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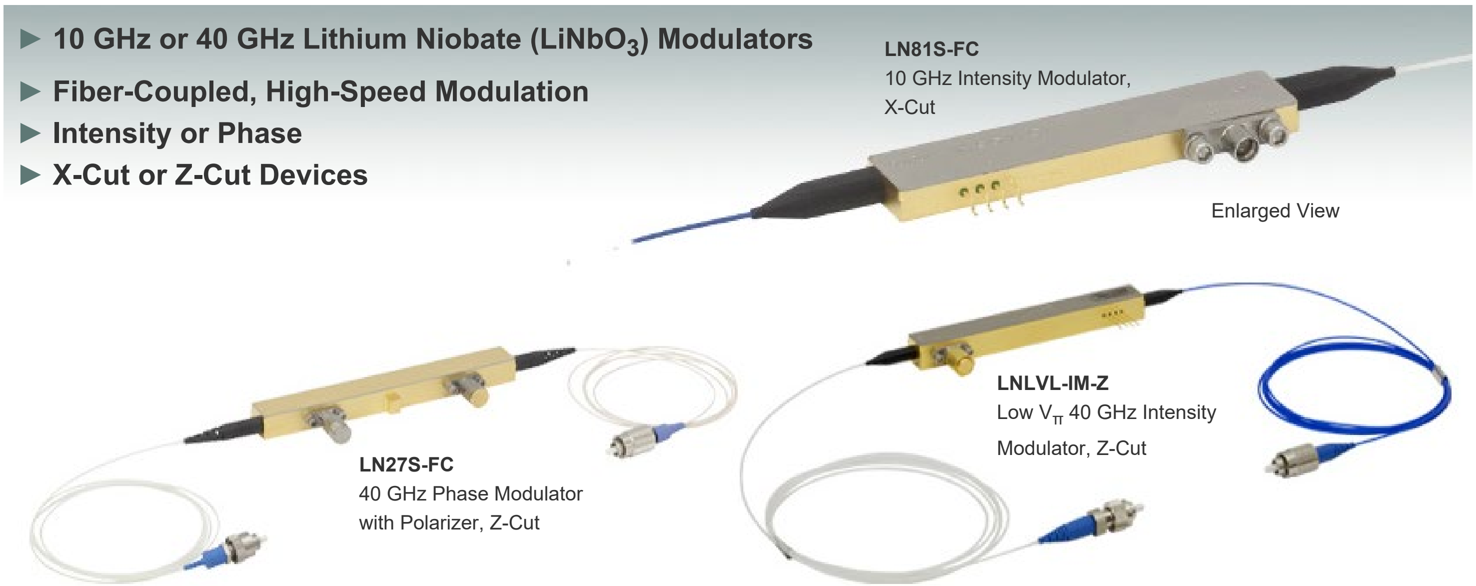
THORLABS

LN05S-FC - August 17, 2022

Item # LN05S-FC was discontinued on August 17, 2022. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

LITHIUM NIOBATE ELECTRO-OPTIC MODULATORS, FIBER-COUPLED (1260 NM - 1625 NM)

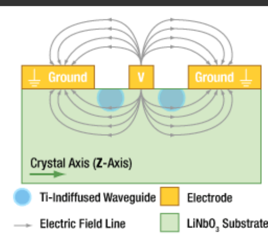


Hide Overview

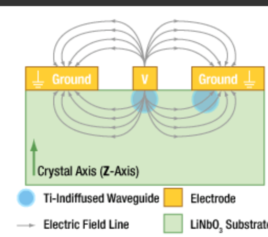
OVERVIEW

Features

- Titanium-Indiffused Waveguides
- Low Optical Loss
- Long-Term Bias Stability
- Hermetically Sealed Packaging
- Field-Replaceable RF Input Connectors
- FC/PC Fiber Connectors



Click to Enlarge
X-Cut $LiNbO_3$ Intensity Modulator Cross-Section



Click to Enlarge
Z-Cut $LiNbO_3$ Intensity Modulator Cross-Section

Thorlabs Quantum Electronics manufactures a variety of lithium niobate ($LiNbO_3$) optical phase and intensity modulators. These high-performance devices are based on titanium-indiffused waveguide technology, offer large bandwidths, and are ideal for developing high-speed modulation systems.

The modulators are fabricated from either X-cut or Z-cut $LiNbO_3$ (see the example diagrams to the right). X-cut intensity modulators employ a symmetrical design that provides low frequency-chirp in the modulated signal, while Z-cut intensity modulators provide more efficient modulation (i.e., lower V_π or half-wave voltage) at the expense of higher frequency-chirp. Phase modulators are only offered as Z-cut devices because their single optical path does not benefit from the symmetry of the X-cut design.

The Z-cut devices are also capable of supporting both the ordinary and extraordinary optical modes, which have different modulation efficiencies. An integrated optical polarizer, positioned before the output port of the device, is included in Z-cut devices as only one mode is desirable for most applications. For applications where the polarizer is not desired, there is an option to have it removed. Please contact Tech Support with inquiries.

The modulators come with a polarization-maintaining (PM) input fiber pigtail and a single-mode (SM) output fiber pigtail that are terminated with FC/PC connectors. The PM fiber is keyed to the slow axis, which is also aligned to the extraordinary mode of the modulator. Please note that options for PM output fiber pigtails and FC/APC connectors are available for all $LiNbO_3$ modulators. For more information on custom configurations (e.g., fiber type, connectors) and quotes, please contact Tech Support.

All Thorlabs fiber-coupled lithium niobate modulators are compatible with our EO modulator drivers. Our fiber-coupled tunable lasers provide an ideal C-band or L-band source for use with these modulators. For all-in-one solutions in high-speed fiber optic test and measurement, we offer reference transmitters, optical transmitter with phase modulators, and calibrated electrical-to-optical converters.

Hide Specs

SPECS

Maximum Ratings for $LiNbO_3$ Modulators	
Input Optical Power	100 mW
Input RF Power	24 dBm
Operating Temperature Range	0 °C - 70 °C
Storage Temperature Range	-40 °C - 85 °C

Intensity Modulator Specifications

Item #	LN81S-FC	LN82S-FC	LNA6213	LN05S-FC	LNA6112	LNLVL-IM-Z
Optical						
Operating Wavelength[a]	1525 nm - 1605 nm	1525 nm - 1605 nm	1260 nm - 1625 nm	1525 nm - 1605 nm	1525 nm - 1605 nm	1525 nm - 1605 nm
Optical Insertion Loss	≤5.0 dB (4.0 dB Typ.)	≤5.0 dB (4.0 dB Typ.)	≤6.5 dB (5.0 dB Typ.) @ 1310 nm ≤5.5 dB (4.5 dB Typ.) @ 1550 nm	≤5.5 dB (4.5 dB Typ.)	≤5.0 dB (4.0 dB Typ.)	≤5.5 dB (4.5 dB Typ.)
Optical Return Loss	≥40 dB	≥40 dB	≥40 dB	≥40 dB	≥40 dB	≥40 dB
Optical Extinction Ratio (@ DC)	≥20 dB	≥20 dB	≥20 dB	≥20 dB	≥20 dB	≥20 dB
Optical Input Power	≤100 mW	≤100 mW	≤100 mW	≤100 mW	≤100 mW	≤100 mW
Electrical						
E/O Bandwidth (-3 dB)	≥10 GHz (14 GHz Typ.)	≥10 GHz (14 GHz Typ.)	≥30 GHz (35 GHz Typ.)	≥30 GHz (35 GHz Typ.)	≥30 GHz (35 GHz Typ.)	10 GHz (Typ.)
Operating Frequency Range	DC to 15 GHz (Min)	DC to 15 GHz (Min)	DC to 40 GHz (Min)	DC to 40 GHz (Min)	DC to 40 GHz (Min)	DC to 40 GHz (Min)
RF V_π (@ 1 GHz)	≤6.5 V (5.6 V Typ.)	≤6.5 V (5.2 V Typ.)	≤6.0 V (5.5 V Typ.)	≤6.0 V (5.5 V Typ.)	≤6.0 V (5.5 V Typ.)	2.2 V (Typ.)
RF V_π (@ 20 GHz)	-	-	-	-	-	≤3.9 V (3.5 V Typ.)
RF V_π (@ 40 GHz)	-	-	-	-	-	≤6.0 V (5.0 V Typ.)
DC Bias V_π (@ 1 kHz)	≤10.0 V (6.5 V Typ.)	≤3.0 V (2.7 V Typ.)[b]	≤5.0 V (3.5 V Typ.)	≤5.0 V (3.5 V Typ.)	≤11.0 V (8.5 V Typ.)	≤11.0 V (9.0 V Typ.)
S11	-12 dB (-10 dB Max), DC to 10 GHz		-12 dB (-10 dB Max), DC to 30 GHz -10 dB (-8 dB Max), 30 to 40 GHz			-12 dB (-10 dB Max), DC to 25 GHz -8 dB (-6 dB Max), 25 to 40 GHz
RF Input Power	24 dBm Maximum					
Photodetector						
Reverse Bias Voltage	-5.5 V to -3.0 V		N/A			
Responsivity	0.1 mA/mW to 0.5 mA/mW		N/A			
Output Optical Power Monitoring Range	-5 dBm to 10 dBm		N/A			

Mechanical						
Crystal Orientation	X-Cut	Z-Cut	Z-Cut	Z-Cut	Z-Cut	Z-Cut
RF Connection	Male SMP (GPO®† Compatible), Full Detent		Female 1.85 mm (V)	Female 1.85 mm (V)	Female 1.85 mm (V)	Female 2.92 mm (K)
Fiber Type	Input: PANDA Polarization Maintaining Output: SMF-28®‡ Single Mode					
Fiber Lead Length	1.5 m Typ.					
Environmental						
Operating Case Temperature	0 °C - 70 °C					
Storage Temperature	-40 °C - 85 °C					

a. These modulators are designed for use at the specified wavelengths. Using the modulator at other wavelengths may cause an increase in the optical loss that is not covered under warranty. In some cases, this loss can be temporary; for instance, the increase in loss caused by shorter wavelengths can usually be reversed by heating the modulator to 80 °C for an hour.
b. The LN82S-FC includes a bias circuit that couples the DC bias onto the RF drive electrode. Depending on the application, an external DC block may be needed at the RF input.

Phase Modulator Specifications

Item #	LN53S-FC	LN65S-FC	LN27S-FC	LN66S-FC
Optical				
Operating Wavelength[a]	1525 nm - 1605 nm			
Optical Insertion Loss	≤4.5 dB (3.0 dB Typ.)		≤4.5 dB (4.0 dB Typ.)	
Optical Return Loss	≥40 dB			
Optical Input Power	≤100 mW			
Electrical				
S11	-12 dB Typ. (-10 dB Max), DC to 10 GHz		-12 dB (-10 dB Max), DC to 30 GHz -10 dB (-8 dB Max), 30 to 40 GHz	
E/O Bandwidth (-3 dB)	10 GHz Typ.		35 GHz Typ.	
Operating Frequency Range	DC to 15 GHz (Typ.)		DC to 40 GHz (Typ.)	
RF V_π	≤8.0 V (7.0 V Typ.) @ 10 GHz		≤9.5 V (7.5 V Typ.) @ 30 GHz	
RF Input Power	24 dBm Maximum			
Mechanical				
Crystal Orientation	Z-Cut			
RF Connection	Male SMP (GPO® Compatible), Full Detent		Female 1.85 mm (V)	
Fiber Type	Input: PANDA Polarization Maintaining Output: SMF-28® Single Mode			
Fiber Lead Length	1.5 m Typ.			
Environmental				
Operating Case Temperature	0 °C - 70 °C			
Storage Temperature	-40 °C - 85 °C			

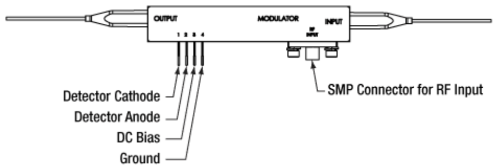
a. These modulators are designed for use at the specified wavelengths. Using the modulator at other wavelengths may cause an increase in the optical loss that is not covered under warranty. In some cases, this loss can be temporary; for instance, the increase in loss caused by shorter wavelengths can usually be reversed by heating the modulator to 80 °C for an hour.

† GPO is a registered trademark of Corning Optical Communications RF.
‡ SMF-28 is a registered trademark of Corning.

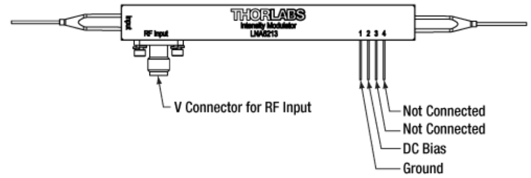
Hide Pin Diagrams

PIN DIAGRAMS

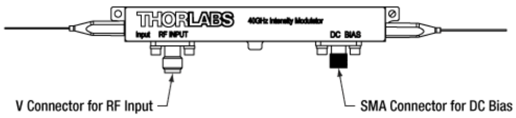
Intensity Modulator Pin Diagrams



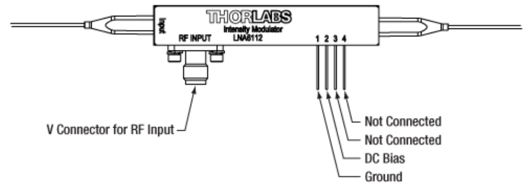
Click to Enlarge
10 GHz Intensity Modulator Pin Diagram



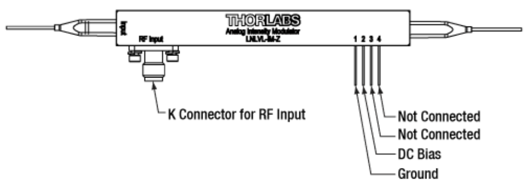
Click to Enlarge
LNA6213 40 GHz Intensity Modulator Pin Diagram



Click to Enlarge
LN05S-FC 40 GHz Intensity Modulator Pin Diagram



Click to Enlarge
LNA6112 Small Form Factor Housing 40 GHz Intensity Modulator Pin Diagram



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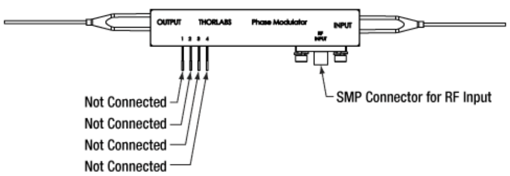
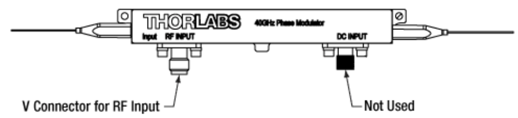
LNLVL-IM-Z Low V_π 40 GHz Intensity Modulator Pin Diagram

Phase Modulator Pin Diagrams



Click to Enlarge
10 GHz Phase Modulator Pin Diagram



Click to Enlarge
40 GHz Phase Modulator Pin Diagram

Hide Lab Facts

LAB FACTS

Driving an Electro-Optic Phase Modulator with the Amplified Output of a Function Generator

Lab Facts

Click for Full Lab Facts Summary

Thorlabs offers a selection of fiber-coupled electro-optic (EO) modulators, which are ideal for modulating light from fiber-coupled laser sources. Applications frequently require EO modulators to be driven at rates of 1 GHz or higher, which places significant demands on the driving radio frequency (RF) voltage source. We investigated whether it would be possible to use a basic setup built around a function generator to drive a fiber-coupled EO phase modulator. The experimental setup we designed and implemented to test this possibility included instrumentation to record the spectrum of the modulated optical signal. By analyzing the modulated optical spectrum, we confirmed this basic RF source is a viable option for driving a fiber-coupled EO phase modulator. Our approach and results are documented in this Lab Fact.

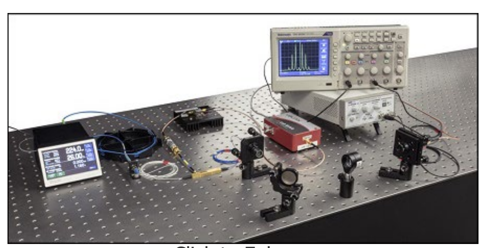


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Figure 1: Experimental Setup Used to Evaluate Whether a Basic RF Source Built Around a Function Generator Could be Sufficient to Drive a Fiber-Coupled EO Phase Modulator

Experimental Design and Setup

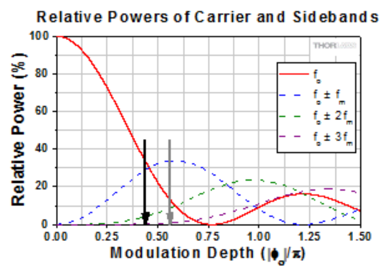
The design of the RF voltage source portion of the setup required first determining the power the RF source should supply to drive the fiber-coupled EO phase modulator. The power requirements were calculated after we made an estimate of the driving voltage needed to achieve the modulation depth desired for this application. Details describing our process for selecting a modulation depth, the relationship between modulation depth and driving voltage, and the calculations we used to estimate the power required from the RF voltage source are included in the Lab Facts document. From our investigations, we determined the power from the function generator alone would not be sufficient for our application. Our solution was to insert a low noise amplifier between the function generator and EO modulator. We also included an electrical low pass filter before the modulator to remove signal distortion that appeared to originate with the function generator. We drove the EO phase modulator with a sinusoidal RF voltage, which imparted a sinusoidal phase modulation on the 1550 nm CW laser signal.

A scanning Fabry-Perot interferometer, whose output was sent to an oscilloscope, was placed after the EO phase modulator and used to measure and monitor the spectrum of the modulated optical signal. It was necessary to use the Fabry-Perot interferometer for this purpose as it has the ability to resolve the very fine spectral features of the phase-modulated optical spectra: at a wavelength of 1550 nm, a frequency difference of 1 GHz is equivalent to a wavelength difference of 0.8 pm. The measured spectra were recorded as functions of scan time. In the Lab Facts document, we describe a straight-forward method to convert from units of Fabry-Perot scan time to units of relative optical frequency. For this work, we estimate $\Delta f = (1.17\ \text{GHz/ms})\Delta t$.

Experimental Results

As is described in the Lab Facts document, theory predicts the spectra of our phase modulated optical signals would include sets of symmetric sidebands arranged around the laser carrier peak at frequency f_o. The sidebands are displaced from the laser carrier peak frequency at integer multiples of the modulation frequency f_m ($f_o \pm Nf_m$ with N = 1, 2, ...). The relative heights of the sidebands are a function of the modulation depth, which is in turn a function of the peak-to-peak value of the RF driving voltage. Given the modulation depth, the relative amplitudes of the laser carrier peak and modulation sidebands can be calculated. This makes it possible to tailor the power distribution across the various peaks to meet an application's needs. We used the predictive power of this model to confirm our RF source was adequately driving the EO modulator.

The spectra shown in Figures 2 and 4 are representative of the modulation spectra we measured. The theoretical curves in Figure 3 are a function of modulation depth and plot the expected relative powers of the laser carrier peak (solid red curve), first order sidebands (dotted blue curve), second order sidebands (dotted green curve), and third order sidebands (dotted violet curve). The black arrow points to the modulation depth corresponding to the spectrum in Figure 2, and the gray arrow points to the modulation depth corresponding to the spectrum in Figure 4. From our results, we determined our measured and applied modulation frequencies agreed, and we confirmed the spectral power distributions in our optical spectra were consistent with the peak-to-peak driving voltage of the RF source. We conclude that the good agreement between the expected and recorded results validates the use of a basic RF source built around a function generator as a driver for fiber-coupled EO phase modulators.



Click to Enlarge
Figure 3: Curves Relating the Power in the Carrier and Several Sideband Peaks as A Function of Modulatrion Depth
The 0.44 modulation depth indicated by the black arrow corresponds to Figure 2, and the 0.56 modulation depth indicated by the gray arrow corresponds to Figure 4.

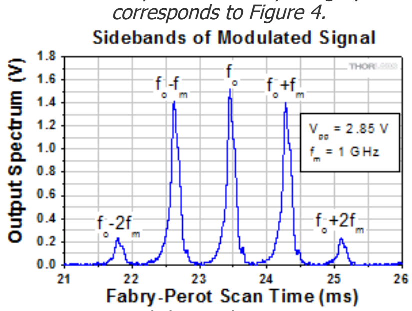


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Figure 2: EO Phase Modulator Spectrum When V_{pp} = 2.85 V
The carrier frequency is f_o; the modulation frequency is f_m = 1 GHz. The X-axis reports the scanning time of the Fabry-Perot interferometer and can be directly related to the signal's relative frequency spectrum.

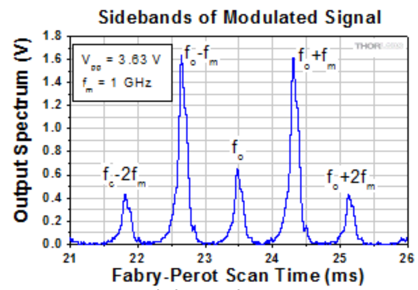

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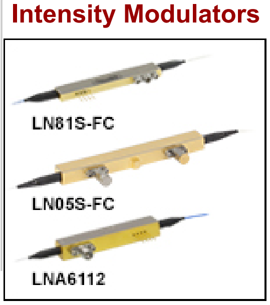
Figure 4: EO Phase Modulator Spectrum When V_{pp} = 3.63 V
The carrier frequency is f_o; the modulation frequency is f_m = 1 GHz. The X-axis reports the scanning time of the Fabry-Perot interferometer and can be directly related to the signal's relative frequency spectrum.

Hide Intensity Modulators

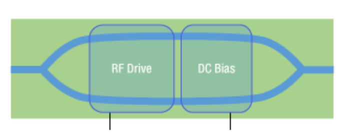
Intensity Modulators



Applications

- RF-Over-Fiber (RFOF) and Microwave Photonics
- High-Speed Telecommunications
- WDM Transmission

$LiNbO_3$ optical intensity modulators use a Mach-Zehnder interferometer structure to allow modulation of the optical output power of the device, as shown by the operational diagram to the right. The devices include two



Click to Enlarge
This operational diagram of an intensity modulator shows the waveguide (blue lines) splitting into two

electrical ports: one for the modulation driving signal and one for biasing the modulator. X-cut or Z-cut devices are available.

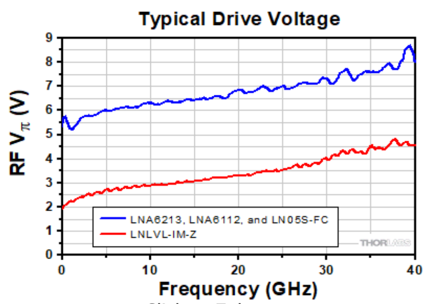
paths embedded in the surface of the lithium niobate (green). The input light is first affected by the modulating RF drive voltage and then the DC bias voltage, as shown by the translucent regions.

X-cut devices allow for both arms of the Mach-Zehnder interferometer to be symmetrically modulated. This symmetry ensures that the modulated output is not also shifted in phase/frequency (chirped).

Z-cut devices have an inequality in the push-pull phase shift between the two arms of the Mach-Zehnder interferometer. This results in a phase/frequency shift (chirp) in the output in addition to the intensity modulation. Z-cut devices also have a better overlap of the electrical and optical fields in the Mach-Zehnder structure, resulting in higher drive efficiencies.

The LN81S-FC and LN82S-FC 10 GHz modulators include an integrated photodetector for optical power monitoring and modulator bias control, eliminating the need for an external fiber tap.

Thorlabs offers four high-speed intensity modulators that can operate up to 40 GHz. The LNA6213 modulator is a high bandwidth device designed to provide up to 40 GHz of modulation over the 1260 nm to 1625 nm operating range. The LNA6112 and LN05S-FC modulators provide similar performances as the LNA6213, but in the 1525 nm to 1605 nm wavelength range. The LNA6112 has a small form factor housing that is 105.0 mm wide compared to the 135.0 mm housings of the other high-speed modulators. The LNLVL-IM-Z modulator provides the lowest RF V_{π}, or half-wave voltage, at any specific frequency over the operating frequency range. The graphs below show a typical drive voltage (left) and electro-optic response (right) over the operating frequency range for these two modulators. See the *Specs* tab for complete specifications.



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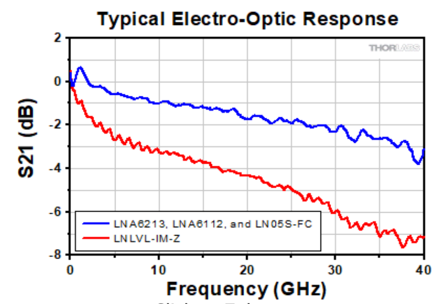

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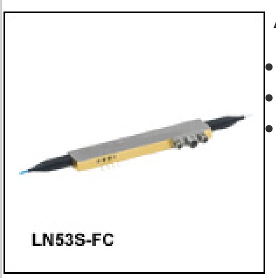
FC will be retired when stock is depleted. The LNA6112 has similar performance over the same wavelength with a smaller housing nt bias control connector. Another suitable alternative is the LNA6213 for some applications, as it offers similar performance over a elength range, with differences in the bias control connector and housing. Click on the red Documents icons ( ) next to the item numbers below for more information.

Limited STOCK

Part Number	Description	Price	Availability
LN81S-FC	10 GHz Intensity Modulator, X-Cut, FC/PC Connectors, 1525 nm - 1605 nm	$2,598.94	7-10 Days
LN82S-FC	10 GHz Intensity Modulator, Z-Cut, FC/PC Connectors, 1525 nm - 1605 nm	$2,598.94	7-10 Days
LN05S-FC	40 GHz Intensity Modulator, Z-Cut, FC/PC Connectors, 1525 nm - 1605 nm	$5,512.57	7-10 Days
LNA6213	40 GHz Intensity Modulator, Z-Cut, FC/PC Connectors, 1260 nm - 1625 nm	$5,512.57	Today
LNA6112	40 GHz Intensity Modulator, Z-Cut, FC/PC Connectors, 1525 nm - 1605 nm, Small Form Factor Housing	$4,635.00	Today
LNLVL-IM-Z	Low V_{π} Intensity Modulator, Z-Cut, FC/PC Connectors, Operational up to 40 GHz, 1525 nm - 1605 nm	$5,512.57	7-10 Days

Hide Phase Modulators

Phase Modulators

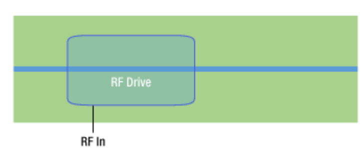


Applications

- Chirp Control for High-Speed Communications
- Coherent Communications
- Optical Sensing

$LiNbO_3$ optical phase modulators consist of a single, through optical waveguide, as shown by the operational diagram to the right. As there is only one optical path to modulate, all of the phase modulators are Z-cut devices in order to optimize drive efficiency.

While most applications benefit from the integrated polarizer in Z-cut modulators, the LN53S-FC and LN66S-FC modulators are offered for applications where the polarizer is undesirable.



Click to Enlarge
This operational diagram of a phase modulator shows the waveguide (blue line) as one through optical path embedded in the surface of the lithium niobate (green). The input light is affected only by the modulating RF drive voltage, as shown by the translucent region.

Part Number	Description	Price	Availability

LN65S-FC	10 GHz Phase Modulator, FC/PC Connectors	$2,381.45	7-10 Days
LN53S-FC	10 GHz Phase Modulator without Polarizer, FC/PC Connectors	$2,381.45	Lead Time
LN27S-FC	40 GHz Phase Modulator, FC/PC Connectors	$4,945.80	Today
LN66S-FC	40 GHz Phase Modulator without Polarizer, FC/PC Connectors	$4,945.80	Lead Time