Frequently Asked Questions for PolaRITE™ II/III Polarization Controllers

[1]. Optics

1. Q: What is the operation wavelength range (or bandwidth) of the PolaRITE™ II/III?

A: General Photonics' standard PolaRITE™ II/III devices are designed for wavelengths from 1260nm-1650nm. Typical communication wavelengths are all covered in this wavelength range. The typical device performance data for PolaRITE™ II/III are specified at 1550 nm. Performance data at 1310 nm can be provided upon customer request.

An ultra-broadband version that covers 970-1650 nm is also available. (Note: Data sheets for operation wavelengths other than 1550 nm or 1310 nm may not be available.)

2. Q: Can I operate the PolaRITE™ II/III at 980 nm, 1060 nm, 1310 nm or 530 nm wavelengths?

A: Yes. PolaRITE™ II/III devices can be manufactured with either user-provided fiber or General Photonics' in-house fiber for use at wavelengths other than the conventional 1550 nm, such as 1310 nm, 1060 nm, 980 nm, or 530 nm for single mode propagation. Operation wavelength should be specified when ordering. Please note that General Photonics' standard fibers cover either the 1260-1650nm or 970-1300nm ranges. Polarization controllers made with nonstandard fibers may have different performance characteristics and may carry different warranty terms from standard units.

3. Q: What is the insertion loss of the PolaRITE™ II/III?

A: PolaRITE™ II/III devices are manufactured with continuous optical fiber. The total insertion loss (IL) consists of intrinsic fiber loss along with loss from mechanical effects. Typically IL for PolaRITE™ II/III devices is on the order of ~ 0.05 dB at 1550 nm.

4. Q: What is the activation loss of the PolaRITE™ II/III?

A: Activation loss is defined as the change in device insertion loss due to operation of the device. In the case of PolaRITE™ II/III devices, the activation loss is a function of the external drive voltages, and results from the loss of optical power in the fiber core during the activation of the PZTs. Micro-bending can be the major contributor to this loss. The activation loss data listed on the device data sheet is the device insertion loss change under full DC voltage (i.e. 150 volts) loading. General Photonics PolaRITE™ II and III are designed for extremely low activation loss, typically under 0.01 dB. Devices with activation loss less than 0.005 dB can also be provided by special request.

5. Q: Why is low activation loss preferred in most applications?

A: Some important applications of polarization controller devices include polarization dependent loss (PDL) measurement and polarization scrambling. In a PDL measurement, the activation loss of the polarization controller will add measurement uncertainty to the results. For example, if the activation loss is 0.2 dB, the PDL measurement uncertainty will be at least 0.2 dB higher. For the scrambler application, the activation loss adds an amplitude noise term to the optical light signal. This noise can interfere with optical signals or degrade signal detection in demanding applications. Therefore, low activation loss is preferred for polarization controllers.

6. Q: What is the PDL of the PolaRITE™ II/III?

A: PDL is defined as the difference between maximum and minimum optical power transmission over all input states of polarization (SOP), expressed in dB. Typically, the PDL of the PolaRITE™ II/III is ~ 0.01 dB.

7. Q: What is the PMD of the PolaRITE™ II/III?

A: Our measurements indicate the following PMD results for the PolaRITE™ II: PMD max < 60 fs (PCS-3X); PMD max < 80 fs (PCS-4X). The maximum PMD occurs near the maximum driving voltage (~ 4 to 5 V_π). For polarization scrambler applications, the drive voltage will be about 1.5 times V_π. At this drive voltage, the PMD will be limited to less than 40 fs (PCS-3X) or 50 fs (PCS-4X). PMD for the PolaRITE™ III is about the same as for the PolaRITE™ II. These results are summarized in the following table.

PolaRITE™ II/III	Controller	Scrambler
PCS/MPC-3X	PMD < 60 fs	PMD < 40 fs
PCS/MPC-4X	PMD < 80 fs	PMD < 50 fs

8. Q: What is the operation principle of PolaRITE™ polarization controllers? What are the differences between the PolaRITE™, PolaRITE™ II, and PolaRITE™ III?

A: All PolaRITE™ polarization controllers have the same operation principle. They are all constructed based on fiber squeezing technology, and all are capable of transforming any input SOP to any arbitrary output SOP. The differences between them are mainly in form factor and control methods. PolaRITE™ manual polarization controllers require external rotation (moving) control. They come in a variety of sizes and connector combinations, and are usually used in static or quasi-static polarization control. PolaRITE™ II comes in 3-axis and 4-axis versions, and is actuated electrically with no external moving parts. In practical use, the electronic control interface of the PolaRITE™ II allows its use in automatic and high-speed applications. PolaRITE™ III is very similar to PolaRITE™ II. The main difference is that PolaRITE™ III is specifically designed for system integration, with a small form factor and high temperature stability.

9. Q: What is the Vπ, DC and Vπ, AC of the PolaRITE™ II?

A: Both $V_{\pi,\ DC}$ and $V_{\pi,\ AC}$ are defined as the voltage change required to offset the relative phase of two eigen-polarization states by π. $V_{\pi,\ DC}$ refers to slow, quasi-DC voltage change, while $V_{\pi,\ AC}$ refers to the voltage change at AC frequency f required for a π phase change. A typical $V_{\pi,\ DC}$ value for the PolaRITE™ II is approximately 30V. It remains nearly constant from DC to ~20 KHz. Because $V_{\pi,\ DC}$ and $V_{\pi,\ AC}$ are equal at low frequencies, we usually do not specify them separately, except at resonance frequencies.

10. Q: What is the resonant frequency and resonant Vπ of the PolaRITE™ II?

A: The electric actuator and its mechanical enclosure can enhance actuation of the PolaRITE™ II device at some characteristic frequencies. These characteristic frequencies (typically near 60 kHz, 100 kHz, 130 kHz and 160 kHz) are called resonant or resonance frequencies of the PolaRITE™ II. The profile of the resonance frequencies depends on the actuator and mechanical boundary conditions of the package. At these frequencies, the half wave voltage V_π is significantly reduced from its DC value. A typical V_π at a resonance frequency is ~ 2-10V, which is much smaller than the ~ 30V $V_{\pi,DC.}$

11. Q: What is the major difference between a Polarization Controller and Scrambler?

A: PolaRITE™ II can perform two major functions: static or quasi-static polarization control and polarization scrambling. Different characteristics are important for these two applications. For scramblers, the device is optimized for low activation loss (< 0.01 dB) and low resonant $V_{\pi.}$ For polarization controller applications, speed and bandwidth are optimized.

12. Q: How do PolaRITE™ II/III devices function as polarization controllers?

A: A PolaRITE™ II/III device can be modeled as three (for PCS/MPC-3X) or four (for PCS/MPC-4X) cascaded variable wave plates. The optical axes of the first and the third waveplates are aligned in the same direction, and the second and the fourth waveplates have optical axis orientations offset by 45 degrees with respect to the first and the third waveplates. In theory, a three variable waveplate combination is enough to convert any input SOP to any output SOP, even if the input SOP is an eigenstate of the first waveplate. Therefore, the PolaRITE™ II/III can function as an electrically actuated polarization controller. One can adjust the DC voltages applied to the connection pins of a PolaRITE™ II/III to obtain the desired SOP. On the Poincaré Sphere surface, two waveplates oriented 45 degrees from each other generate orthogonal SOP traces. This orthogonality makes a polarization state control algorithm much easier than approaches using other mechanisms.

13. Q: How should the PolaRITE™ II be driven to function as a polarization scrambler?

A: For minimum degree of polarization (DOP), two conditions are suggested for using PolaRITE™ II in scrambling operations.

(1). Amplitude conditions:

$V_{pp1} = 1.53\ V_{\pi 1}$ and $V_{pp2} = 1.53\ V_{\pi 2}$

(2). Frequency conditions:

$\omega_1 \neq \omega_2$ and $(2m+1)\ \omega_1 \neq 2n\ \omega_2$ (n, m = 1, 2, 3…)

14. Q: What is the major difference between PCS/MPC-3X and PCS/MPC-4X?

A: The major difference between these models is the numbers of actuators: PCS/MPC-3X has three actuators, and PCS/MPC-4X has four actuators. For endless polarization control, people prefer to use PCS/MPC-4X.

15. Q: What is the response time of PolaRITE™ II/III?

A: When driven by a low amplitude square wave, the optical responses for both rise time and fall time (or switch-on time) are approximately 30 µs.

16. Q: How fast can you switch from one SOP to another SOP using PolaRITE™ II/III?

A: The switching speed depends on the number of steps used by the controlling algorithm and the actuators to reach the desired SOP. The fastest switching speed, ~ 30 µs, occurs when only one step is involved. Generally speaking, the SOP switching speed will be proportional to the number of steps, ~ N x 30 µs (N=1,2,3…m). At the end of the operation, there might be a small settling time while the final SOP stabilizes. In other words, the SOP switching speed depends on the algorithm for the operation.

17. Q: Can SOP Stokes values be maintained when the driving voltage is switched from ON to OFF? How repeatable is it?

A: We tested the SOP drift issue using the PCS-3X with driving voltages V1=V2=V3=70V (DC) as a constant loading condition. Based on two uncorrelated measurements, one with driving voltage off; the other with driving voltage on (i.e. V1=V2=V3=70 V), with the fiber taped tightly to an optical table, the drift rate (measured as the difference in the transmission optical power) over 12 hours' monitoring was approximately 0.01 dB/hr. (The difference is for the purpose of background random drift deduction.)

18. Q: Is there any hysteresis in your actuator?

A: Yes. A non-symmetric displacement occurs as a forward and reverse voltage is applied to the actuator. You can observe a hysteresis curve in optical transmission on an oscilloscope when an oscillating voltage is applied to the actuator. This hysteresis becomes more and more pronounced as the amplitude of the sweep voltage increases.

19. Can I eliminate this hysteresis?

A: Yes. You can develop a non-symmetric compensation drive voltage source such that the forward applied voltage is smaller than the reverse voltage, resulting in a reverse voltage trace identical to the forward trace.

20. Q: How can I use PolaRITE™ II as a polarization stabilizer?

A: An SOP stabilization system requires three elements: an SOP generator, an SOP monitor, and a control circuit. The PolaRITE™ II/III functions as the SOP generator in this system. General Photonics' PolaDetect™ polarimeter or similar devices can be used to monitor SOP. Based on the driving conditions and the signal from the SOP monitor, a control circuit can be designed for open loop or closed loop SOP stabilization. General Photonics' polarization stabilizer (POS-20X) incorporates all three elements to form such a system.

21. Q: Can PolaRITE™ II/III generate all SOPs over the entire Poincaré Sphere?

A: Yes, PolaRITE™ II/III devices can generate SOPs over the entire Poincaré Sphere.

22. What happens if the input SOP is an eigenstate of your first actuator?

A: If the input SOP is an eigenstate of the first actuator, that is, linearly polarized light with electric field vector either parallel or perpendicular to the actuation direction, the first actuator will only modulate the phase front of the light beam. It will not change the SOP. Therefore, a control voltage must be applied to the third actuator to fix this singularity problem.

23. Q: How can I remove the gold-colored fiber coating before splicing the fiber?

A: A cigarette lighter can be used to burn off the fiber coating. Flame exposure time should be minimized to avoid fiber damage. The fiber should then be wiped with alcohol to remove the residue.

24. Q: What is the highest optical power that the PolaRITE™ II/III can handle?

A: The optical power handling capability is the same as that of the optical fiber used in PolaRITE™ II/III construction (typically SMF-28). Based on manufacturer data, optical power up to 1,000 mW CW at 1550 nm can be launched into this device. Basically, the optical power output of most fiber-coupled devices should be safe for the PolaRITE™ II/III.

25. Q: (a). Can the PolaRITE™ II/III perform endless polarization control? (b). Is there any information on how to operate the PC in endless mode? (c). What is the response time when my PolaRITE™ II/III device is operating in endless mode?

A:(a). Both the PCS/MPC-3X and PCS/MPC-4X can provide endless polarization control, but the control algorithms for the four axis versions are less complicated than for the three axis versions.

(b). Please refer to the following references regarding endless polarization control:

(1). N. G. Walker and G.R. Walker, "Endless Polarization Control using four fiber squeezers," Electron Letters, vol.23, No. 6, pp.290-292 (1987).

(2). R. Noe, "Endless polarization control in coherent optical communications," Electron Letters, vol. 22, No. 15, pp.772-773 (1986).

(3). 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).

(c). The response time depends on how you write the algorithms.

26. Q: Will your electro-mechanical actuator damage optical fiber?

A: NO. We all know that polarization maintaining fibers are very reliable. In PolaRITE™ II/III, the maximum mechanical stress applied to the optical fiber due to actuation is slightly smaller than or about the same as that in a typical polarization maintaining fiber. In addition, General Photonics Corporation has implemented manufacturing processes and used specially selected materials to safeguard device durability. Therefore, fiber damage is not a concern in PolaRITE™ II/III devices. Under the most extreme activation conditions, the fiber's lifetime (MTTF) is estimated to be over one billion years, based on extensive in-house stress experiments and commonly used fiber stress analysis modeling.

27. Q: What is the lifetime of PolaRITE™ II/III?

A: The lifetime of the device is limited by the lifetime of the piezo-electric actuators used, which is mainly affected by humidity. With hermetical sealing, the lifetime (MTTF) is about 40 years. General Photonics is working on a hermetically sealed version of the PolaRITE III, which is expected to have a lifetime of 40 years.

28. Q: What current is required to drive the PolaRITE™ II/III?

A: The piezo can be considered a pure capacitive load with a capacitance of 0.18μF. Therefore, the total current has the following dependence on drive voltage and frequency:

$$I(t) = C\, dV/dt$$

where C is the capacitance. For a sinusoidal drive signal

$$V = V_0 * \sin(2\pi f t + \varphi),$$

$$dV/dt = 2\pi V_0 f * \cos(2\pi f t + \varphi),$$

The peak current is then $2\pi V_0 f$.

For a linear ramp, $I = C * \Delta V/\Delta t$.

For example, the current required to drive a piezo with a capacitance of 0.18μF from 0 to 20V in 100μs is I = 0.18μF * 20V/100μs = 36 mA.

29. Q: How is the performance of the PolaRITE™ II/III affected by temperature?

A:The recommended operating temperature range of both devices is -25 to 80°C (outer case temperature). The resonance frequencies of the device may change with temperature, which may affect resonant scrambling performance, but non-resonance half-wave voltages should be relatively uniform within the specified temperature range.

[2]. Electronics:

1. Q: What drivers are available for the PolaRITE II/III polarization controllers?

A. The PolaRITE III polarization controller is available either with (PCD-M02) or without (MPC-3X/4X) an integrated driver board.

The PCD-M02 has an on-board DC/DC converter, so it does not require an external high-voltage power supply. It can accept either a 0-5V analog control signal or a digital TTL control signal.

2. Q: What are the frequency limits for the PCD-M02?

A:The operation bandwidth of the PCD-M02 depends on the required output voltage level.

For the PCD-M02 with I_{max} = 60 mA and C = 0.18μF, $V_{pp} \cdot f_{max} \approx 100$ V-kHz. This determines the single-channel maximum output voltage and frequency conditions. For I_{RMS} = 20 mA, $V_{pp} \cdot f_{cont} \approx 50$ V-kHz. This determines the maximum output voltage and frequency conditions when all output channels are used simultaneously with the same driving signal.

If the voltage-frequency product exceeds the guidelines set out here, waveform distortion can result.

For full range (V_{pp}=150V) operation, one can achieve 4~5 π retardation on each actuator section, but the operation frequency is limited to 0~333 Hz for the PCD-M02 (using all channels).

In most cases, however, during continuous operation of the PCD-M02 for polarization scrambler applications, only 1.53π retardation is required for each actuator. The corresponding driving voltage is on the order of Vpp= ~50V. In this situation, the operation frequency range can be extended to 0-1kHz .

The PCD-M02 is not recommended for driving at resonant frequencies. Because most resonant frequencies are distributed between 50 kHz and 200 kHz, and the driving voltage at resonant frequencies is typically <10V, a function generator can be an alternative driver if users desire operation at these resonant peaks.

3. Q: What is the upper limit on input frequency for your PolaRITE™ II/III drivers such that the output waveform remains undistorted?

A: Strictly speaking, the upper limit of the non-deformed frequency depends on the output voltage and PZT impedance loading. Without any loading, the driver output is perfectly linear with the input. With PZT loading, the effective impedance is strongly modulated, resulting in the upper frequency limitation. See the answer to question 2 for more details.

4. Q: What is the power consumption of the PCD-M02?

A: The PCD-M02 in its standard configuration requires a +12V/1.2A power supply and a −12V/0.1A power supply. The maximum peak current per channel is 60 mA when one channel is operated separately, or 20 mA/channel when all 4 channels are operated together.

5. Q: How can I remote control the driver? Do you provide any operation utilities for remote communication and control?

A: The PCD-M02 can be controlled digitally using TTL levels. It requires a R/W bit, chip select, 2 channel-control bits, and 12 signal bits. A DIO card can be used to generate the control signals. Many DIO cards can be remote-controlled via RS-232 or USB.