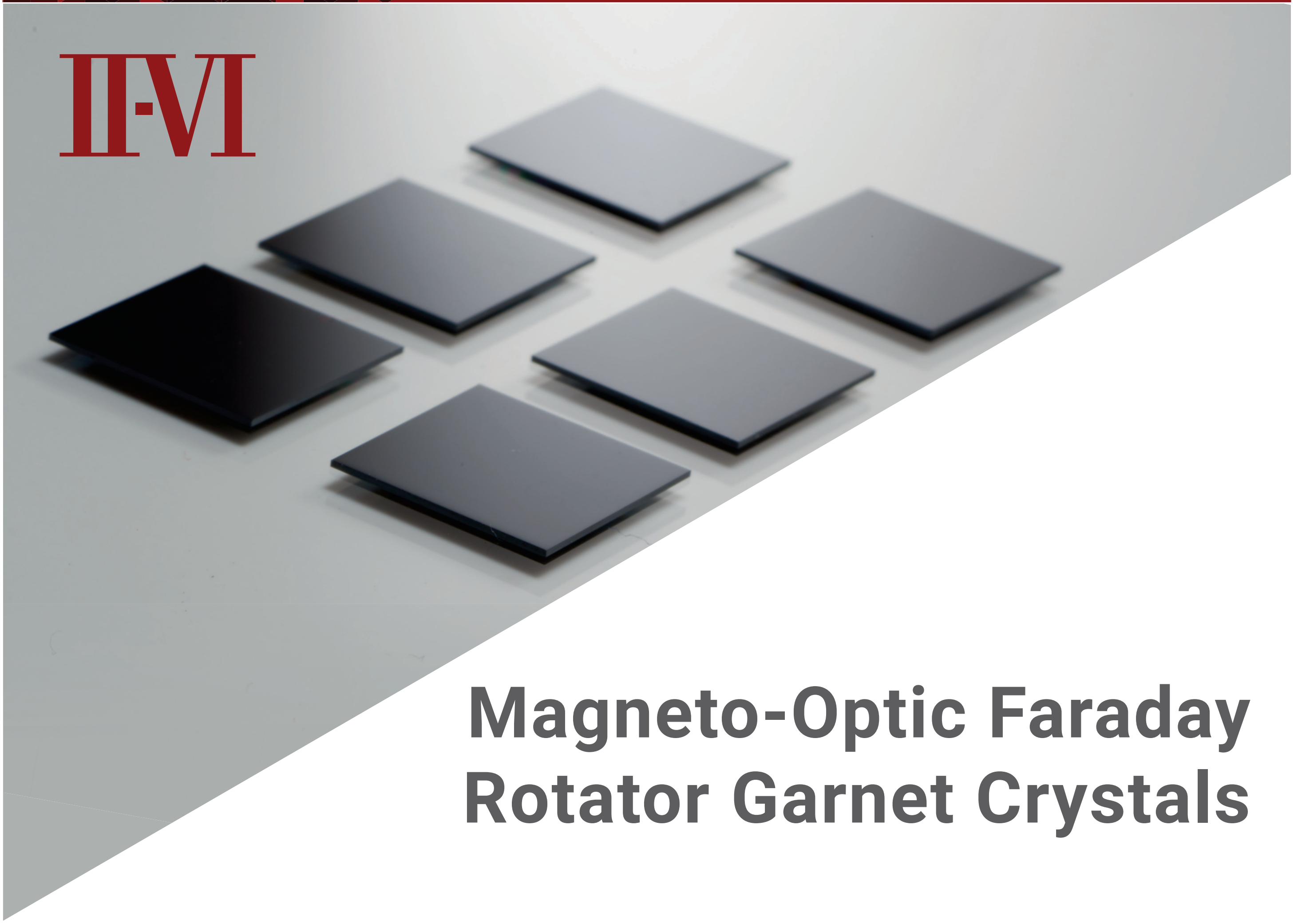

# Magneto-Optic Faraday Rotator Garnet Crystals

Bismuth-doped rare-earth iron garnet (BIG) thick films are the principal Faraday rotator materials for non-reciprocal passive optical devices in telecommunications applications. These materials are highly transparent at the principal near-infrared telecommunications wavelengths and exhibit high specific Faraday rotation. Combined with the correct polarizing or birefringent elements, Faraday rotators can be made into polarization dependent and independent isolators as well as incorporated into a host of other non-reciprocal devices including isolators, circulators and switches. Increasingly magneto-optic materials are also of interest for sensor applications. BIG Thick Film single crystals are grown by Liquid Phase Epitaxy and are optimized to yield low optical absorption in the Near IR telecommunications wavelengths. All II-VI thick film Faraday rotators have been third-party certified to be in compliance with the European Union's Restriction of Hazardous Substances (RoHS) directive.

**BIG Thick Film Garnet Products**

- FLM Low Saturation Magnetization, Moderate Temperature Dependence
- FLT Low Temperature Dependence
- FLL Low Loss across 1290-1610 nm
- MGL Magnetless Faraday rotator

# FLM Garnet - Low Moment Faraday Rotator

For Non-Reciprocal Passive Optical Components
(Isolators, Circulators, Switches, Interleavers)

FLM

Bismuth-doped rare-earth iron garnet thick films are the principal Faraday rotator materials for non-reciprocal devices in telecommunications applications. They have high specific rotations and are highly transparent in the near infrared telecom band. Combined with the correct polarizing or birefringent elements, these Faraday rotators can be made into polarization dependent and independent isolators as well as incorporated into many other non-reciprocal devices. Integrated Photonics' low moment FLM Faraday rotator composition provides a good compromise between low temperature dependence and low saturation magnetization.

## Product Features

- Third-party certified RoHS compliant
- Excellent crystal quality for high isolation ≥ 40 dB
- Good process control for low insertion loss ≤ 0.05 dB @ 1310 nm, ≤ 0.08 dB @ 1550 nm
- Low magnetic saturating field < 350 Oe
- Anti-Reflection coating per customer requirements
  - Pinhole free
  - Reflectance ≤ 0.15% per side
  - Highly durable against abrasion, humidity, high processing temperatures and other environmental factors
- Custom fabrication to customer's specification
  - A wide variety of wavelengths are available or can be fabricated
  - Coatings available for air, epoxy, uncoated or in combinations

| Properties | FLM Garnet |
|---|---|
| Temperature Coefficient; dθ/dT (deg/°C) | −0.060 |
| Wavelength Dispersion; dθ/dλ (deg/nm) | −0.058 @ 1550 nm, −0.087 @ 1310 nm |
| Thermal Expansivity; α (°C-1) | $11.0\times10^{-6}$ |
| Refractive Index; n | 2.344 @ 1550 nm, 2.356 @ 1310 nm |
| Curie Temperature; Tc (°C) | 250 |
| Specific Faraday Rotation; θ/t (deg/mm) | −96 @ 1550 nm, −141 @ 1310 nm |
| Thickness for 45 degrees; t (μm) | ~470 @ 1550 nm, ~320 @ 1310 nm |
| Saturating Field; Hs (Oersted) | ≤ 350 for 11x11mm, ≤ 2250 for 1x1 mm |

## Ordering Information

Part numbers are given as **FLM-(Wavelength)-(Rotation Tolerance)-(AR Coating)-(Dimensions in mm)**

- Wavelength, λ(nm)—Typical wavelengths are 1310, 1480 and 1550 nm, but custom wavelengths are available by customer request. All Faraday rotations are 45 degrees at 22°C and the center specification wavelength unless otherwise specified.
- Rotation Tolerance, ±Δθ (degrees)—The Faraday rotation is given to a specific tolerance, typically ±0.5, ±1.0 or ±2.0 degrees.
- Anti-Reflection (AR) Coatings—Films may be coated to Air or Epoxy, Uncoated or to some custom specification. Ordering information must specify coatings for both sides such as AA-to Air both sides, EE-to Epoxy both sides, AE-One side to Air and one to Epoxy or UU-uncoated.
- Dimensions (mm)—The part number gives the square dimensions of the part in mm. Standard size is 11x11 mm.

e. g. **FLM-1550-1.0-AA-11.0** would be a Faraday rotator for 1550 nm with 45.0 ±1.0 degrees Faraday rotation, Anti-Reflection coated 2 sides to Air in the form of a square 11.0 mm on a side.

# FLT Garnet - Low Temperature Dependence Faraday Rotator

Ideal for Uncooled Transceiver Free-Space Isolators or other Wide-band Passive Optical Components such as In-line Isolators, Circulators, Switches, Interleavers

FLT

Bismuth-doped rare-earth iron garnet thick films are the principal Faraday rotator materials for non-reciprocal devices in telecommunications and non-telecom applications. They have high specific rotations and are highly transparent in the near-infrared telecom band. Combined with the correct polarizing or birefringent elements, these Faraday rotators can be made into polarization-dependent and independent isolators as well as incorporated into many other non-reciprocal devices. II-VI **FLT** Faraday rotator composition is optimized for **low temperature** dependence as is required for many uncooled and wide band applications.

## Product Features

- Third-party certified RoHS compliant
- Excellent crystal quality for high isolation ≥ 40 dB
- Low insertion loss ≤ 0.05 dB @ 1310 nm, ≤ 0.08 dB @ 1550 nm
- Low temperature dependence -0.04-0.045 deg/°C
- Low wavelength dependence
- Anti-Reflection coating per customer requirements
  - Pinhole free; Reflectance ≤ 0.15% per side
  - Highly durable against abrasion, humidity, high processing temperatures and other environmental factors
- Custom fabrication to customer's specification
  - A wide variety of wavelengths are available or can be fabricated
  - Coatings available for air, epoxy, uncoated or in combinations

| Properties | FLT Garnet |
|---|---|
| Temperature Coefficient; dθ/dT (deg/°C) | −0.045 @ 1550 nm, −0.04 @ 1310 nm |
| Wavelength Dispersion; dθ/dλ (deg/nm) | −0.058 @ 1550 nm, −0.087 @ 1310 nm |
| Thermal Expansivity; α (°C-1) | $11.0\times10^{-6}$ |
| Refractive Index; n | 2.361 @ 1550 nm, 2.374 @ 1310 nm |
| Curie Temperature; Tc (°C) | 300 |
| Specific Faraday Rotation; θ/t (deg/mm) | −96 @ 1550 nm, −141 @ 1310 nm |
| Thickness for 45 degrees; t (μm) | ~470 @ 1550 nm, ~320 @ 1310 nm |
| Saturating Field; Hs (Oersted) | < 800 for 11x11mm, < 650 for 2x2 mm, < 550 for 1x1 mm |

## Ordering Information

Part numbers are given as **FLT-(Wavelength)-(Rotation Tolerance)-(AR Coating)-(Dimensions in mm)**

- Wavelength, λ(nm)—Typical wavelengths are 1310, 1480 and 1550 nm, but custom wavelengths are available by customer request. All Faraday rotations are 45 degrees at 22°C and the center specification wavelength unless otherwise specified.
- Rotation Tolerance, ±Δθ (degrees)—The Faraday rotation is given to a specific tolerance, typically ±0.5, ±1.0 or ±2.0 degrees.
- Anti-Reflection (AR) Coatings—Films may be coated to Air or Epoxy, Uncoated or to some custom specification. Ordering information must specify coatings for both sides such as AA-to Air both sides, EE-to Epoxy both sides, AE-One side to Air and one to Epoxy or UU-uncoated.
- Dimensions (mm)—The part number gives the square dimensions of the part in mm. Standard size is 11x11 mm.

e. g. **FLT-1550-1.0-AA-11.0** would be a Faraday rotator for 1550 nm with 45.0 ±1.0 degrees Faraday rotation, Anti-Reflection coated 2 sides to Air in the form of a square 11.0 mm on a side.

# FLL Garnet - Low Loss Faraday Rotator

For Non-Reciprocal Passive Optical Components
(Isolators, Circulators, Switches, Interleavers)

FLL

Bismuth-doped rare-earth iron garnet thick films are the principal Faraday rotator materials for non-reciprocal devices in telecommunications applications. They have high specific rotations and are highly transparent in the near infrared telecom band. Combined with the correct polarizing or birefringent elements, these Faraday rotators can be made into polarization dependent and independent isolators as well as incorporated into many other non-reciprocal devices. II-VI low loss FLL Faraday rotator composition is optimized to give low insertion loss across the telecommunications bands 1290-1610 nm.

## Product Features

- Third-party certified RoHS compliant
- Excellent crystal quality for high isolation ≥ 40 dB
- Good crystal design and process control for low insertion loss ≤ 0.05 dB (0.02 dB typical)
- Anti-Reflection coating per customer requirements
  - Pinhole free
  - Reflectance ≤ 0.15% per side
  - Highly durable against abrasion, humidity, high processing temperatures and other environmental factors
- Custom fabrication to customer's specification
  - A wide variety of wavelengths are available or can be fabricated
  - Coatings available for air, epoxy, uncoated or in combinations

| Properties | FLL Garnet |
|---|---|
| Temperature Coefficient; dθ/dT (deg/°C) | −0.065 |
| Wavelength Dispersion; dθ/dλ (deg/nm) | −0.07 @ 1550 nm, −0.09 @ 1310 nm |
| Thermal Expansivity; α (°C-1) | $11.0\times10^{-6}$ |
| Refractive Index; n | 2.356 @ 1550 nm, 2.369 @ 1310 nm |
| Curie Temperature; Tc (°C) | 270 |
| Specific Faraday Rotation; θ/t (deg/mm) | −105 @ 1550 nm, −158 @ 1310 nm |
| Thickness for 45 degrees; t (μm) | ~430 @ 1550 nm, ~285 @ 1310 nm |
| Saturating Field; Hs (Oersted) | ≤ 1000 for 11x11mm, ≤ 800 for 2x2 mm, ≤ 650 for 1x1 mm |

## Ordering Information

Part numbers are given as **FLL-(Wavelength)-(Rotation Tolerance)-(AR Coating)-(Dimensions in mm)**

- Wavelength, λ(nm)—Typical wavelengths are 1310, 1480, 1550 and 1610 nm, but custom wavelengths are available by customer request. All Faraday rotations are 45 degrees at 22°C and the center specification wavelength unless otherwise specified.
- Rotation Tolerance, ±Δθ (degrees)—The Faraday rotation is given to a specific tolerance, typically ±0.5, ±1.0 or ±2.0 degrees.
- Anti-Reflection (AR) Coatings—Films may be coated to Air or Epoxy, Uncoated or to some custom specification. Ordering information must specify coatings for both sides such as AA-to Air both sides, EE-to Epoxy both sides, AE-One side to Air and one to Epoxy or UU-uncoated.
- Dimensions (mm)—The part number gives the square dimensions of the part in mm. Standard size is 11x11 mm.

e. g. **FLL-1550-1.0-AA-11.0** would be a Faraday rotator for 1550 nm with 45.0 ±1.0 degrees Faraday rotation, Anti-Reflection coated 2 sides to Air in the form of a square 11.0 mm on a side.

# MGL Garnet - Latching Faraday Rotator

For Non-Reciprocal Passive Optical Components
(Isolators, Circulators, Switches, Interleavers)

Bismuth-doped rare-earth iron garnet thick films are the principal Faraday rotator materials for non-reciprocal devices in telecommunications applications. They have high specific rotations and are highly transparent in the near infrared telecom band. Combined with the correct polarizing or birefringent elements, these Faraday rotators can be made into polarization dependent and independent isolators as well as incorporated into many other non-reciprocal devices. II-VI Latching MGL Faraday rotator composition is custom designed to provide a stable single-domain device without the use of a cumbersome bias magnet. II-VI Latching garnets are stable indefinitely under operating and storage conditions even at temperatures up to 150℃, with brief temperature exposures up to 170℃ and stray fields up to the switching field. This frees the device designer from constraints of positioning, packaging materials, thermal mass and volume. II-VI Latching MGL material has been designed to have the most stable saturation magnetization over a wide temperature range and therefore has the highest possible switching fields from below -60 up to 150℃. The combination of rare earths used in the MGL material has a much better latching stability over a wide temperature range and much lower intrinsic insertion loss in the C and L bands than standard Tb-containing materials. II-VI has patented an improved embodiment of the Latching composition; U. S. Patent 6,770,223.

## Product Features

- Third-party certified RoHS compliant
  - **Latching** material is **Lead-Free**
- Excellent crystal quality for high isolation ≥ 40 dB
- Good crystal design and process control for low insertion loss ≤ 0.05 dB
- High magnetic switching fields for die (≤ 5×5 mm)
  - Hsw ≥ 500 Oe at room temperature
  - Hsw ≥ 100 Oe to 150°C
  - Higher or lower room temperature Hsw available on request
- Anti-Reflection coating per customer requirements
  - Pinhole free
  - Reflectance ≤ 0.15% per side
  - Highly durable against abrasion, humidity, high processing temperatures and other environmental factors
- Custom fabrication to customer's specification
  - A wide variety of wavelengths are available or can be fabricated
  - Coatings available for air, epoxy, uncoated or in combinations

| Properties | MGL Garnet |
|---|---|
| Temperature Coefficient; dθ/dT (deg/°C) | −0.093 |
| Wavelength Dispersion; dθ/dλ (deg/nm) | −0.068 @ 1550 nm, −0.087 @ 1310 nm |
| Thermal Expansivity; α (°C-1) | $11.0\times10^{-6}$ |
| Refractive Index; n | 2.317 @ 1550 nm, 2.327 @ 1310 nm |
| Curie Temperature; Tc (°C) | 185 |
| Specific Faraday Rotation; θ/t (deg/mm) | −93 @ 1550 nm, −141 @ 1310 nm |
| Thickness for 45 degrees; t (µm) | ~485 @ 1550 nm, ~320 @ 1310 nm |
| Saturating Field; Hsw (Oersted) for a die ≤ 5 mm square | ≥ 500 @ 22 °C |

## Ordering Information

Part numbers are given as **MGL-(Wavelength)-(Rotation Tolerance)-(AR Coating)-(Dimensions in mm)**

- Wavelength, λ(nm)—Typical wavelengths are 1310, 1480, 1550 and 1610 nm, but custom wavelengths are available by customer request. All Faraday rotations are 45 degrees at 22°C and the center specification wavelength unless otherwise specified.
- Rotation Tolerance, ±Δθ (degrees)—The Faraday rotation is given to a specific tolerance, typically ±0.5, ±1.0 or ±2.0 degrees.
- Anti-Reflection (AR) Coatings—Films may be coated to Air or Epoxy, Uncoated or to some custom specification. Ordering information must specify coatings for both sides such as AA-to Air both sides, EE-to Epoxy both sides, AE-One side to Air and one to Epoxy or UU-uncoated.
- Dimensions (mm)—The part number gives the square dimensions of the part in mm. Standard size is 11x11 mm.

e. g. **MGL-1550-1.0-AA-11.0** would be a **Latching** Faraday rotator for 1550 nm with 45.0 ±1.0 degrees Faraday rotation, Anti-Reflection coated 2 sides to Air in the form of a square 11.0 mm on a side.

## User Notes

MGL Latching garnet Faraday rotators are designed to be operated without a bias magnet. If placed in a device with a bias magnet, they will not work properly in certain temperature ranges.

### Poling

Latching Faraday rotators are "poled" or magnetized to a single saturated domain perpendicular to the major face of the Faraday rotator before shipping. The poling direction cannot be determined from visual examination of the die. The Faraday rotators will remain poled in this direction unless subjected to

- Temperatures near or in excess of the Curie temperature (185°C)
- High stress as may be exerted by processing including dicing, direct bonding or epoxy bonding
- Large magnetic fields greater than or equal to the switching field
- Some combination of the above elements, but each to a lesser degree

A demagnetized garnet reverts to a multi-domain state. In the event that a Faraday rotator becomes depoled during device assembly (e. g. as a result of high welding or soldering temperatures) or is magnetized in a direction opposite to that desired for the device, it can readily be repoled by application of a uniform magnetic field of ≥ 4000 Oe. It is recommended that all processed devices that have been diced, bonded, etc. be poled before incorporating into a device. The following factors are important in repoling.

- A permanent magnet or electromagnet may be used, but the sample must be extracted from the field (or the field removed) in such a way that the field direction remains uniform. For this reason, toroidal magnets cannot be used for poling because the field changes sign down the axis of the bore as the sample is removed.
- The field strength must be delivered at the sample. Magnets of a nominal internal magnetization of 4000 G do not always deliver a field of similar strength outside the magnet. Also housings and fixtures made of magnetic material may redirect the field lines so the desired field does not reach the sample.
- Under-poling (poling with a field not greater than the switching field) may result in domain nuclei remaining at defects so that the desired full coercive behavior is not realized.
- Heating the sample to a moderate temperature (50-100°C) allows the material to be poled with a reduced field.

If in-situ poling in a large package is desired, users may wish to request material with slightly lower switching fields. Material with higher switching fields can be used to increase high temperature stability.

### Handling

Garnets are inherently brittle materials and can be chipped or broken by harsh handling. Handling the die with metal tweezers can chip or crack the edges and scratch the anti-reflection coatings. This not only cosmetically damages the material, but can degrade the switching fields of the material even though severe damage is not observed. It is therefore recommended that garnets be handled only with plastic tweezers. Faraday rotators are not guaranteed against customer handling damage.

### Stress

Non-hydrodynamic stress (bending, twisting or compression) will degrade the performance of any Faraday rotator and can reduce the switching field or even demagnetize a Latching Faraday rotator. It is recommended that users examine their mounting design to make sure that the assembled Faraday rotator is not under stress. If poor performance (unexplained low isolation and high insertion loss) is seen in a finished device, it is often the case that stress is responsible.