Introducing Exail Polarization

SWitch

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Principle

Exail Polarization Switch is based on a birefringent $LiNbO_3$ phase modulator. The principle of the polarization switch is to illuminate the waveguide with a linear polarization aligned at 45 ° of its main axis in order to obtain a switch between polarization states.

The $LiNbO_3$ crystal's birefringence characteristics (extraordinary and ordinary main axis) result in the input State Of Polarization (SOP) being evenly divided into two orthogonal TE- and TM-polarization states. Coupled with the phase modulator configuration, the TE- and TM-polarizations waves propagate at distinct speeds.

When a voltage is applied via the control electrodes, an additional optical path difference between the TE- and TM-components is produced by the electro-optic effect, resulting in a new adjustable SOP for the output light.

Exail Optical Polarization Switch PSW-LN-0.1 modulator is based on a modified phase modulator. The optical waveguide is made by Titanium in-Diffusion to support both TE- and TM-polarization states. The PSW-LN-0.1 features a low Polarization Dependent Loss (PDL) leading to a high PER. The use of lumped electrodes allows low frequency application (up to 200 MHz).

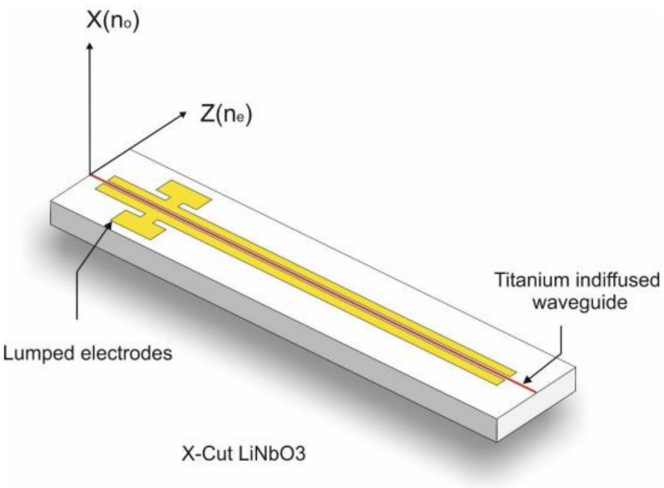

Figure 1 : Schematic of PSW-LN-0.1

To achieve the switch we use an input PM fiber whose slow axis is set at 45 ° from the slow and fast axis of the $LiNbO_3$ crystal and an output PM fiber whose axis is set at 45 ° from the slow and fast axis of the $LiNbO_3$ crystal.

The PSW-LN acts as a half-wave plate, see figure 2. 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 and with a proper voltage applied, 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.

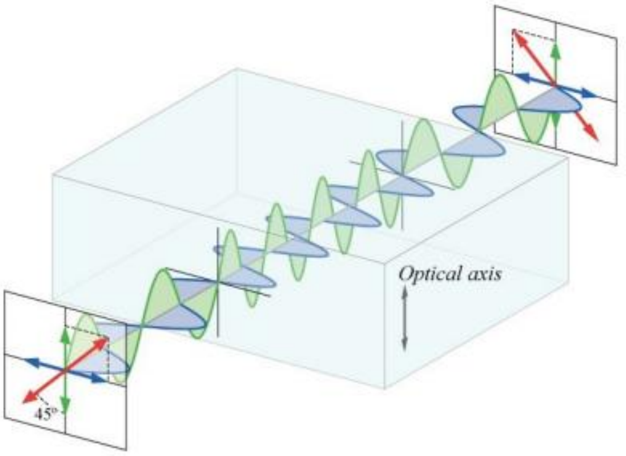

Figure 2 : Polarization Switch principle

Mathematically it can be expressed as follow:

> Phase shift on extraordinary fast axis:

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

> Phase shift on ordinary slow axis:

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

> Differential phase shift:

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

Where:

- n_e : extraordinary refractive index
- r_{13}, r_{33} : $LiNbO_3$ electro-optic coefficients
- L : crystal length
- V_0 : applied voltage
- η : electro-optic overlap
- n_o : ordinary refractive index
- l : electrode length
- g : electrodes gap
- λ : optical wavelength

Polarization State Vs Applied Voltage

The polarization change depends on the voltage applied to the Switch. Below are the results obtained with classical applied voltage values.

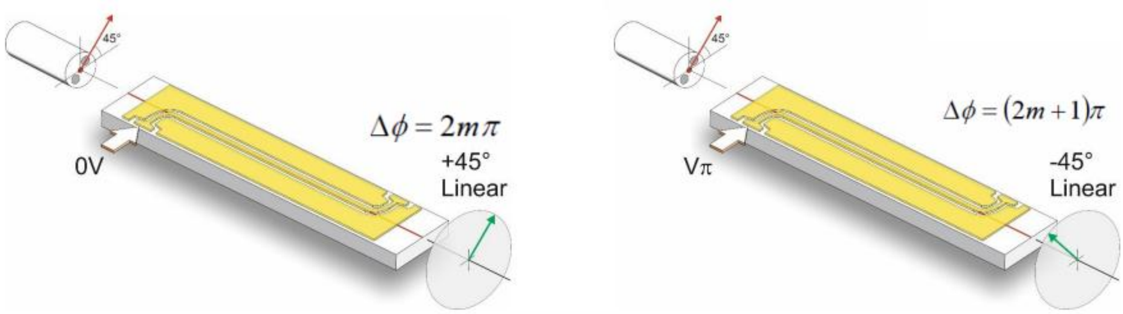

Figure 3 : Use of PSW-LN-0.1

The switching voltage of the PSW-LN-0.1 is the voltage needed to switch from a +/- 45 ° linear polarization state to a -/+ 45 ° linear polarization state with the formula:

$$V_s = \frac{\lambda g}{(n_e^3 r_{33} - n_0^2 r_{13}) l\eta}$$

The input and output power of the PSW-LN-0.1 depending on the voltage applied will have the following shape:

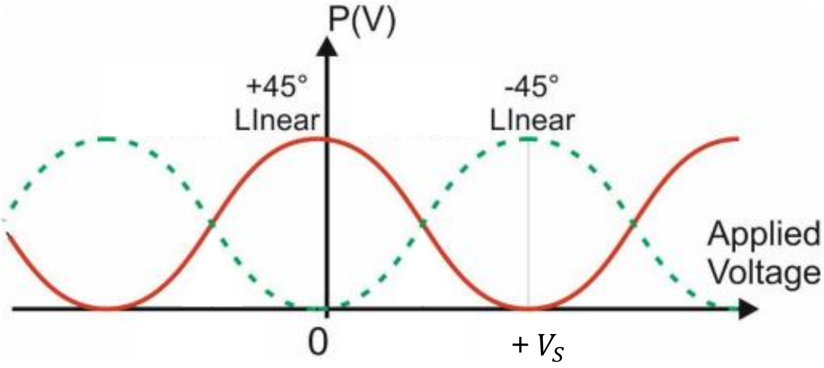

Figure 4 : Input (red) and Output (green) power of the PSW-LN-0.1, depending on the applied voltage

Conclusion

The PSW-LN Polarization Switch serves as a switch between the fast and low polarization axes. Upon applying a modulation signal with carefully chosen peak levels to the modulator, the linearly polarized input light exits either maintaining its original direction or undergoing a 90° rotation.

In the end, the phase modulation signal can be fine-tuned to yield an exceptionally linear State of Polarization (SOP) on either axis of the output fiber. This concealed polarization rotation offers a discreet and effective solution for rapid Polarization Switching addressing applications such as Polarization Shift Keying.

For more information, see the corresponding datasheet.

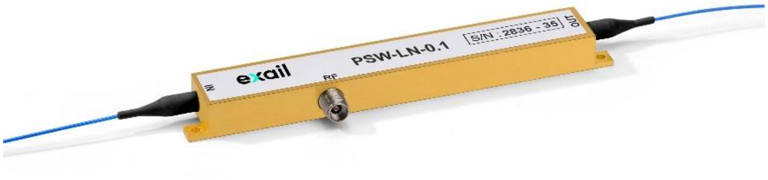

Figure 5: Exail PSW-LN-0.1