iXblue solutions for high power lasers based on beam combining technique
High input impedance:
  - for efficient RF generator signal transmission transfer to the modulator.
  - To avoid thermal effect and signal degradation due to phase drift.
    ⇒ High impedance modulator and purely capacitive electrodes vanish thermal effect and phase drift. This ensures stable operating performance over a large temperature range.

High packaging quality:
  - Telcordia and space qualifications (TRL9 with NASA)
    ⇒ Packaging and specific mechanical housing for harsh environmental conditions.

Application Note: “iXblue: Use of LiNbO₃ modulators at low frequencies”

Very low $V_\pi$:
  - Modulator $V_\pi$ is proportional to the Electro-Optical bandwidth
  - The (NIR-)MPX-LN-0,1 features a $V_\pi$ of only 1,5 V @ 50 MHz
    ⇒ Low $V_\pi$ at low frequencies minimizes RF power consumption
iXblue solutions for high power lasers based on beam combining technique

NIR-MPX-LN-0.1 a low frequencies phase modulator

- Incomparable optical waveguide and the key optical performances reached:
  - Annealed Proton Exchange process on a selected LiNbO$_3$ doped wafer.
  - Polarizing waveguide: PER > 20 dB, and > 25 dB with option PER.
  - Very low insertion loss: IL < 3 dB. Gaussian distribution with a 2 dB typical mean.
  - High optical power handling capability of up to 300 mW.
  - High resistance to refractive index effect changes and Pyro-electric effect.
    - iXblue offers the best LiNbO$_3$ phase modulator optical performance.
    - High optical performance is stable over the temperature range and over time

Application Note: “iXblue; Introducing the iXblue NIR-MPX-LN-0.1”

- Mitigate the RAM effect:
  - The (NIR-)MPX-LN-0.1 is a DC coupled device: a permanent DC signal can be applied w/o modulator damages
  - Applying a constant DC voltage allows to reduce the RAM from typically 30dB to near 40dB (patented technique)
    - Residual amplitude modulation can be strongly reduced thanks to a permanent DC voltage

Application Note: “Residual Amplitude Modulation of optical phase modulators”
iXblue solutions for high power lasers based on beam combining technique

DR-VE-0.1-MO a RF amplifier to match the (NIR-)MPX-LN-0.1 phase modulator

- Perfect matching between the modulator and the RF generator:
  - High impedance for efficient RF signal amplification from the generator to the modulator,
  - Adapted bandwidth
  - Mechanical matching
  - DC coupled amplifier

⇒ Simple and inexpensive, the DR-VE-0.1-MO is a DC-coupled voltage amplifier that operates over a DC to 200 MHz bandwidth.
⇒ Draws very little current.
iXblue solutions for high power lasers based on beam combining technique

Custom component integration designs based on Customer specification: the ModBox

• Custom Optical Systems & Instruments
  o The ModBox systems are Optical Transmitter solutions based on external LiNbO$_3$ modulation means.
  o iXblue has the inter-disciplinary expertise to integrate simple to complex electro-optical systems and sub-systems.
  o In-depth knowledge in Photonics, RF and hyper-frequency, electronics and interfacing.
  o ModBox addresses the Telecom, Communication and lasers markets, from 780 nm to 2 500 nm.
  o Strong background and High competences in the high energetics and powerful lasers field.
    ⇒ Who knows better than the EOM manufacturer on how to use their own products ?

• Turn-key ModBox is a dedicated product for customers needs
  o From prototype base plates to modules, or racks,
  o to industrial and reproduceable module or rack solutions.
  o Prototype ModBox hardware will be accessible and re-configurable.
  o The ModBox system meets the European standards and are compliant with the EMC and optical norms EN61326-1 Ed. 2006 / NF EN 60825-1 & EN 60825-2 Ed.2014.
The Modbox integration scenarios

- The rack size depends on the number of components to integrate
- One rack can embed several phase modulator channels, each constituted by:
  - a phase modulator (NIR-)MPX-LN-0.1 optimized for 300 mW CW power handling
  - an optional RF amplifier DR-VE-0.1-MO
  - an optional fix delay line
  - an optional tunable delay line for an adjustable delay up to 600 ps
  - an optional power supply (220 V) otherwise 12 V supply in

Example of integration into a rack

- 8x(NIR-)MPX-LN-0.1 + 8xDR-VE-0.1-MO + 8xTunable Delay Line
- 2U rack with a 495 mm depth
- USB connection and GUI for driver and delay line controls
Annex
Induced electro-optical phase variation

- Refractive index variation induced by the electro-optical effect when a DC voltage $V$ is applied:
  \[
  \Delta n(V) = \frac{1}{2} n_e^3 r_{33} \Gamma V \gamma
  \]
- Relative phase variation:
  \[
  \Delta \varphi(V) = \frac{2\pi}{\lambda} \Delta n(V)L = \frac{2\pi}{\lambda} \frac{1}{2} n_e^3 r_{33} \Gamma V \gamma = \pi \frac{V}{V_\pi}
  \]
- Maximum RF phase variation with a sinusoidal peak to peak voltage $V$ at a frequency $f$:
  \[
  \Delta \varphi(V, f) = \pi \frac{V}{V_\pi(f)}
  \]
- Exemple: using the maximal range of +/-20V and a $V_\pi=1.5V$, a phase shift of $27\pi$ rads can be generated.

Equivalent time delay to the phase variation

\[
\Delta t(V) = \frac{\Delta nL}{c} = \frac{\lambda}{2c} \frac{V}{V_\pi}
\]