Technical Brief #6

Polarization Controllers

This note is one of a series of technical briefs developed from customer FAQs and intended to answer the majority of questions concerning the operation of Phoenix products. They are targeted at engineers to assist in incorporating Phoenix products into designs. Any detailed technical questions should be forwarded to Phoenix support.

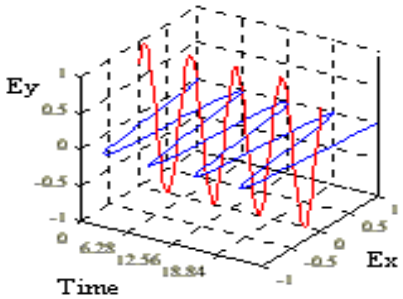
What is a variable waveplate?

The basis of the range of polarization control components is the fiber waveplate. Fabricated from a length of polarization maintaining fiber the input state of polarization is modified depending on the birefringence and length of fiber.

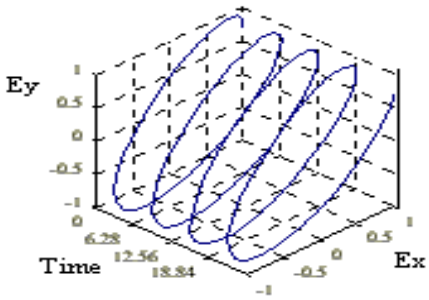
A waveplate creates a differential phase shift between the two orthogonal linear polarization modes. Changing the birefringence of the waveplate enables a variable differential phase shift to be created from 0 to 360^0.

Poincaré sphere representation of polarization

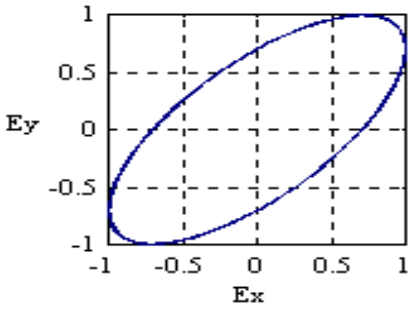
The state of polarization (SOP) of an electromagnetic wave can be described by the amplitude and phase relationship between two orthogonal linear vectors at right angles to the propagation direction (a). The general state of polarization is elliptical (c) which evolves along the propagation axis in a helical (b) fashion, the handedness determined by whether there is a phase lead or lag between the two resolved axes.



(a)

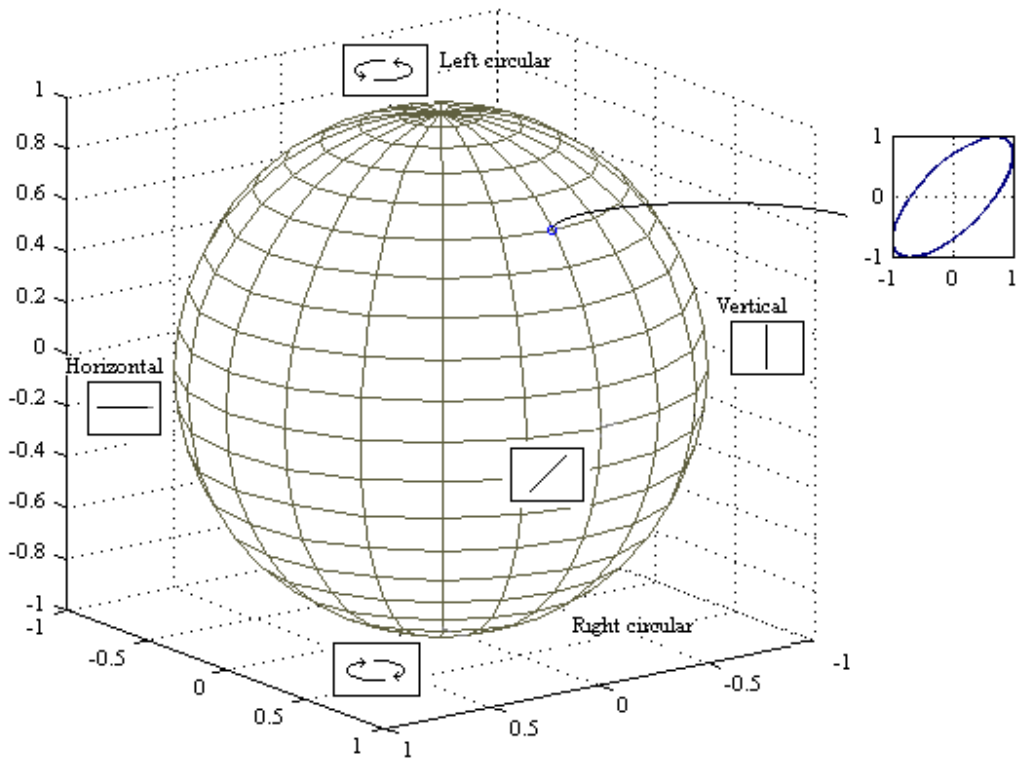


(b)



(c)

The SOP is represented graphically by the Poincaré sphere (diagram below) on the surface of which any possible SOP can be plotted. The equator of the sphere represents linear polarization states, the vertical (V) and the horizontal (H) corresponding to the two defined orthogonal linear polarization axes. The poles of the sphere represent right and left circular polarization. In the co-ordinate system shown in the diagram, the surface of the 'northern' hemisphere represents any left-handed elliptical state and the surface of the 'southern' hemisphere represents any right handed elliptical state.



Principle of operation

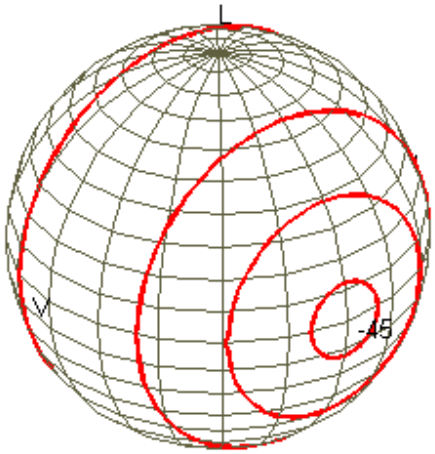
The principle of operation of the range of Phoenix polarization control devices is to vary the birefringence of a length of polarization maintaining optical fiber. The two axes of the fiber resolve the incident SOP into two orthogonal components, varying the birefringence alters the phase difference between the two components as they propagate along the fiber which when recombined produces another SOP. In terms of Poincaré sphere representation the devices move the SOP from one point on the surface of the sphere to another point along a route defined by the particular device type. This technique forms the basis of a range of devices which enable the definition of any output SOP from any input SOP.

Variable waveplates

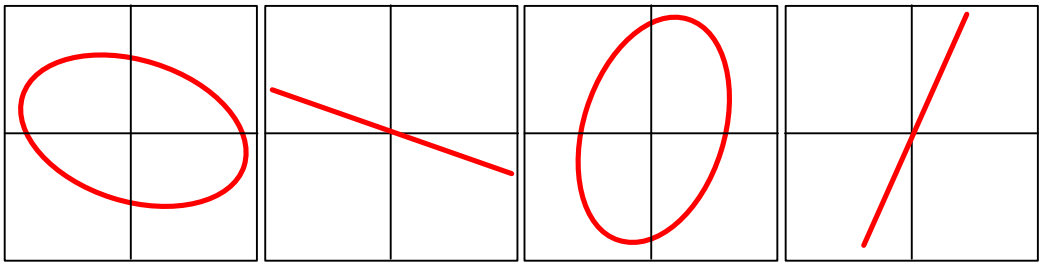
Option 1 single mode fiber in and single mode fiber out

The SOP input to the waveplate from the single mode fiber is arbitrary, the waveplate will provide a complete cycle of the Poincaré sphere.

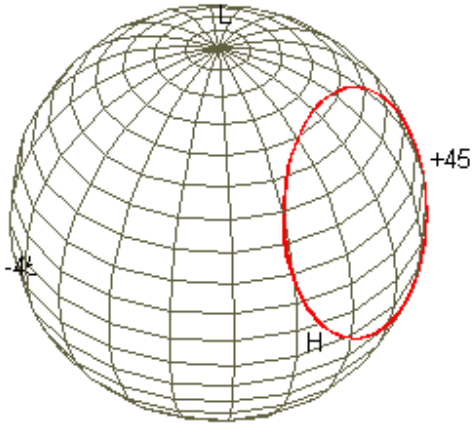
Condition 1 – Variation of input fiber SOP



With no birefringence induced in the output single mode fiber lead the variable waveplate will describe a circle around the Poincaré sphere which will pass through two linear polarization states. The position of the circle described is defined by the input SOP and can vary from a fixed linear state corresponding to one of the PM fiber axis through the great circle corresponding to a linear launch at 45 deg to the PM fiber axes to a fixed linear state corresponding to the second axis. Plots on the sphere show some examples of the circles described as the input SOP is varied and the generalized elliptical states from four points around the sphere are shown below.

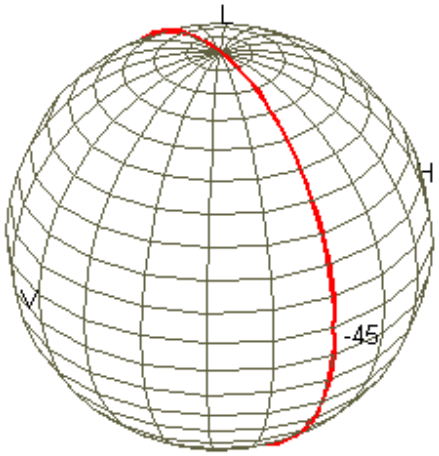


Condition 2 – Variation of output fiber SOP



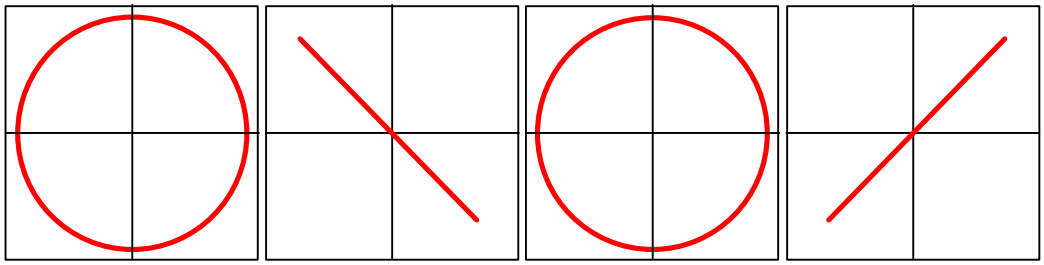
Changing the SOP after the waveplate can move the center of the described circle to any position on the sphere. A change in SOP can be caused by additional birefringent components in the fiber system following the waveplate or birefringence created in the output lead through tight bends or lateral force.

Option 2 PM fiber input and output with integrated fiber polarizer at the input



This device is for applications in which a linear state of polarization is defined on one of the axes of a polarization maintaining fiber. The input polarizer is included to increase the extinction ratio of the input linear polarization state, aligned to the slow axis (fast axis alignment can be supplied).

The SOP at the output of the PM fiber can be rotated through the great circle of the Poincaré sphere giving linear state at 45 degrees to the axes, both circular polarization states and transitional states.

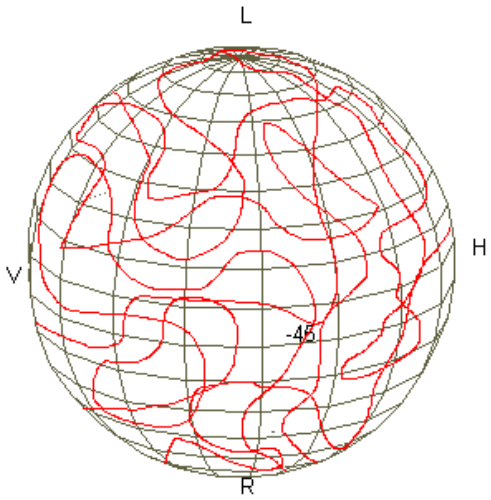


The SOP in the plane of the fiber tail output is dependent on the birefringence of the fiber tail and will be dependent on the temperature. However changes will be on the great circle around the sphere passing through both poles and the equator.

Polarization state scanner and controller

The SOP scanner/controller has three cascaded variable waveplates and can convert any arbitrary SOP to any other SOP.

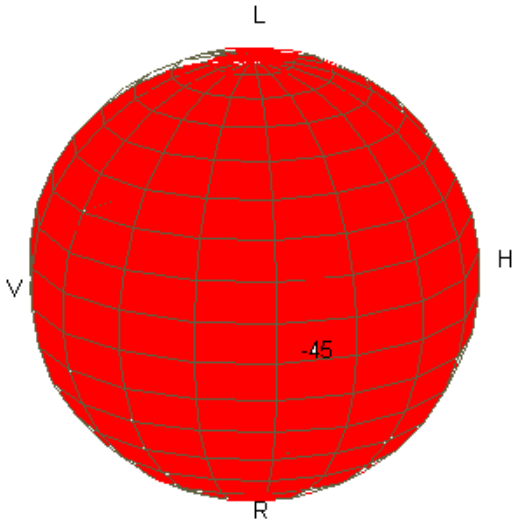
Polarization control



The unit has three current controls and adjusting the current to each of these allows access to any position on the sphere surface from any other position, i.e. conversion of any input SOP to any output SOP.

The device can be used in SOP control loop to maintain a fixed polarization state.

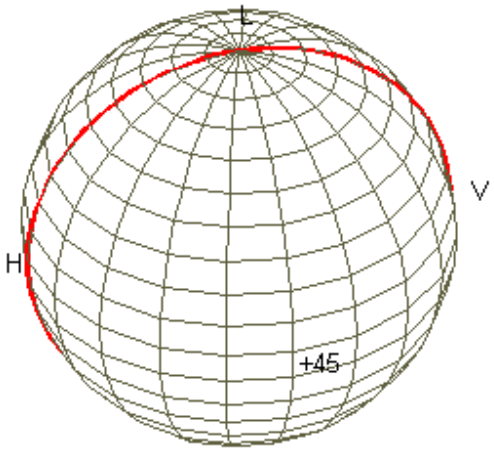
Polarization scanning



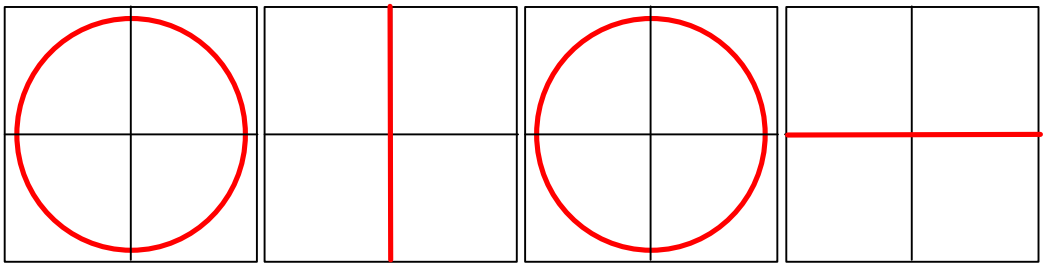
Applying a time varying current to the three sections provides continuous SOP scanning over the full surface of the Poincaré sphere.

In scanning mode the device can be used for component polarization parameter measurement, such as PDL or PDR.

Polarization switch

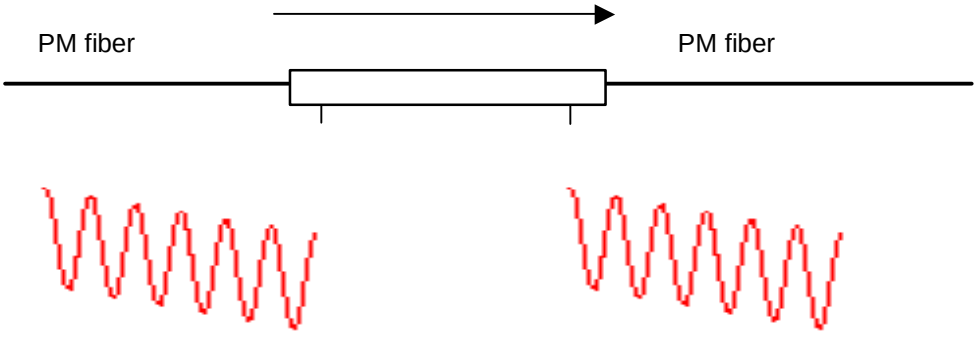


Varying the control current to the polarization switch provides a cycle around the great circle of the Poincaré sphere, similar to the PM waveplate. However, in this case the linear states are aligned to the axes of the output fiber tail. The cycle around the sphere cuts the equator through the vertical and horizontal linear states (relative to the input PM fiber axes. Therefore the input linear state on slow axis can be switched between the fast and slow axis at the device output, by switching between two drive currents. An option is available with a fiber polarizer at the input to ensure a high extinction ratio for the input polarization state.

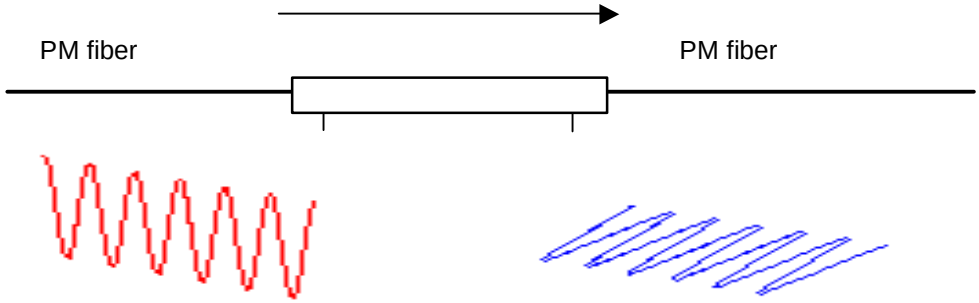


Change of linear output state, i.e. switching between the two axes, can be achieved by switching the drive current.

Current I_v applied to switch



Current I_H applied to switch



Temperature dependence

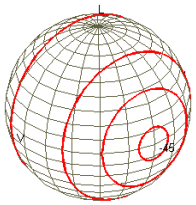
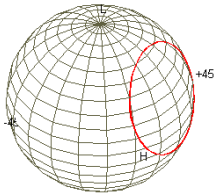
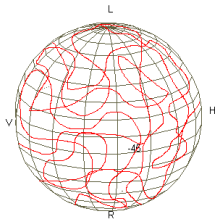
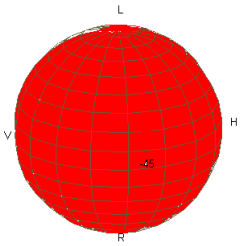
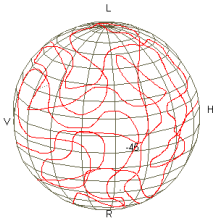
The waveplates are thermally controlled devices and the change in birefringence induced is ambient temperature dependent. The packaging has been designed to reduce response time to external thermal fluctuations, giving a good stability within the package dimension constraints. For situations in which the stability of the waveplate polarization transfer function is critical, for example in the switch, the device cases should be thermally controlled.

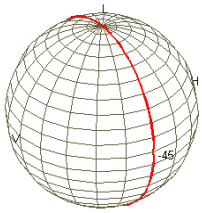
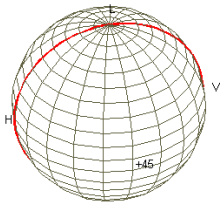
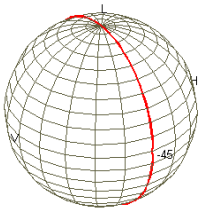
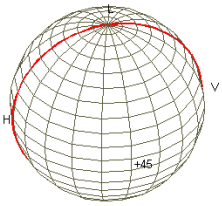
The units have been designed for OEM use, easy incorporation into PCB and flat packed for thermal control with for example a Peltier.

Wavelength dependence

All of the waveplates will operate within the specified wavelength range. The birefringence and consequently retardation of the waveplate is wavelength dependent giving a variation in polarization state transfer function with change in wavelength.

Which device to use?

Requirement		Device
Single mode fiber systems		
SOP scanning around a single plane of the Poincaré sphere	 	Variable waveplate, single mode fiber input and output
Conversion of any SOP to any other SOP		Polarization scanner
Scanning of all possible polarization states		Polarization scanner
Control of output SOP for slowly varying input SOP		Polarization scanner

Requirement		**Device**
Polarization maintaining fiber systems		
Conversion of on-axis linear state to orthogonal linear state		Polarization switch
Change input linear state to either circular state and two linear states @ 45deg to fiber axes		Variable waveplate, polarization maintaining fiber input and output.
Change input linear state to either circular state and two linear states aligned to fiber axes		Polarization switch
Scanning input linear polarization state around the great circle of the Poincaré sphere	 	Variable waveplate, polarization maintaining fiber input and output. Polarization switch