Principle

The LiNbO$_3$ Optical Polarization Switch PSW-LN-0.1 modulator is based on:

- A modified phase modulator.
- An optical waveguide made by titanium in-diffusion and supporting both TE- and TM-polarization states.
- A waveguide with a low PDL (Polarization dependent loss) = high extinction ratio between crossed polarization interferences.
- An input polarization maintaining (PM) fiber whose slow axis is set at 45° from the slow and fast axis of the LiNbO$_3$ crystal.
- An output PM fiber whose axis is set at 45° from the slow and fast axis of the LiNbO$_3$ crystal.
- A reliability and lumped electrodes for low frequency application (up to 200 MHz).
The PSW-LN Rotators are based on a birefringent LiNbO$_3$ phase modulator whose waveguide is illuminated at 45 ° of its main axis. The input state of polarization (SOP) is thus equally split up in two orthogonal TE and TM polarization states.

When a voltage is applied via the control electrodes, an optical path difference between the TE and TM components is produced, resulting in a new state of polarization (SOP) for the output light.

The PSW-LN acts as a half-wave plate: the linearly polarized light entering the modulator at 45° of the crystal optical axis can be resolved into two waves, parallel (shown as green) and perpendicular (blue).

In LiNbO$_3$ crystal, the parallel wave propagates slightly slower than the perpendicular one, and the speed is adjusted by the voltage applied to the modulator.

At the end side of the crystal, the parallel wave is exactly half of a wavelength delayed relative to the perpendicular wave, and the resulting combination (red) is orthogonally polarized compared to the entrance state.
**Principle:**

Phase shift on extraordinary fast axis

\[ \phi_e = \frac{2\pi}{\lambda} \left[ n_e L + \frac{1}{2} n_e^3 r_{33} \eta \frac{V_0}{g} \right] \]

Phase shift on ordinary slow axis

\[ \phi_o = \frac{2\pi}{\lambda} \left[ n_o L + \frac{1}{2} n_o^3 r_{13} \eta \frac{V_0}{g} \right] \]

Differential phase shift

\[ \Delta \phi = \frac{2\pi}{\lambda} \left[ (n_e - n_o)L + \frac{1}{2} (n_e^3 r_{33} - n_o^3 r_{13}) \eta \frac{V_0}{g} \right] \]

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<table>
<thead>
<tr>
<th>Symbol</th>
<th>Glossary</th>
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<tbody>
<tr>
<td>(n_e)</td>
<td>Extraordinary refractive index</td>
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<tr>
<td>(n_o)</td>
<td>Ordinary refractive index</td>
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<tr>
<td>(r_{13}, r_{33})</td>
<td>(\text{LiNbO}_3) Electro-optic coefficients</td>
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<tr>
<td>(L)</td>
<td>Crystal length</td>
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<tr>
<td>(l)</td>
<td>Electrode length</td>
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<td>(g)</td>
<td>Electrodes gap</td>
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<td>(\lambda)</td>
<td>Optical Wavelength</td>
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<td>Applied Voltage</td>
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<td>(\eta)</td>
<td>Electro-optic overlap</td>
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Configuration: PSW-LN-0.1
Polarization state vs Applied Voltage

\[ \Delta \phi = 2m \pi - \frac{\pi}{2} \]
- Left Circular

\[ \Delta \phi = 2m \pi + \frac{\pi}{2} \]
- Right Circular

\[ \Delta \phi = 2m \pi \]
- Linear

\[ \Delta \phi = (2m + 1) \pi \]
- Linear
Polarization switch on the Poincaré Sphere vs applied voltage

- Switching voltage: voltage needed to switch from a +/- 45° linear polarization state to a -/+ 45° linear polarization state.

\[ V_\pi = \frac{\lambda g}{(n_e r_{33} - n_o r_{13}) \ell \eta} \]
Characterization: PS-LN-0.1

- Exemple of an experimental Poincaré sphere trace of the output SOP for a continuous voltage of 10 $V_{pp}$ applied to the modulator.

- All the output SOP are located on a circle with a trajectory crossing close to the states of right and left circular polarization and two states of linear polarizations indicated by PL.
Characterization: PS-LN-0.1

Differential Half-wave voltage measurement 4.5V @ 1310nm (On request)

Differential Half-wave voltage measurement 6.5V @ 1540nm