PolaRITE™ II/III Polarization Controllers/ Scramblers

Principle of Operation

The PolaRITE™ II/III Polarization Controller consists of multiple fiber squeezers oriented 45° from each other. Models PCS-3X and MPC-3X contain 3 squeezers, while PCS-4X and MPC-4X contain 4. Each fiber squeezer is driven by an applied voltage signal. Squeezing the optical fiber produces a linear birefringence in the fiber, and thus alters the state of polarization of a light signal passing through it. General Photonics uses proprietary technologies to treat the fiber that significantly increase fiber reliability under stress. In our tests, over 10 billion activation cycles at half wave voltages have been achieved without a single failure.

Any arbitrary polarization state of monochromatic light can be represented by a single point on the Poincaré Sphere, as shown in Fig. 1. In principle, increasing the voltage (increasing the squeezing pressure) of one fiber squeezer (X1 or X3) effectively causes the polarization state to rotate clockwise about the OQ axis, while decreasing the voltage causes the point to rotate counter-clockwise. On the other hand, increasing the voltage in a second fiber squeezer (X2) oriented 45° from the first one causes the polarization state to rotate clockwise about an axis (OH) orthogonal to the first one, while decreasing the voltage rotates the polarization counterclockwise. It is conceivable that one may generate any polarization state from any arbitrary input polarization state by using a minimum of two such fiber squeezers, as long as the input principal state is not parallel to an axis of either the first or second fiber squeezer.

Unique Features

Due to its all-fiber nature, the PolaRITE™ II/III has practically no insertion loss, no back reflection, and no polarization dependent loss. In addition, it has a response time of less than 35µs, significantly faster than that of a liquid crystal based device. This high-speed operation is essential for tracking fast polarization variations like those caused by passing locomotives, as in fibers laid along railway tracks, or by ocean waves, as in trans-oceanic fiber trunks.

Perhaps most impressively, General Photonics has succeeded in reducing activation-induced losses in its fiber squeezer controller to less than 0.002 dB. The low activation-induced loss makes these components ideal for applications in high precision PDL measurement instruments, and in feedback loops for compensating for polarization induced penalties. For the standard product, the activation loss is specified to be less than 0.01 dB, which is sufficient for most applications. General Photonics can also provide units with lower activation loss at a premium.

Another unique and attractive feature of General Photonics' device is that its performance is wavelength independent: the device functions equally well for optical signals ranging from 1260 nm to 1650 nm. This one-device-fits-all feature helps to simplify system design, lower implementation cost, and enable system channel expandability.

The implementation of fiber squeezers is also cost effective. Half-wave voltage requirements of the fiber squeezer controllers have been reduced to less than 30 VDC at 1550 nm. The low voltage requirements allow the use of readily available low cost electronics to drive and control the fiber squeezer controller. The half-wave voltage $V_\pi(\lambda)$ at a wavelength λ other than 1550 nm can be easily calculated by:

$$V_\pi(\lambda) = V_\pi(1550nm) \times \lambda / 1550 \qquad (1)$$

where $V_\pi(1550nm)$ is the half-wave voltage at 1550 nm. For example, the half-wave voltage at 1310 nm is 85% of the half-wave voltage at 1550 nm.

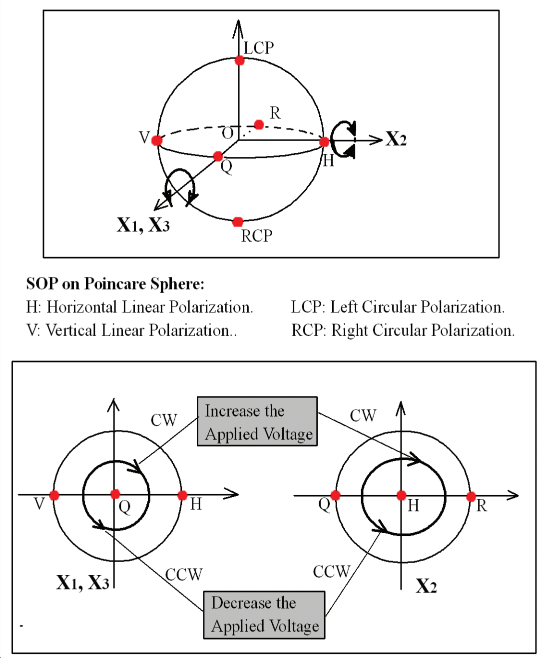


Figure 1: Poincare Sphere SOP representation and SOP tracing on Poincare Sphere using *PolaRITE II Polarization Controller.*

Operation Procedures

The PolaRITE™ II/III has four modes of operation: simple polarization control, reset free polarization control, slow polarization scrambling, and fast polarization scrambling.

There are eight electrical connection pins. The pin assignments are shown in Figure 2(a)-(d). There are slight differences between different device models and applications. Please be advised that only positive voltages (0 ~ 150 volts) should be applied to these pins.

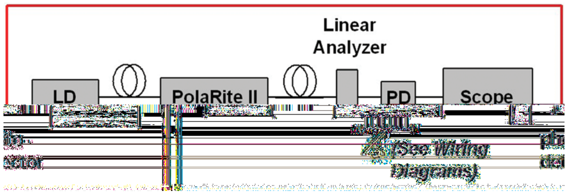


Fig. 2 A simple set-up for monitoring PolaRITE II/III polarization control and scrambling. Wiring diagrams are illustrated in Figures 2(a) to 2(d) for different types of PolaRITE II/III.

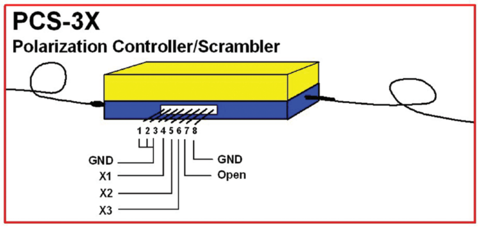


Fig. 2(a) Wiring diagram of PCS-3X and MPC-3X as polarization controller and/or scrambler. Pin 8 and pins 1-3 are connected internally.

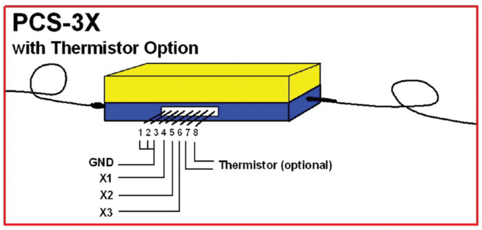


Fig. 2(b) Wiring diagram for PCS-3X and MPC-3X with thermistor option.

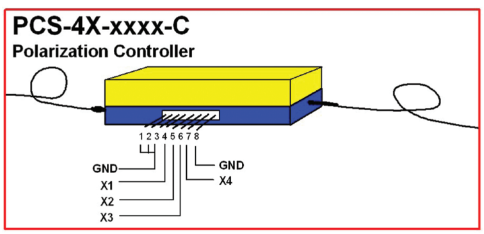


Fig. 2(c) Wiring diagram of PCS-4X-XXXX-C and MPC-4X model for polarization control applications. Pin 8 and pins 1-3 are connected internally.

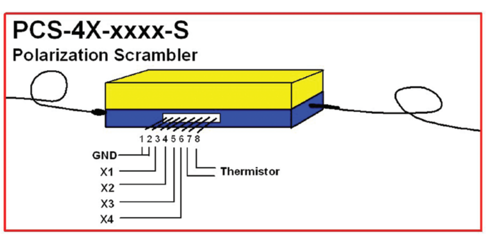


Fig. 2(d) Wiring diagram of PCS-4X-XXXX-S model for polarization scrambling.

A. Instructions for Simple Polarization Control

In this operation mode, three DC voltages are required to activate the actuators. Please be advised that the following procedures are for reference only. Other control procedures can also be implemented.

Step 1: Applied voltages on channels X1, X2 and X3 can range from 0 to 150 volts.

Step 2: To measure the half-wave voltage of channel 1 (i.e. X1 V_π (DC)): one can obtain the DC half-wave voltage by monitoring the optical power at the photodetector in the setup shown in Figure 2. As the applied voltage between pin 4 and GND increases, the output optical power (photodetector photocurrent or voltage) will vary periodically. The voltage change corresponding to one period will be twice the DC half-wave voltage of X1.

Step 3: Half-wave voltages for channels 2 and 3 (X2 and X3) can be determined by following the same procedures described in Step 2, with the voltages applied between (pin 5 & GND → X2) and (pin 6 & GND → X3).

Factory measured DC half-wave voltages for all actuators are provided on the device data sheet for customer reference.

B. Reset Free Polarization Control

Follow the procedures specified in the references below (see footnotes (a)-(c)) for reset free operation. In general, a 4-squeezer (model PCS-4X or MPC-4X) polarization controller is preferred for convenient reset-free operation, although a 3-squeezer (model PCS-3X or MPC-3X) polarization controller can also be used to fix the output polarization against input polarization fluctuations.

C. Slow Polarization Scrambling (0 ~ 20 kHz)

Slow polarization scrambling is preferred for PDL measurement, because most precision power meters have slow response times. PolaRITE II/III half-wave voltages (DC) are typically about 30 volts for each actuator. A voltage of 2X half-wave voltage is required to fully trace one closed circle on the Poincaré Sphere. At slow scrambling frequencies (typically below 20 kHz), the half-wave voltages at different frequencies do not differ significantly from the half-wave voltage at DC. If the driving voltages are sinusoidal, the required peak-to-peak voltages and frequencies should be satisfied by the following conditions (Golden Rules):

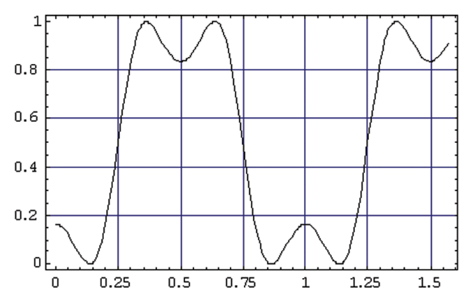


Fig. 3 The optical transmission waveform detected from scope under the condition $V_{pp}= 1.53\ V_\pi$

$$V_{pp1}=1.53\ V_{\pi 1} \quad (2)$$

$$V_{pp2}= 1.53\ V_{\pi 2} \quad (3)$$

$$f_1 \neq nf_2 \text{ and } f_1 \neq 2nf_2/(2m+1) \quad (4)$$

$$n, m = 1, 2, 3,\ldots$$

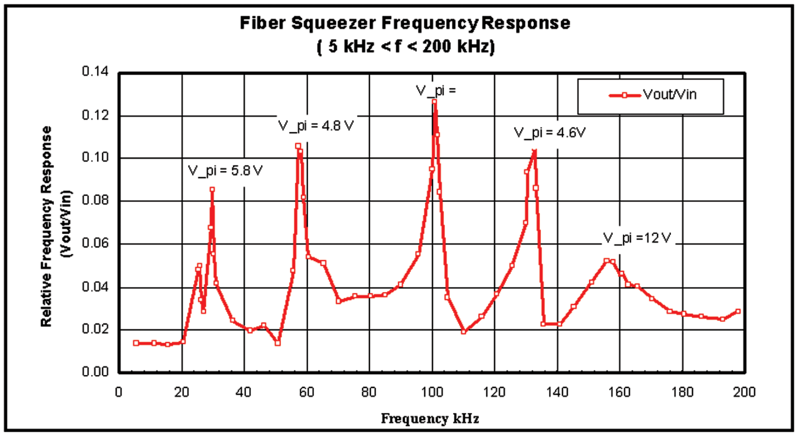
where Vpp1 and Vpp2 are the peak-to-peak amplitudes of the sinusoidal voltage signals applied to X1 and X2, respectively. With the amplitude defined in Eq. 2, the detected waveform from the power meter in Fig. 2 is illustrated in Fig. 3. Please note that the scrambling result will be degraded if Eq. 2 and Eq. 3 are not satisfied.

1 a) N. G. Walker and G. R. Walker, "Endless polarization control using four fiber squeezers," Electron Letters, Vol. 23, No. 6, pp. 290-292 (1987).
b) R. Noe, "Endless polarization control in coherent optical communications," Electron Letters, Vol. 22, No. 15, pp.772-773 (1986).
c) R. Noe, H. Heidrich, and D. Hoffmann, "Endless polarization control for coherent optics," Journal of Lightwave Technology, Vol. 6, No. 7, pp. 1199-1207 (1988).

When the input optical signal polarization is unknown or changes with time, another driving voltage is applied to the third actuator at a different frequency to eliminate the input polarization dependence. The amplitude of the driving voltage should be adjusted to have the same relationship to $V_{\pi 3}$ as in Eq. 2-3. The third stage is important when the input polarization is aligned along the squeezing axis of the first actuator.

D. Fast Polarization Scrambling

Fast polarization scrambling is required to eliminate the polarization dependent gain (PDG) of EDFAs. PolaRITE™ II has several low driving voltage scrambling frequencies (~ 60 kHz, 100 kHz, and 130 kHz - consult the data sheet for the exact peak scrambling frequencies) at which the half wave voltages are reduced significantly to only a few volts (The exact peak scrambling frequencies and the corresponding half-wave voltages are provided in the data sheet of each unit.).



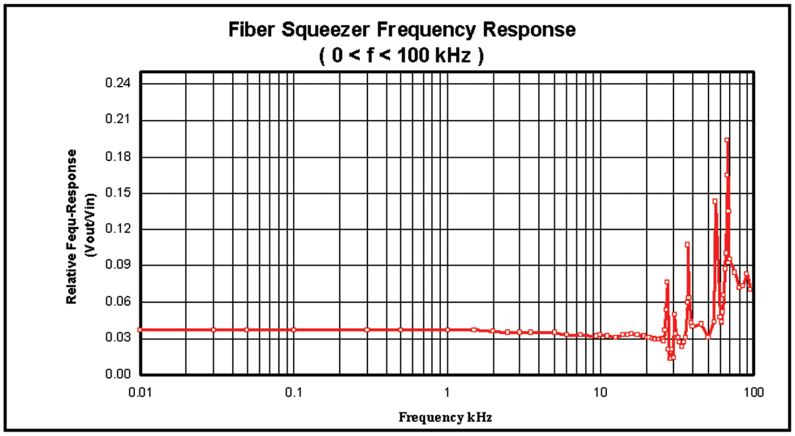


Fig. 4

Fig. 4 shows the small-signal frequency response of a typical fiber squeezer. It is evident that at the peak frequencies, the device is much more efficient than at other frequencies, resulting from their much lower half-wave voltages. Therefore, scrambling at these peak frequencies is most energy efficient and cost effective. Again, at least two sinusoidal signals satisfying Eq. 2-4 should be applied to two adjacent actuators. The driving voltage signals can be generated directly from a function generator. Again, the scrambling result will degrade if Eq. 2-3 are not satisfied. Applying the third driving voltage to the X3 actuator at a different frequency will eliminate the input polarization dependence.