THORLABS

EO-PM-NR-Cx
EO-PM-R-20-Cx

Electro-Optic Phase Modulator

Operating Manual

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Chapter 1 Description

1.1. Overview

The electro-optic phase modulator (EO-PM) consists of an electro-optic crystal, lithium niobate, packaged in a compact housing with an RF input connector. By applying an appropriate voltage to the RF input, a corresponding change in the extraordinary refractive index will occur. If the optical input is both linearly polarized and aligned with the extraordinary axis of the modulator crystal, the output will undergo a pure phase shift with no change in the state of polarization. This effect is utilized in applications where only a phase shift is required (i.e., generating RF sidebands and Mach Zhender interferometers).

The extraordinary axis (the crystal Z-axis or optic axis) is oriented vertically with respect to the modulator package. With linearly polarized input light, the angle of the input polarization with respect to the optic axis determines how the output will be affected: When the input polarization is vertically aligned, a pure phase shift will occur. If the input polarization is horizontal, a pure phase shift will also occur but with approximately 30% less efficiency than for vertical polarization (r13/r33 = 30% for Lithium Niobate). If the input polarization is at 45°, the output polarization will undergo a change from linear to elliptical. In this mode, the modulator can be considered an electronically tunable waveplate.

1.2. EO Phase Modulator Versions

Thorlabs offers the EO phase modulators in two basic versions:

1. **DC-coupled Broadband Version**: The electro-optic crystal is directly coupled to the RF modulation input connector, allowing the full bandwidth of the crystal to be utilized. The broadband version can be driven from DC up to the frequency limit of the RF driver (**Note**: The external driver must be capable of driving the capacitive load of the crystal).

2. **High Q Resonant Mode Modulator**: A high Q tank circuit is used to boost the RF input voltage up to the high voltage needed by the EO crystal. An impedance matching network transforms the reactive crystal load to a 50 Ω input to allow for easy matching to standard RF drivers and function generators.

Note: By definition, high Q circuits have a narrow operating bandwidth. The resonant EO modulators have a typical operating bandwidth that is 5% of the center frequency. Therefore, the operating frequency must be specified at time of purchase.

1.3. Standard Features

- Broadband DC coupled and High Q Resonant models
- MgO doped Lithium Niobate crystal
- Standard Broadband AR coatings cover 400 to 1650 nm range
- 2 mm diameter clear aperture
- SMA RF modulation input connector
- DC to 100 MHz
- Flange with thru holes on housing for secure mounting
- #1/4-20 and #8-32 tapped mounting holes on bottom
- Custom OEM versions available

1.4. EO-PM Specifications

Specification	Value
Modulator Crystal	MgO Doped Lithium Niobate ($LiNbO_3$)
Wavelength Range	
C1	600 to 900 nm
C2	900 to 1250 nm
C3	1250 to 1650 nm
C4	400 to 600 nm
Clear Aperture	2 mm diameter
Input Connector	SMA Female
Halfwave Voltage, Vπ, Non-Resonant	135 V @ 633 nm (See Figure 1)
Halfwave Voltage, Vπ, Resonant	15 V @ 633 nm
Input Capacitance, Non-Resonant	14 pF (typical)
Input Impedance, Resonant	50 ohms
Maximum RF Input Power, Resonant	3 W (35 Vpp)
Maximum Optical Power Density	2 W/mm^2 @ 532 nm 4 W/mm^2 @ 1064 nm

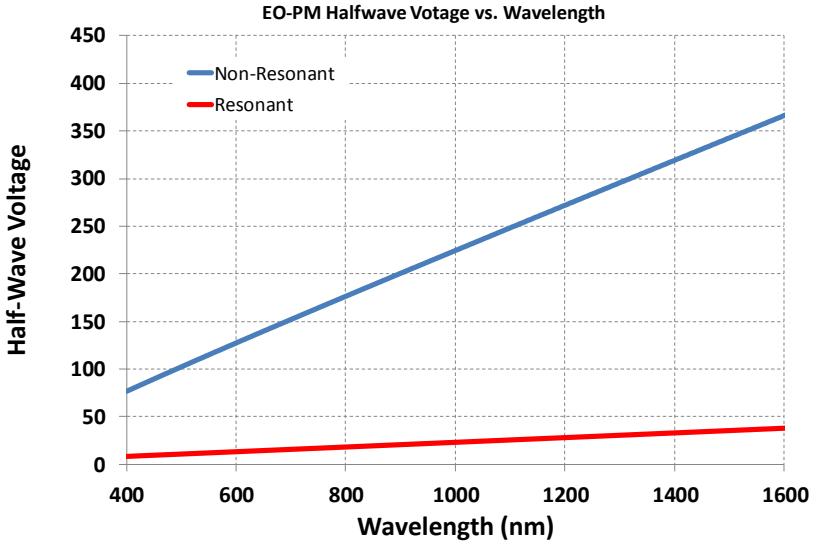


Figure 1 Halfwave Voltage

Chapter 2 Setup

WARNING

Do not remove cover. High voltages are used to drive the crystals. Contact with these high voltages may be harmful to the user.

2.1. Unpacking

The modulator is shipped form the factory ready to be placed into your setup. Carefully unpack the modulator and inspect the optics by looking through the aperture. If the modulator is shipped with protective tape over the optical apertures, it will need to be removed prior to operation.

2.2. Generating RF Sidebands

An EO phase modulator is ideal for generating RF sidebands on top of a laser line. By applying a sinusoidal varying RD drive voltage, the phase of the optical signal will have a time varying sinusoidal modulation at the same frequency as the modulating signal. This phase modulation will result in a frequency modulation of the optical signal.

If the frequency modulated signal is viewed with a spectrum analyzer (i.e., with Thorlabs Scanning Fabry-Perot Interferometer), a series of sidebands can be easily observed. These sidebands are an infinite series with each pair of sidebands spaced symmetrically about the fundamental with a separation equal to a multiple of the modulation frequency (i.e. with a laser operating at a fundamental of f_o, and a modulation frequency of f_m, the first pair of side bands will be at $f_o \pm f_m$, the second pair of sidebands will be at $f_o \pm 2*f_m$, etc.).

The amount of energy transferred from the fundamental to the n^{th} sideband with a phase modulation depth of ϕ radians is described by the square of the Bessel function of order n, $J_n (\phi)^2$. Figure 2 on page 6 shows the relative power of the fundamental and the first three sidebands as a function of the phase modulation depth.

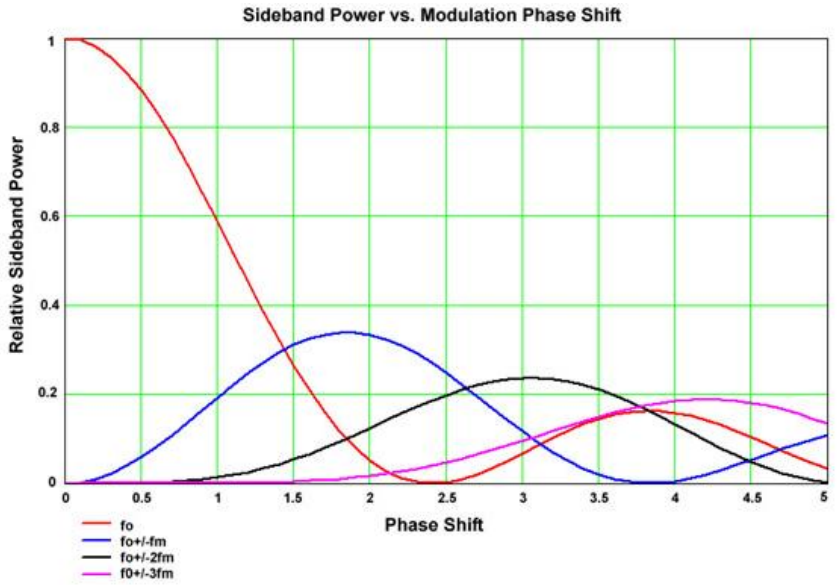


Figure 2 Sideband Power Versus Phase Shift

Note: At a depth of about 2.4 rad, almost all of the energy is transferred from the fundamental to the sidebands.

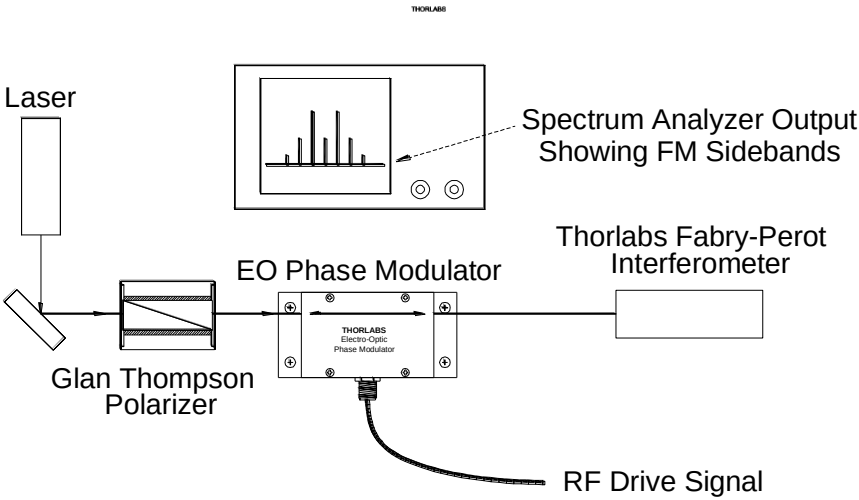


Figure 3 Typical Setup for Sideband Generation

Sideband Generation Example: Figure 4 below is an actual oscilloscope trace from the output of a scanning Fabry-Perot spectrum analyzer. The modulator was a resonant mode EO-PM operating at 30 MHz and being driven from 8 V_{peak} sine wave.

Note the suppression of the fundamental (center band) indicating a very good depth of modulation (2.1 rad).

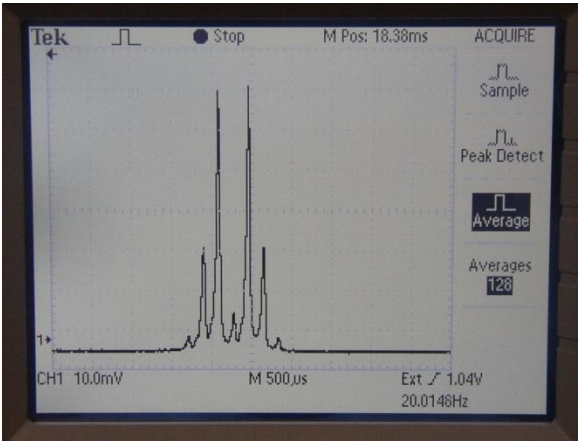


Figure 4 Sideband Generation Sample

Chapter 3 Photorefractive Limits

Lithium Niobate, $LiNbO_3$, has an optical transparency range from 320 nm to over 5 µm and can withstand pulsed power densities up to 1 MW/cm^2. However, short wavelength operation is limited by photorefractive effects which lead to color center formation and progressively increasing absorption. Photorefractive damage is noted by increase scattering and absorption in the optical path along with gray appearance in the crystal (gray tracking).

Photorefractive limits are a concern in the visible region (400 – 700 nm) particularly with frequency- doubled lasers.

The lithium niobate crystals in Thorlabs' EO modulators are MgO-doped for increased resistance to photorefractive damage.

Chapter 4 Cleaning and Maintenance

Under normal operating conditions, the modulator needs very little, if any maintenance.

4.1. Cleaning the Optics

The modulator crystal is recessed inside the housing and under normal conditions, the crystal faces should not need cleaning. If necessary, use a gentle stream of compressed air (dry nitrogen under low pressure or a can of compressed air made specifically for cleaning optics).

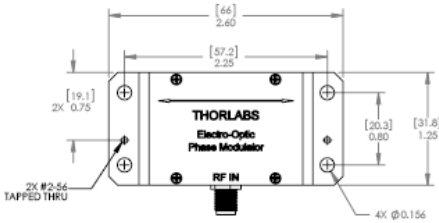
WARNING

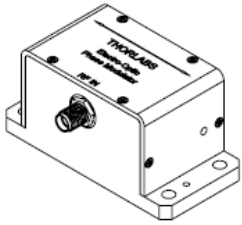
Damage may result from excessive cleaning air pressure or if condensation is allowed to build up from using a stream of compressed air from an inverted can.

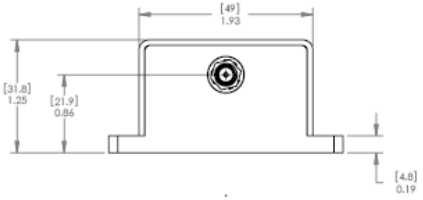
4.2. Cleaning the Modulator Housing

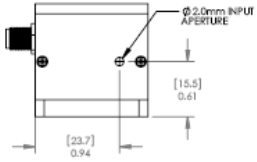
The housing can be wiped clean with a lint free rag wetted with propanol or a commercial window cleaner. Do not soak the housing – it is not watertight and any moisture introduced inside the modulator may cause condensation problems.

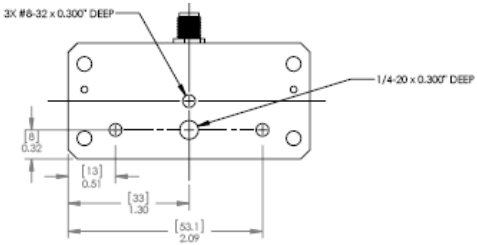
Chapter 5 Mechanical Drawings











Chapter 6 Warranty Information

6.1. General Product Warranty

Thorlabs warrants that all products sold will be free from defects in material and workmanship, and will conform to the published specifications under normal use and service when correctly installed and maintained.

6.2. Opto-Mechanics

Lifetime Warranty: Thorlabs offers a lifetime warranty on all opto-mechanical components. Thorlabs will repair or replace any opto-mechanical product which after evaluation has failed to perform in the above conditions.

6.3. Optical Tables and Breadboards

Lifetime Warranty: We provide a lifetime guarantee that all of our passively damped optical tables and breadboards will meet all originally stated performance specifications under normal use and proper handling. We additionally guarantee that all our table tops and breadboards, both active and passive, will be free from defects in workmanship, including de-lamination of the skins under normal use and handling.

6.4. Lasers and Imaging Systems

Thorlabs offers a one year warranty on all lasers and imaging systems, with the exceptions of laser diodes. Some products are warranted for the number of hours specified in the operating manual of each laser.

6.5. Opto-Electronics, Control Electronics, Optics, and Non-Positioning Product Lines

Thorlabs offers a two year warranty on the above mentioned product lines, providing normal use and maintenance of the products and when properly handled and correctly installed.

Thorlabs shall repair or replace any defective or nonconforming product as detailed above. We ask that the buyer contact Thorlabs for a Return Material Authorization number (RMA#) from our Customer Service/Returns department in order to most efficiently process the return and/or repair.

Products returned for repair that are not covered under warranty, a Thorlabs standard repair charge shall be applicable in addition to all shipping expenses. This repair charge will be quoted to the customer before the work is performed.

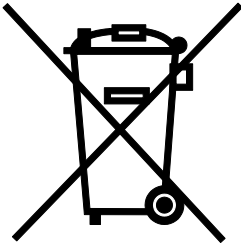
6.6. Warranty Exclusions

The stated warranty does not apply to products which are (a) specials, modifications, or customized items (including custom patch cables) meeting the specifications you provide; (b) ESD sensitive items whose static protection packaging has been opened; (c) items repaired, modified, or altered by any party other than Thorlabs; (d) items used in conjunction with equipment not provided by, or acknowledged as compatible by Thorlabs; € subjected to unusual physical, thermal, or electrical stress; (f) damaged due to improper installation, misuse, abuse, or storage; (g) damaged due to accident or negligence in use, storage, transportation, or handling.

Chapter 7 Regulatory

As required by the WEEE (Waste Electrical and Electronic Equipment Directive) of the European Community and the corresponding national laws, Thorlabs offers all end users in the EC the possibility to return “end of life” units without incurring disposal charges.

- This offer is valid for Thorlabs electrical and electronic equipment:
- Sold after August 13, 2005
- Marked correspondingly with the crossed out “wheelie bin” logo (see right)
- Sold to a company or institute within the EC
- Currently owned by a company or institute within the EC
- Still complete, not disassembled and not contaminated



Wheelie Bin Logo

As the WEEE directive applies to self-contained operational electrical and electronic products, this end of life take back service does not refer to other Thorlabs products, such as:

- Pure OEM products, that means assemblies to be built into a unit by the user (e.g. OEM laser driver cards)
- Components
- Mechanics and optics
- Left over parts of units disassembled by the user (PCB’s, housings etc.).

If you wish to return a Thorlabs unit for waste recovery, please contact Thorlabs or your nearest dealer for further information.

7.1. Waste Treatment is Your Own Responsibility

If you do not return an “end of life” unit to Thorlabs, you must hand it to a company specialized in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.

7.2. Ecological Background

It is well known that WEEE pollutes the environment by releasing toxic products during decomposition. The aim of the European RoHS directive is to reduce the content of toxic substances in electronic products in the future.

The intent of the WEEE directive is to enforce the recycling of WEEE. A controlled recycling of end of life products will thereby avoid negative impacts on the environment.

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