THORLABS

EO-AM-NR-Cx
EO-AM-R-20-Cx

Electro-Optic Amplitude Modulator

User Guide

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Chapter 1 Description

1.1. Overview

The electro-optic amplitude modulator (EO-AM) is a Pockels cell type modulator consisting of two lithium niobate crystals packaged in a compact housing with an RF input connector. Voltage applied across the crystal structure induces change in the indices of refraction (both ordinary and extraordinary), leading to an electric field dependent birefringence. An optical wave (with polarization components on both the ordinary and extraordinary axes) will experience a change in polarization state after traversing the crystal, from the relative phase delay between the orthogonal components. The electro-optic crystal acts as a variable waveplate with retardance linearly dependent on the applied voltage. Figure 1, below, shows the polarization state emerging from the electro-optic crystal as a function of applied voltage when the input polarization state is linear at 45° relative to the ordinary and extraordinary axes.

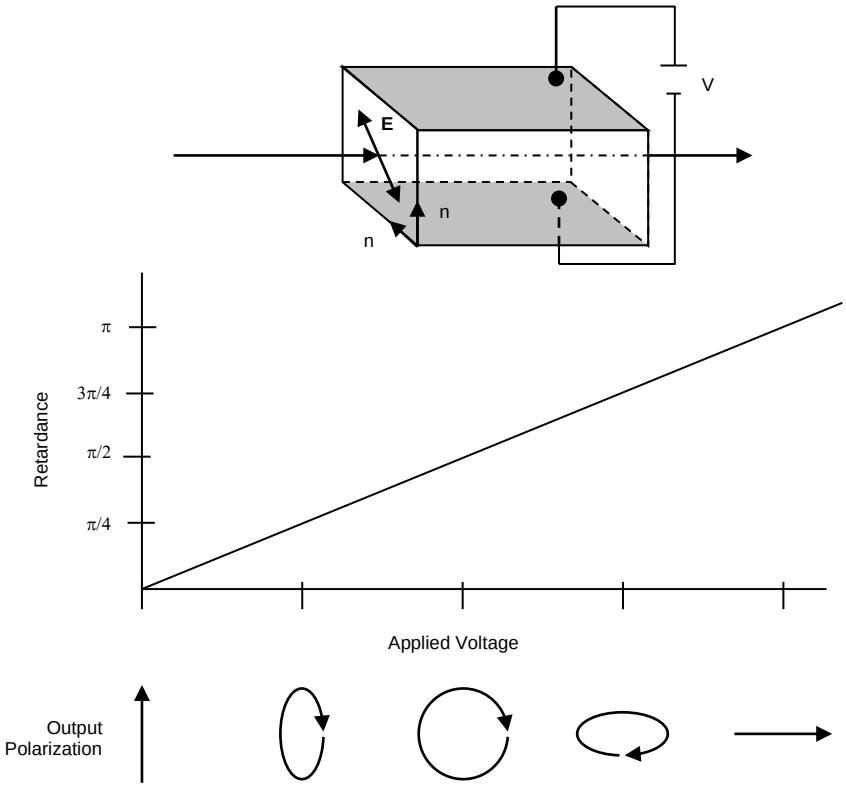

Figure 1 Output Polarization

The voltage required to produce a retardance of π radians is called the halfwave voltage or simply Vπ. For an optical input linearly polarized at 45°, applying a halfwave voltage rotates the polarization by 90°. When the output beam is then passed through a linear polarizer, the resulting intensity can be rapidly modulated from maximum intensity (output linearly polarized along the polarizer transmission axis) to minimum intensity (output polarized perpendicular to the polarizer transmission axis) by changing the voltage applied to the crystal from 0 volts to Vπ.

Note: Regarding static birefringence, lithium nobiate is birefringent even without an electric field applied. This static birefringence will induce a change in polarization without an electric field applied. In addition, this static birefringence is temperature dependent leading to variations in the output polarization with slight changes in temperature. To minimize this effect, the modulator is constructed of two matched lithium niobate crystals rotated 90° with respect to each other. The temperature dependent static birefringence in the first crystal is canceled by the temperature dependent static birefringence in the second. In this manner, the temperature sensitivity of the modulator is generally less than 1 mrad retardance per °C.

The halfwave voltage of lithium niobate is dependent on the optical wavelength and is given by:

$$V_\pi = \frac{\lambda}{n_e^3 r_{33} - n_o^3 r_{13}} \frac{d}{L},$$

Where λ = optical wavelength

d = electrode spacing

L = optical path length

r_{ij} = electro-optic coefficients

n_{oe} = ordinary and extraordinary indices of refraction

The indices of refraction themselves are also functions of wavelength and temperature. While the above formula for the halfwave voltage is relatively complicated, a reasonably close approximation for this modulator is obtained using a linear fit over the typical operating range,

$$V_\pi = 0.361\lambda - 23.844$$

where λ is the optical wavelength in nm.

1.2. EO Amplitude Modulator Versions

Thorlabs offers the EO amplitude 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 have sufficient slew rate, and output current level for driving the capacitive load of the crystal. Driver limitations and crystal capacitance typically determine the limit for maximum drive frequency)

2. **High Q Resonant Mode Modulator**: A high Q resonant circuit is used to boost the RF input voltage up to the high voltage needed by the EO crystal. The required peak to peak input voltage (as given in the formula above) is then reduced by the Q-factor of the tank circuit, when driven sinusoidally at the resonant frequency. 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 generations.

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 Nioabate 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-AM Specifications

Specification	Description
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	205 V @ 633 nm (See Fig. 2)
Halfwave Voltage, Vπ, Resonant	15V @ 633 nm
Extinction Ratio	>10 dB
Input Capacitance, Non-Resonant	14 pF (typical)
Input Impedance, Resonant	50 ohms
Maximum Optical Power Density	2 W/mm^2 @ 532 nm 4 W/mm^2 @ 1064 nm

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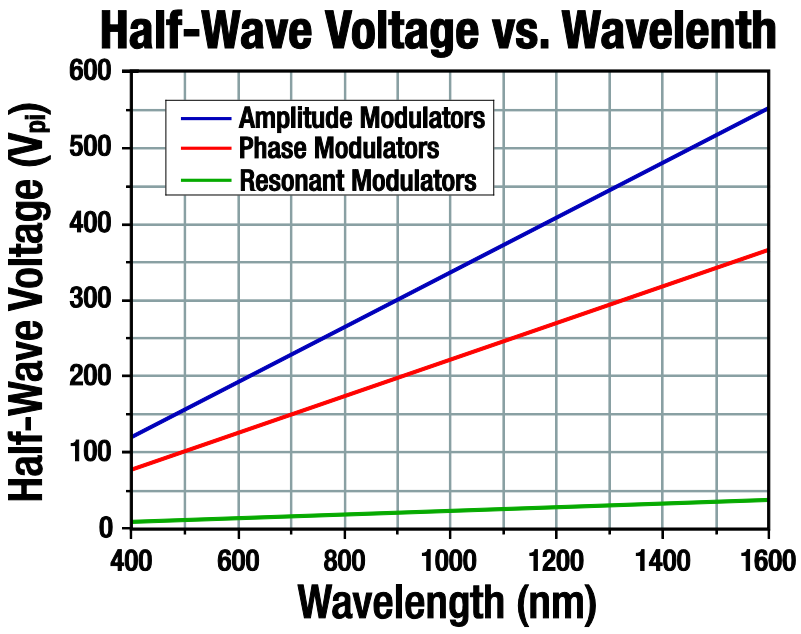


Figure 2 Halfwave Voltage

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.

WARNING

Do not drop or bang modulator. While Thorlabs supplies a rugged enclosure, excessive mechanical shock will damage the LiNbO3 crystal.

2.2. Alignment

The EO-AM can be used as a variable waveplate without additional optics. Maximum amplitude modulation requires both polarized input and a polarizer/analyzer at the output. The optical input may be polarized either vertically or horizontally. The output polarizer may be aligned either parallel or perpendicular to the input polarization. Parallel alignment of the output polarizer will give maximum transmission at low applied voltage and minimum transmission at high applied voltage. Conversely, perpendicular alignment of the output polarizer will give minimum transmission at low applied voltage and maximum transmission at high applied voltage. Best results are obtained when the optical propagation is precisely aligned along the principal axis of the crystals. With the input beam polarized either vertically or horizontally, direct the beam through the center of the modulator aperture. Place a card several inches from the output of the modulator and mark the location where the beam strikes the card. Insert a polarizer with polarization perpendicular to the input polarization between the card and the modulator. Cover the input aperture with a piece of frosted adhesive tape (Scotch™ Magic Mending Table No. 810 or similar material).

As shown in Figure 3 on page 7, a geometric pattern (isogyre) similar to Isogyre “A” will be projected on the viewing card. Adjust the modulator angle of incidence such that the center of the geometric pattern is coincident with the mark previously made on the card indicating the beam location.

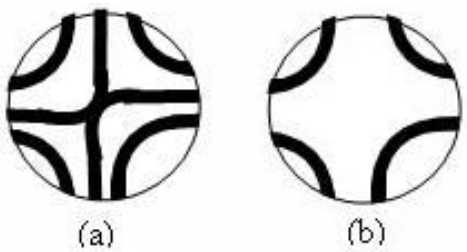


Figure 3 Geometric Pattern (Isogyre “A” and Isogyre “B”)

If voltage is applied to the modulator in this configuration, the pattern will be observed to change from Isogyre “A” to Isogyre “B” as the voltage increases. If the isogyre is not fully closed with zero applied voltage (i.e., transmission of a centered beam through the analyzer is not at a minimum) the pattern can be adjusted using a bias voltage (for broadband modulators only) or by using a quarter-waveplate at the modulator entrance. Alternatively, the modulator can be tilted slightly so that the location of one of the dark lines corresponds to the mark on the card denoting the position of the beam without the tape (or alternative diffuser).

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).

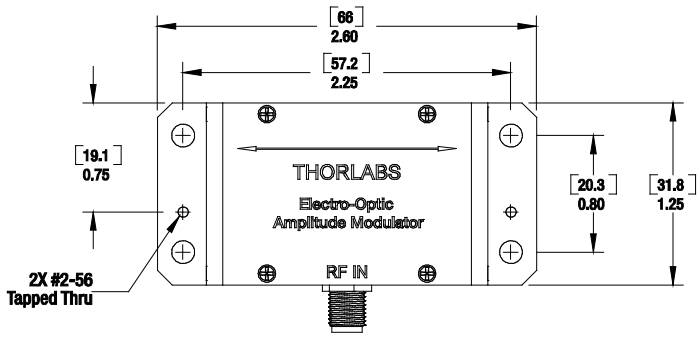
WARNING

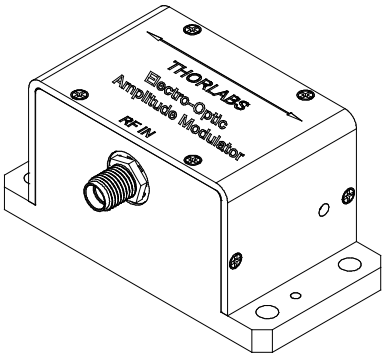
Damage may result from excessive cleaning air pressure of if condensation is allowed to build up from using a stream of compressed air from an inverted can.

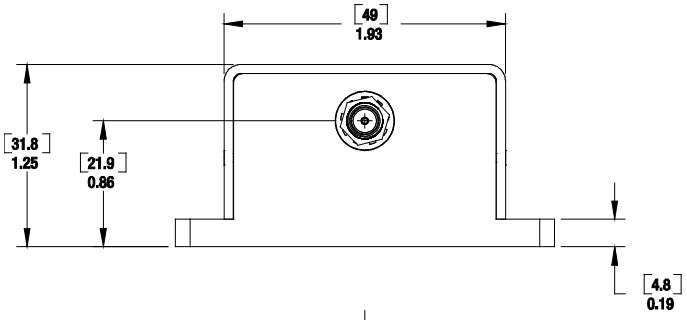
4.2. Cleaning the Compensator Housing

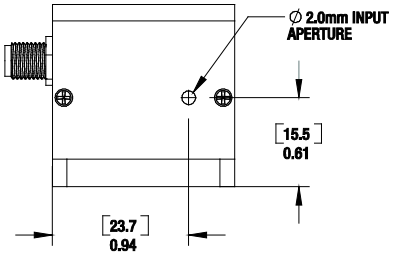
The housing can be wiped clean with a lint free rag wetted with propanol or a commercial window cleaner. Do not soak the housing – it is not watertight and any moisture introduced inside the modulator may cause condensation problems.

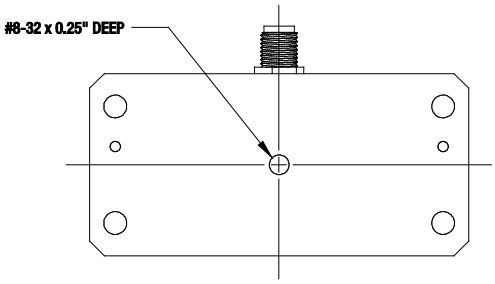
Chapter 5 Mechanical Drawings











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.

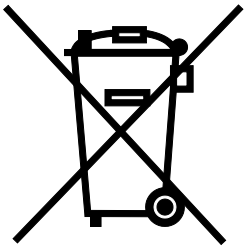
6.6. Warranty Exclusions

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; (e) 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.

Chapter 8 Thorlabs Worldwide Contacts

For technical support or sales inquiries, please visit us at www.thorlabs.com/contact for our most up-to-date contact information.

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