Introducing the NIR-MPX-LN & NIR-MPZ-LN series

exail

The NIR-MPX-LN and NIR-MPZ-LN series are phase electro-optical modulators featuring a wide bandwidth of up to 40 GHz. These modulators are designed to operate in between the 980 nm to 1150 nm optical wavelength range. Modulator chip is screened for the wavelength operation to warranty mono-mode propagation property over the optical $LiNbO_3$ waveguide.

These modulators have become the reference components for many applications in the laser application field. They integrate all the Exail knowhow coming from more than 40 years of development on NIR optical waveguide manufacturing.

Exail has a unique and extensive know-how in the technique used for producing near infrared modulators - typically for the 780 nm up to 1150 nm wavelength range. We present in this document our technological choices and their consequences on the performance of the phase NIR-MPX and NIR-MPZ modulators.

Spurious effects in $LiNbO_3$ modulators

We know that the performance of modulators using a $LiNbO_3$ substrate is susceptible to external factors such as:

- Temperature via the Strain-induced effect,
- Electric charge accumulation via the Pyro-electric effect,
- Optical input power via the Photo-refractive effect,

What can we do to mitigate these effects?

Crystal cut configuration (Pyro-electric effect mitigation)

When designing a $LiNbO_3$ modulator, two crystal orientations are mainly used:

- The X-cut
- The Z-cut

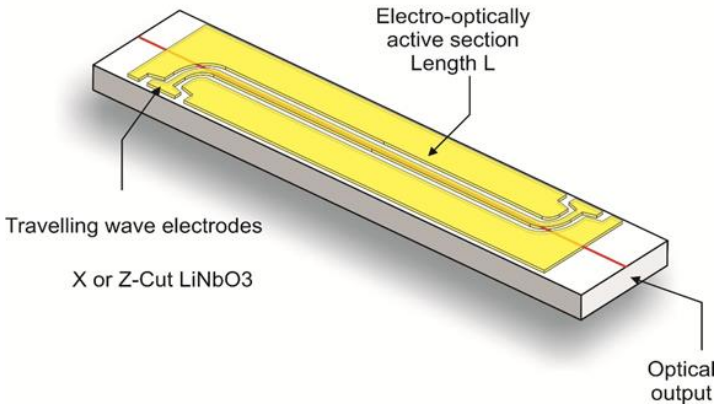


Figure 1: Phase Modulator diagram

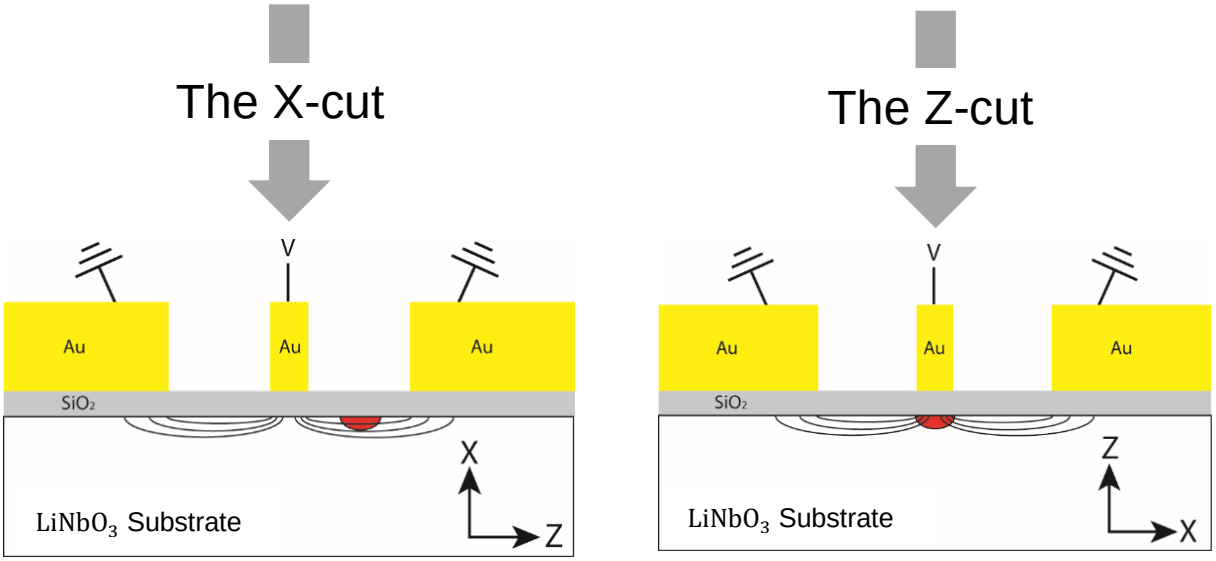


Figure 2: The two mainly used crystal-cut configurations
The red dot corresponds to the optical waveguide's location

The pyro-electric effect is a variation of the spontaneous polarization along the Z-axis. It is due to temperature fluctuations that manifest by the accumulation of surface charges on the Z+ and Z- faces leading to the creation of a parasitic transient depolarizing electric field.

The X-cut modulators are known for their high stability to environmental conditions: the pyro-electric effect is intrinsically low. They feature a low insertion loss and a low V_π when working at low frequencies: typically from DC to few GHz. However these performances are lower than the Z-cut at high frequencies.

The Z-cut modulators are known for their sensitivity to the pyro-electric effect (see figure 3) but they feature the best performances in terms of insertion losses and V_π for high frequencies: typically from few GHz to 40 GHz. This comes from a high electro-optical efficiency coefficient and a better overlap of the optical and electrical fields in comparison with the X-cut.

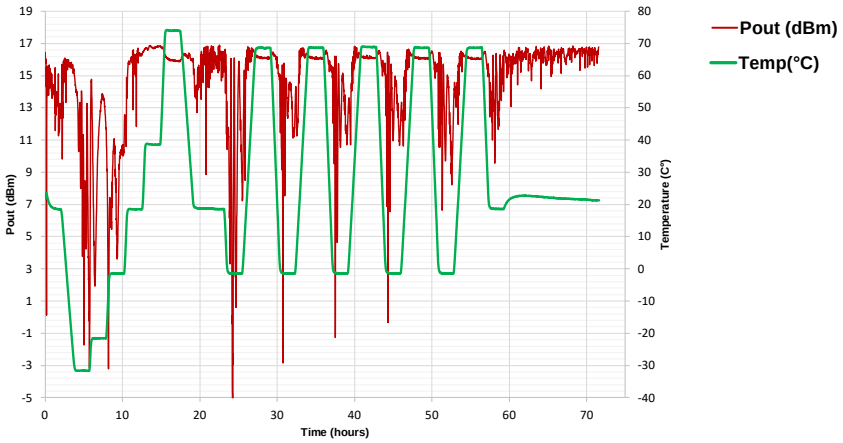


Figure 3 : Output optical power stability for a Z-Cut phase modulator

Exail has developped a special process to mitigate the pyro-electric effect on the Z-cut allowing us to benefit from the high performances of the Z-cut while maintaining a high optical stability (see figure 4).

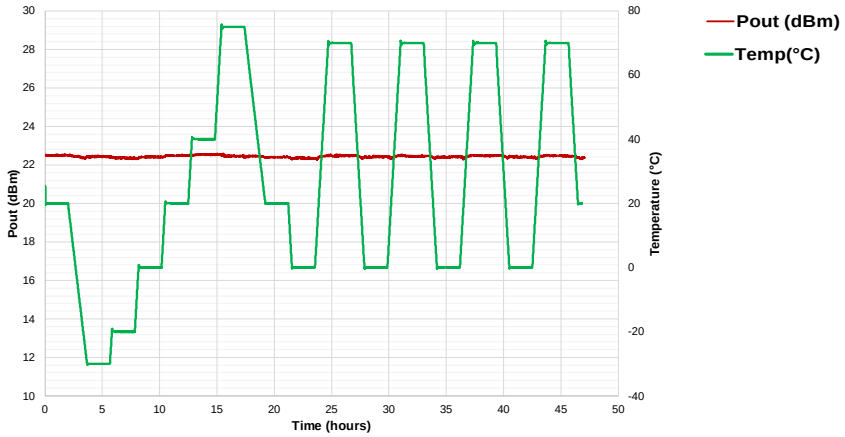


Figure 4 : Output optical power for the NIR-MPZ-LN-20 modulator

Optical waveguide technology (Photo-refractive effect mitigation)

Numerous studies have been conducted about the photo-refractive effect - under high intensity optical power and short wavelength typically in the Near-Infrared a change of the refractive index appears. It has become clear that the optical waveguide manufacturing process in Lithium Niobate substrate is a key factor in effectively mitigating this effect.

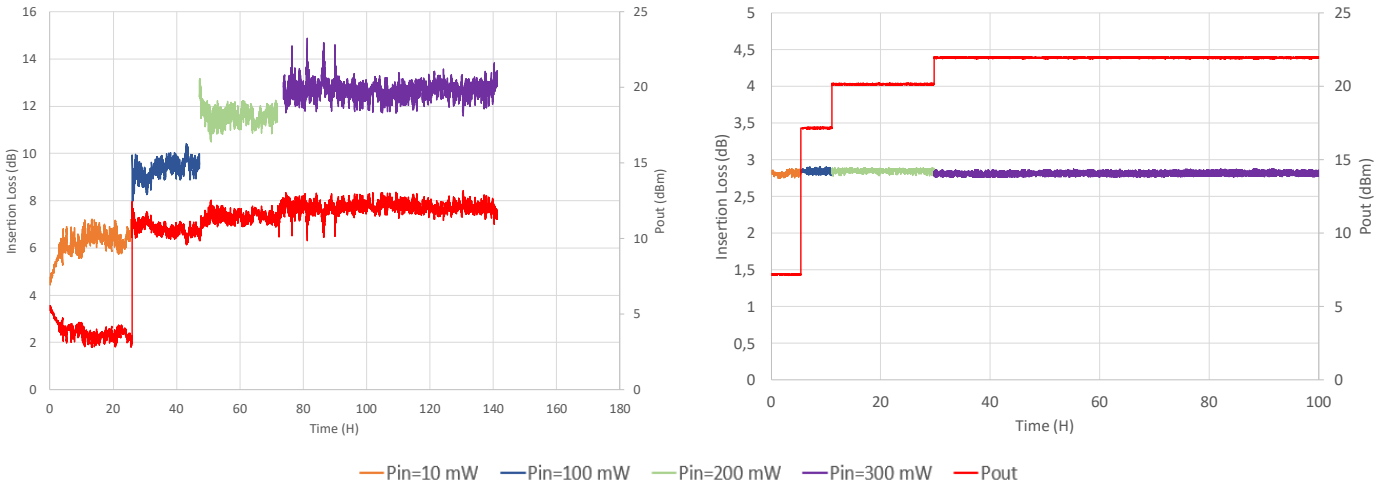
Two technologies are chiefly used today: the diffusion of Titanium ions in the $LiNbO_3$ substrate (Ti-In-Diffusion), and the Annealed Proton Exchange (APE). These two processes aim at locally increasing the refractive index to create the optical waveguide on the $LiNbO_3$ substrate.

Ti-In-Diffusion is the most widely used process, mainly for electro-optic modulators used in the telecommunication industry (optical bands O, C and L). It is a reliable process that is easy to implement and yields modulators with low optical losses.

However, modulators produced with Ti-In-Diffusion waveguides are more susceptible to photo-refractive effect. This becomes even more critical at shorter wavelengths: in the Near Infrared region.

When the photo-refractive effect appears, the refractive index of the optical waveguide varies in time due to high optical power making the performances of the modulator unstable. This translates to high optical losses variations (see figure 5).

To illustrate, two NIR-MPZ-LN-20 produced with both techniques have been tested to characterized their response to the photo-refractive effect when increasing optical input powers.



Titanium waveguide technology

APE waveguide technology

Figure 5: Measurements of insertion loss and the output optical power at 1064 nm for two NIR-MPZ-LN-20 manufactured with to different procceses, TI-In-Diffusion and APE

We can see that the APE waveguide features a high stability of the insertion loss and an output optical power increasing when we increase the input optical power. On the contrary the Ti-In-Diffusion leads to higher insertion loss with no stability with time and a saturation of the output optical power as soon as we have an input higher than a hundred milliwatt.

All Exail modulators operating in the Near Infrared range are manufactured with the APE process. These modulators offer much better stability thanks to a higher photo-refractive effect threshold.

We know that other performances of phase modulators using a $LiNbO_3$ substrate are critical and were optimized such as:

- Electro-optical Bandwidth,
- Polarization Extinction Ratio,
- Reliability over environmental conditions

Electro-optical effect and bandwidth

Exail is one of the top manufacturers for very high bandwidth electro-optic modulators used for telecommunications.

To cover the low frequencies from DC up to few MHz a specific RF electrodes design has been developed with a high input impedance. The benefits of this unique design are introduced in the Application Note “Use of $LiNbO_3$ modulators at low frequencies”.

To cover the high frequencies from few MHz up to 40 GHz the RF electrodes are terminated with a 50 Ω load, which makes it possible to minimize the level of the parasitic electric reflections (S11) and thus improve the efficiency of the electro-optic conversion (see figure 6).

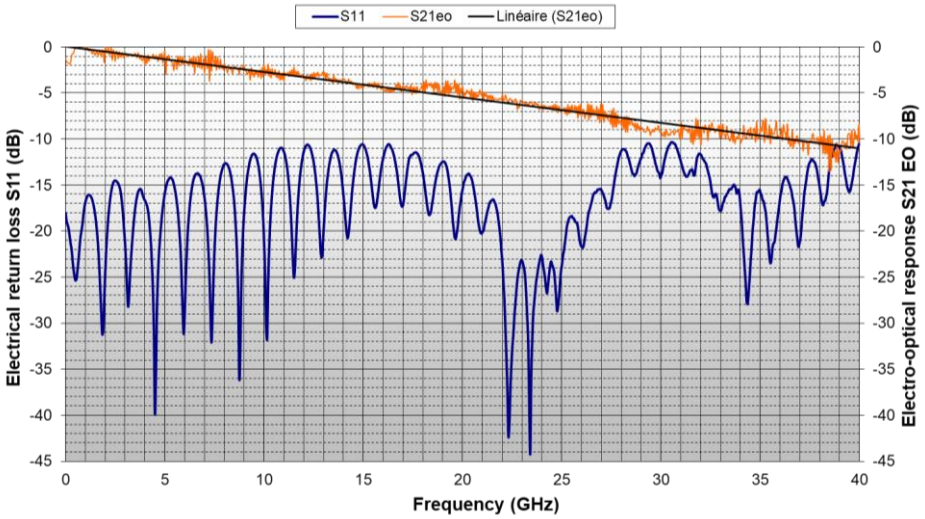


Figure 6: S-Parameters of a NIR-MPZ-LN-20 modulator

Note that even though the -3 dB electro-optical bandwidth is only 12 GHz, we do not have any drop which makes our usable electro-optical bandwidth way larger. Using the figure 7, we can see that the NIR-MPZ-LN-20 has a 20 GHz bandwidth by applying a V_π close to 5,5 V. So customers can work with the overall frequency range.

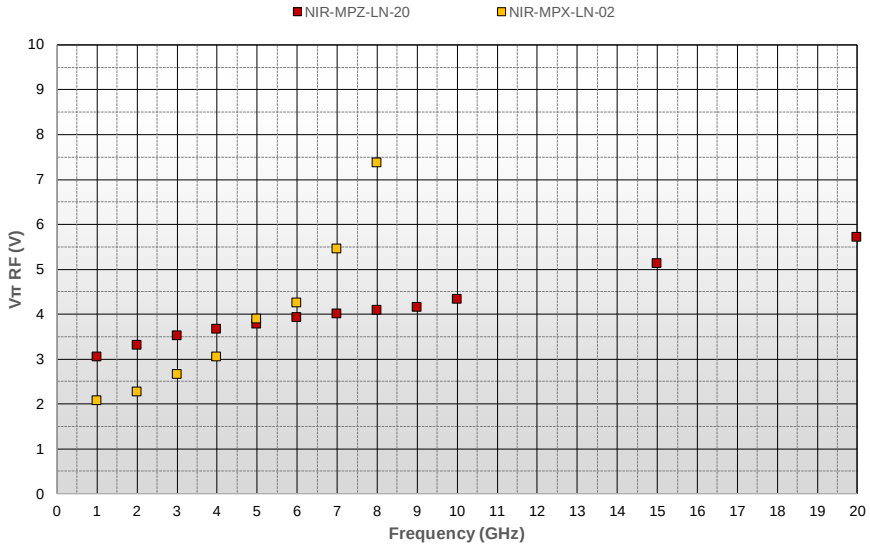


Figure 7: V_π vs frequency measurements of a NIR-MPX-LN-02 and NIR-MPZ-LN-20

High Polarization Extinction Ratio

The APE technology used to manufacture optical waveguides in the near infrared has a double advantage:

- It is effective in preventing the photo-refractive effect in $LiNbO_3$.
- It creates a polarizing waveguide, which further improves the polarization extinction rate (very strongly disturbed by parasitic polarization)

Exail offers polarization extinction ratios, typically 30 dB.

Environmental qualifications

Exail has applied a comprehensive range of tests, such as endurance life, mechanical vibrations and shock tests. As an example, you can see below Accelerated Aging Tests of NIR-MPX-LN and NIR-MPZ-LN modulators. The stability of the output power of Exail modulators is maintained for 250 hours for the NIR-MPZ serie (see on figure 8.a) and more than 5000 hours for the NIR-MPX serie (see on figure 8.b) with very high optical input power – 300 mW – and at high temperature - 85°C.

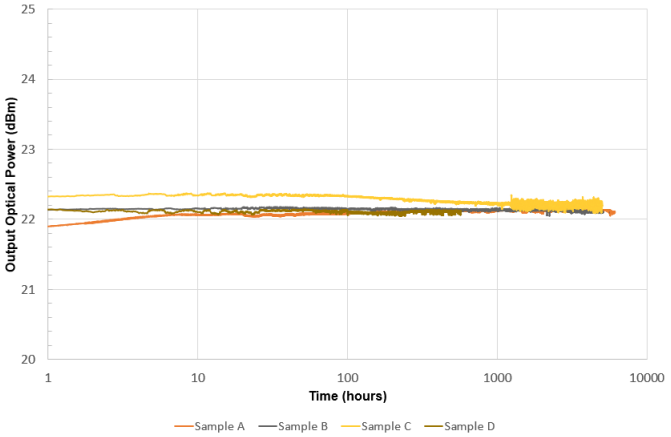


Figure 8.a: Accelerated Aging Tests of the output optical power of NIR-MPX-LN-02 over time for an input of 300 mW and a temperature of 85°C

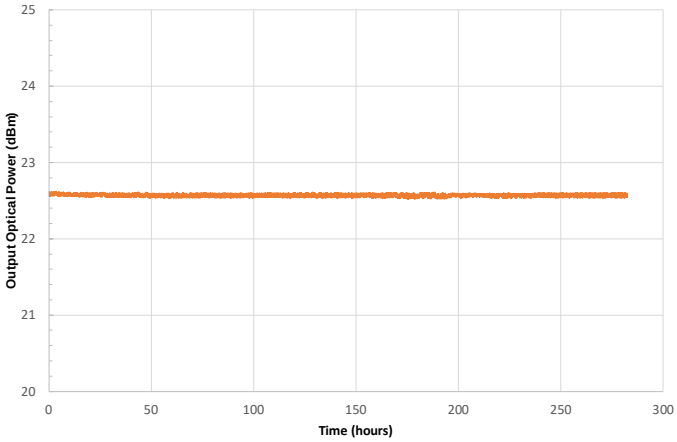
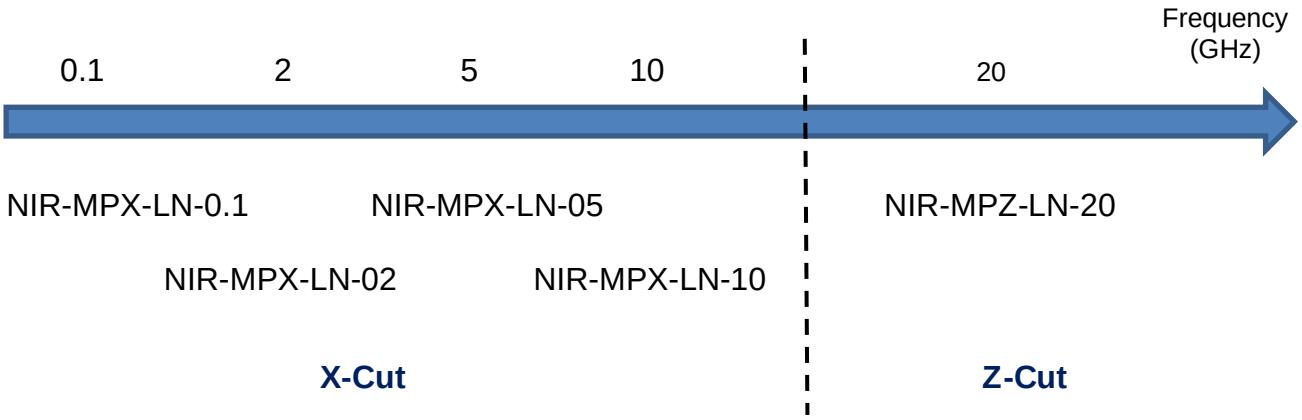


Figure 8.b: Accelerated Aging Tests of the output optical power of NIR-MPZ-LN-20 over time for an input of 300 mW and a temperature of 85°C

Exail also provides Space Qualified near infrared phase modulators versions based on a unique packaging technology and process. Thanks to this spaced graded modulator packaging knowhow and heritage, Exail uses processes (including the machining), and some raw material to manufacture high class standard modulators.

Conclusion

Exail provides a wide variety of phase modulators addressing all the applications from the DC up to 40 GHz at 1064 nm. We have succeeded in addressing the challenges of the stability over environmental conditions while keeping the highest performances (in terms of Insertion Loss and electro-optic efficiency) to give you the state-of-the-art phase modulators. All the performances are listed in the following datasheet. As you can see below each application has its corresponding phase modulator.



Moreover, as Exail masters the entire chain of the modulator manufacturing (Exail plant is based in France), from the modulator chips design to its packaging, selected phase modulators can be provided with Low Insertion Loss (option LIL), with High Polarization Extinction Ratio (option PER), and with low Residual Amplitude Modulation (LRAM). Modulator specifications are given from the on-line website.

Figure 7: Picture of the NIR-MPX-LN-20 modulator