MIOC

for Navigation & Fiber Optic Sensing

Precision Unleashed for FOG and Fiber Optic Sensing
with Advanced Lithium Niobate Innovation

Spring 2024
Optilab LLC

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What is MIOC?

Multi-function Integrated Optical Chip (MIOC) is the key component in many fiber optic sensing solutions, i.e., Interferometric Fiber Optic Gyroscope (IFOG) for measuring the angular velocity of an inertial navigation system and the Optic Current Sensor (FOCS) for measuring electric current in power systems. The MIOC consists of a polarizer, a Y-junction coupler, and dual electro-optical phase modulators. It is often fabricated on an X-cut single-crystal lithium niobate (LiNbO3) wafer. Optilab uses the Annealed Proton Exchange (APE) process to fabricate the optical waveguide of an MIOC along the Y direction of the crystal structure.

Featuring over 60 dB Polarization Extinction Ratio (PER) and highly reliable chip-fiber coupling, Optilab's MIOC product can minimize bias drift resulting from polarization crosstalk-induced non-reciprocity. Optilab's MIOC products are also qualified for operation in a wide temperature range.

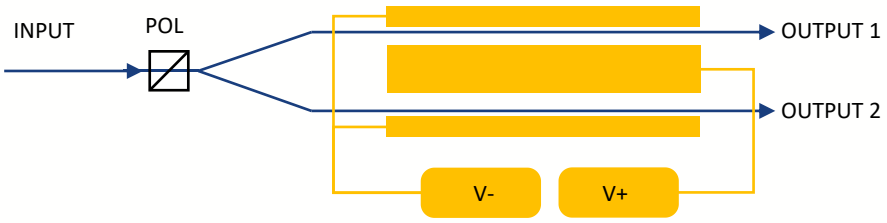
Features

- 1550±20 nm Operation
- PM Input and Output Port
- Polarization Extinction Ratio > 60 dB
- Low Vπ Voltage 4 V
- Low Optical Insertion Loss

Applications

- Fiber Optic Gyroscope (FOG)
- Fiber Optic Current Sensor (FOCS)
- Hydrophone and Other Optic Sensitive Fields
- Research and Development

MIOC Function Diagram



PUSH-PULL PHASE MODULATTION

Application Areas

Fiber Pigtailed MIOC Specs

Room Temperature (+15°C to + 30 °C)

Parameter	Symbol	Unit	P Grade	A Grade	B Grade
Operating Wavelength	λ	nm		1530 to 1570	
Insertion Loss	IL	dB	≤ 3.1	≤ 3.6	≤ 4.1
Splitting Ratio	SR	%	50±2	50±3	50±5
Half Wave Voltage	Vpi	V	≤ 4.0	≤ 4.1	≤ 4.3
Pigtail Polarization Crosstalk	XT	dB	≤ -30	≤ -27	≤ -25
Chip Polarization Extinction Ratio	PER	dB	≥ 60 typ. (≥ 80 option avail.)		
Residual Amplitude Modulation	RAM	%	≤ 0.1	≤ 0.1	≤ 0.2
Optical Back Reflection Loss	OBRL	dB	≥ 50	≥ 47	≥ 45

Full Temperature Range (-45°C to + 75 °C)

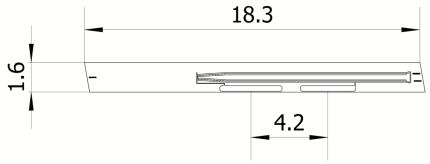
Parameter	Symbol	Unit	P Grade	A Grade	B Grade
Insertion Loss Variation	Δλ	dB	≤ 0.3	≤ 0.5	≤ 0.7
Splitting Ratio	IL_T	%	50±3	50±5	50±5
Pigtail Polarization Crosstalk	SR_T	dB	≤ -27	≤ -25	≤ -20

Mechanical Drawings

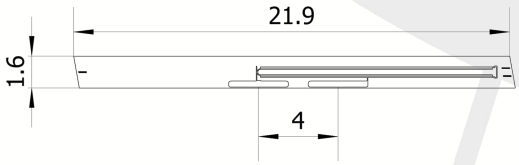
Unit: mm

BC: Optical Bare Chip

18 mm:

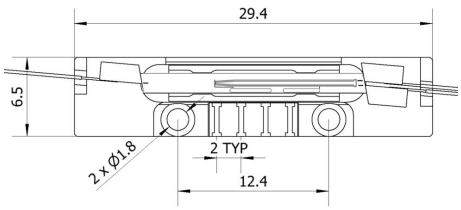


22 mm:

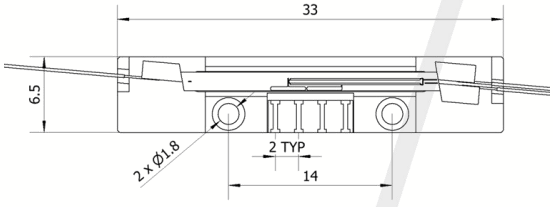


SP Package: Fiber Pigtailed Chip on A Submount

18 mm:

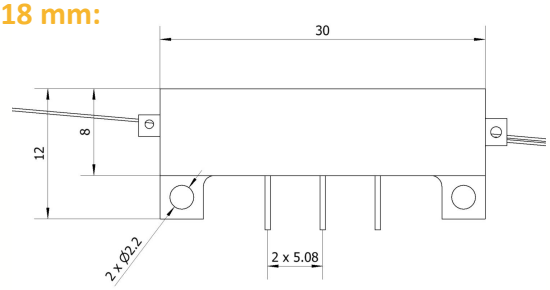


22 mm:

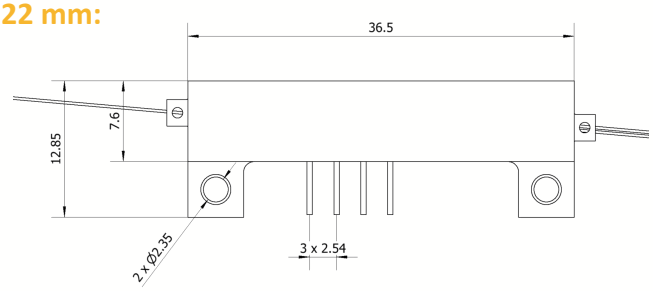


PG Package: Fully Packaged Model

18 mm:



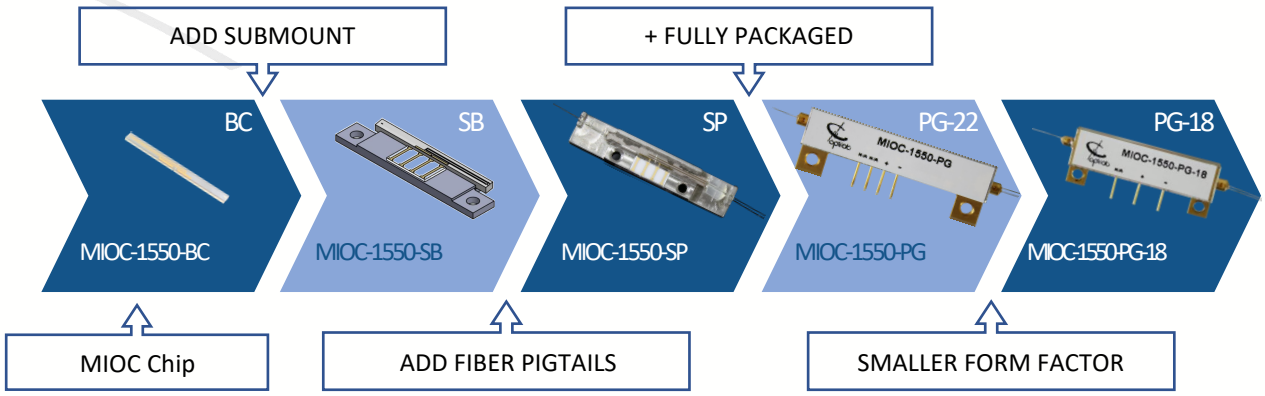
22 mm:



Remark: Package shell can be customized with different sizes according to customer requirements.

MIOC Models and Ordering Options

Optilab carries two main product lines in the MIOC series: the 18 mm version and the 22 mm version. The 22-mm-long optical chip is the original version produced for years and continues to be available for our customers. The 18-mm-long optical chip is the state-of-the-art version, featuring an 18% size reduction while maintaining the same or better electro-optical performance compared to the original 22-mm version. Both length versions are available in four form factors: the optical bare chip (BC), the bare chip on a submount (SB), the fiber pigtailed chip on a submount (SP), and the fully packaged model (PG). Optilab offers both 80 µm PM fiber and 125 µm PM fiber options for the fiber pigtail. The TE mode of optical output can be aligned to a slow axis, a fast axis, or 45 degrees on an individual port basis. Other types of fibers and alignment options are also available upon request.



Ordering Options

MIOC-1550-LL-FF-G-XX-YY-ZZ * 850 nm, 1310 nm available upon request

LL: Chip Length
-18: 18 mm
-22: 22 mm

FF: Form Factor
-BC: Bare chip
-SB: Bare chip on submount
-SP: Fiber pigtailed w/ submount
-PG: Packaged

G: Grade
-P: Premium grade
-A: A grade
-B: B grade

Fiber Type Option:
-0: No fiber pigtail
-1: Corning RCPM15, 80/165 µm
-2: Corning PM15-U25D, 125/250 µm

XX: Input Fiber
YY: Output Fiber #1
ZZ: Output Fiber #2
*For reach fiber:
First digit: Fiber Type
Second digit: Alignment direction

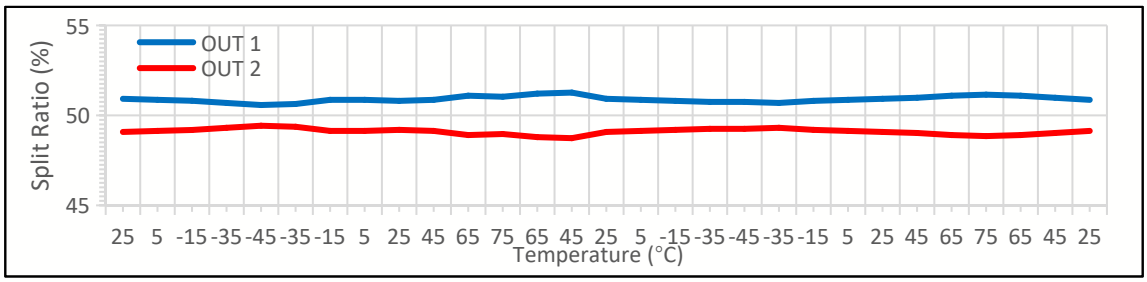
Fiber Alignment Direction Option:
-0: Not applicable
-1: Slow axis aligned to TE mode
-2: Fast axis aligned to TE mode
-3: 45˚ alignment

-1 = default option
-0 = Not applicable
Example: MI-1550-22-PG-P-00-11-23

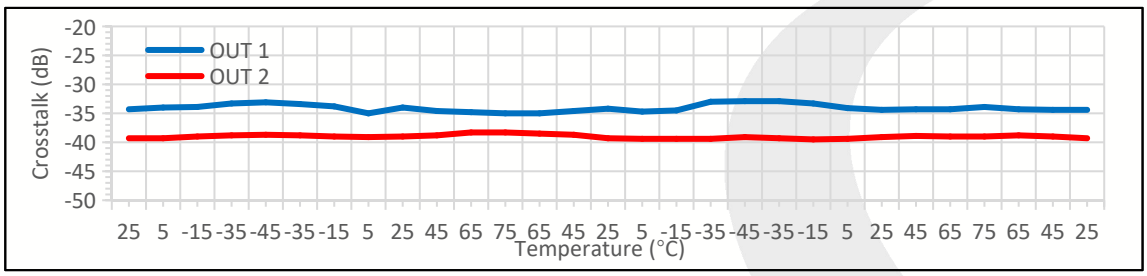
*NOTE: if no fiber pigtail is chosen then fiber alignment is not applicable (Only PM fiber needs alignment)

Sample Qualification Data

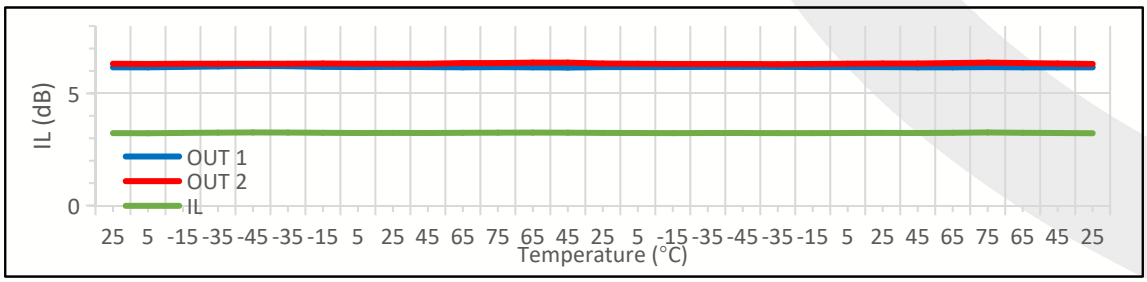
Sample Data of Split Ratio



Sample Data of Polarization Crosstalk



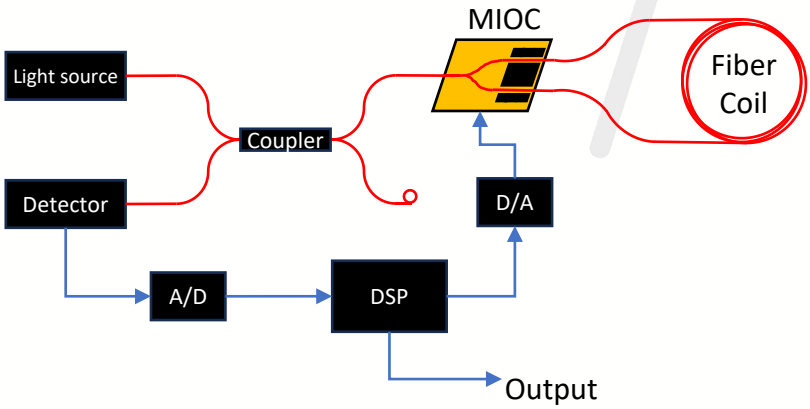
Sample Data of Insertion Loss



Applications

1. Interferometric Fiber Optic Gyro

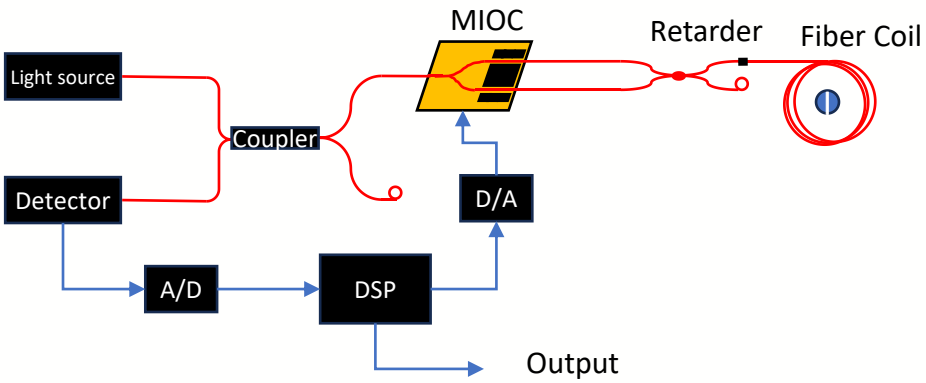
The interferometric fiber optic gyroscope (IFOG) is a rotation sensor based on the optical common path interferometer (Sagnac interferometer), which is widely applied in navigation and positioning. High accuracy, high reliability, and miniaturization are the main directions for the development of the IFOG.



MIOC is one of the crucial components in the IFOG to achieve these features. The extra-high polarization extinction ratio and the minimum phase error of the MIOC make a non-ignorable contribution to the performance of a compact IFOG.

2. Fiber Optic Current Sensor

The polarization-rotated reflection interferometer type Fiber Optic Current Sensor (FOCS) is suitable for DC/AC current sensing and has a large dynamic measurement range. Thanks to its immunity to EMI/RFI, FOCS can be deployed in the hash environment for sensing DC



or AC current up to 500 kA, e.g., HVDC or HVAC power transmission lines with over 1 MV voltage. Featuring over 50 dB of dynamic range and an ultra-high bandwidth over 200 kHz, it can also be used for current sensing scenarios, including ultra-low current measurement and large current spikes and ripples, which are crucial in power grid monitoring.

Explanation of Key Parameters

- **Insertion Loss**

The optical insertion loss is defined as the ratio between the total output power of the two output ports and the input optical power.

$$IL\ (dB) = 10 * Log10(\frac{P_{O1} + P_{O2}}{P_{in}})$$

where P_{o1} and P_{o2} are the output power from the two output ports in mW, and P_{in} is input optical power in mW. It should be noted that MIOC device has an optical polarizer built in. It only passes the TE mode and rejects the TM mode over 60 dB. Therefore, the input power defined in the equation above should be the optical power polarized in TE mode. Counting in the optical power in TM mode (if present) would result in an overestimation of insertion loss.

- **Split Ratio**

Ideally the Y junction should split the optical power equally (50/50). However, the real device could show inequality in the amount of optical power split. The split ratio is defined as:

$$SR = \frac{P_{O1}}{P_{O1} + P_{O2}} \times\ 100\%$$

The SR can be improved during pigtail process by compensating the fiber chip coupling efficiency. Though a not careful fiber alignment process can also make the SR even worse.

- **Polarization Crosstalk**

Polarization crosstalk measures the amount of cross coupling from lightwave linearly polarized in one direction to the orthogonal direction. Such cross coupling degrades the sensor performance significantly in certain sensor configurations. The polarization crosstalk can be induced by mechanical or temperature stress, and often mainly caused by the angle alignment error between the MIOC chip and the slow axis of a PM fiber. Optilab developed a white light interferometer (WLI) based system to characterize the polarization crosstalk.

- **Halfwave Voltage**

Halfwave voltage Vpi is the voltage difference required to shift the phase difference between two optical output ports by π. Optilab uses the Serrodyne phase modulation method to measure Vpi of the MIOC devices.

- **Residual Amplitude Modulation**

The applied electrical signal to the phase modulator could induce a small amount of unwanted amplitude modulation in addition to the phase modulation. It is defined as the ratio between the modulated optical peak to peak power to the average optical power.

$$RAM = \frac{P_{pp}}{P_{ave}} \times 100\%$$

RAM is mainly caused by the interference between the forward optical guided wave and the weak parasitic reflected wave at the chip to air or chip to fiber interface. Optilab uses 10-degree optical dicing at the input and output interface of the optical chip to minimize back reflection thus minimize RAM.

- **Optical Back Reflection Loss**

Optical back reflection loss measures the amount of optical back reflection occurred at fiber to chip interface. It is defined as the ratio between backward reflection power and forward input power. The higher back reflection loss means the less unwanted back reflection occurs. Optilab uses 10-degree optical dicing at the input and output interface of the optical chip to minimize back reflection.

$$OBRL\ (dB) = 10 * Log10(\frac{P_{BW}}{P_{FW}})$$

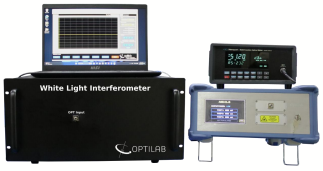
Related Products

1. FC/APC Connector for 80 µm PM Fiber

Low Insertion Loss < 0.2 dB
- 80 µm PM Fiber to 80 µm PM Fiber
- 80 µm PM Fiber to 125 µm PM Fiber

Low Polarization Crosstalk
- Less than ±2˚ Axis Angle Alignment Error

2. WLI-1550 1550 nm White Light Interferometer for MIOC, FOGS



- High Spatial Resolution: 2 cm on PM Fiber Test
- Large Fiber Measurement Range: ≥ 400 m
- Larger PER Measurement Range: ≥ 10 dB
- High X-talk Sensitivity: ≤-50 dB
- User Friendly GUI

3. MTC-8 8-Channel Multichannel Temperature Chamber

- Designed for MIOC Temperaure Cycling Test
- Wide Temperature Range from -50°C to 80°C
- Stable Temperature Ramping
- Versatility
- Advanced Temperature Control

Optilab

MIOC Series

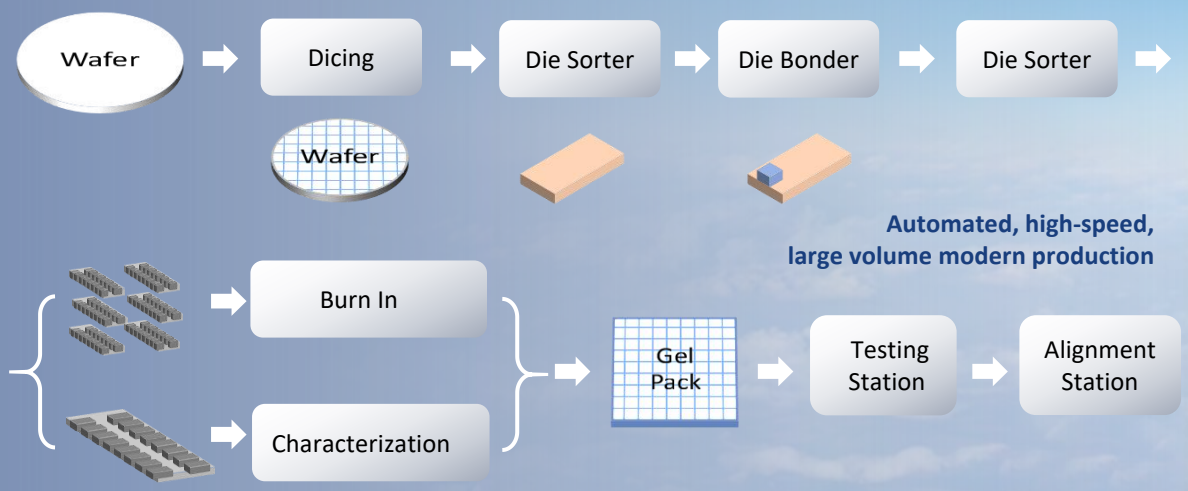
Precision Unleashed for FOG and Fiber Optic Sensing with Advanced Lithium Niobate Innovation

THOUSANDS OF PRODUCTS IN STOCK!

Outstanding Achievements and Advantages

2003	200+	100+	5K+
Business Since	Existing Solutions	Customized Projects	Current Customers

Advanced Packaging to Enable Solutions



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