ARCoptix

Variable Spiral plate
With LC Driver
USER MANUAL

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Principle of the variable Spiral plate

The Spiral plate (VSP) is a liquid crystal cell with transparent ITO electrodes and a non-uniform aligned liquid crystal layer that gives the element its special optical properties. A transverse view in Figure 1 gives an overview of the VSP structure.

Figure 1. Transverse view of the VSP: Liquid crystal layer between two glass substrates with transparent electrode. Optical axis director can be tilted with the help of an applied bias V.

By applying a bias on the two transparent electrodes it is possible to tilt the liquid crystal molecules and at the same time the optical axis (and apparent birefringence). This mechanism permits to adapt the retardance (most cases tuned to Pi) of the variable Spiral plate to the wavelength of the light traversing the element.

The VSP (also caller Q-plate) has a topological charge of Q= 0,5. This means that the formula describing the orientation of the optical axis (when looking at the VSP from the top) in polar coordinates is given by:

$$\alpha(\rho, \phi) = \alpha(\phi) = q\phi + \alpha_0,$$

Where q is the topological charge (0,5 in our case) and a0 a constant offset angle. The topological charge of the q–plate is 0.5. It is defined at production and cannot be modified. Figure 2 shows the optical axis distribution for such a VSP. Notice that on demand also a topological charge 1 can be produced.
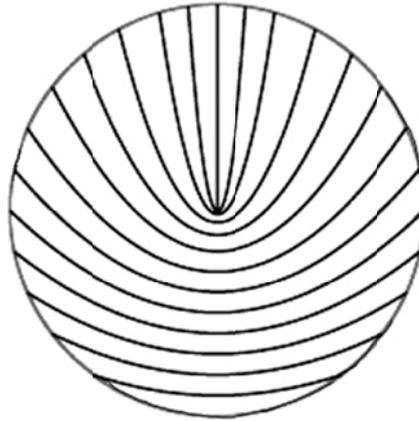
Figure 2.Lines showing the local optical axis (front view) of a q=0.5 VSP.

The LG(0,1) spiral mode and the LG(0,1) radial pol. Mode have the same doughnut shaped intensity distribution but their electric field distribution (polarization and phase) are different. The spiral phase mode can be written in cylindrical coordinates (r, φ) as following (ref: G. Machavariani & al. "Effect of the spiral phase element on the radial-polarization (0,1)* LG beam",Opt. comm. V.271):

$$E(r,\varphi) = E_0 \sqrt{\rho} \exp(-\rho/2) \exp(\pm i\varphi)$$

or decomposed into two orthogonal coherent components as following:

$$E_x(r,\varphi) = E_0 \sqrt{\rho} \exp(-\rho/2)\cos(\varphi)$$
$$E_y(r,\varphi) = E_0 \sqrt{\rho} \exp(-\rho/2)\sin(\varphi)$$

Notice that the null intensity in the center is due to the phase singularity and the phase of the beam is helical.

For the radial polarization mode, the field must be defined as vectors and can be expressed as:

$$\bar{E}(r,\varphi) = E_x(r,\varphi) \cdot \vec{e}_x + E_y(r,\varphi) \cdot \vec{e}_y$$

Where Ex and Ey are given above and ex and ey are the x and y unit vectors.

Different working modes:

There are mainly three types of functioning modes with the VSP:

1) Radial or azimuthal output polarization

2) Spiral phase with constant circular output polarization

3) Neutral (no change)

The output beam of the VSP will be defined by two parameters:

1) The input polarization linear or circular

2) The phase retardation of the VSP.
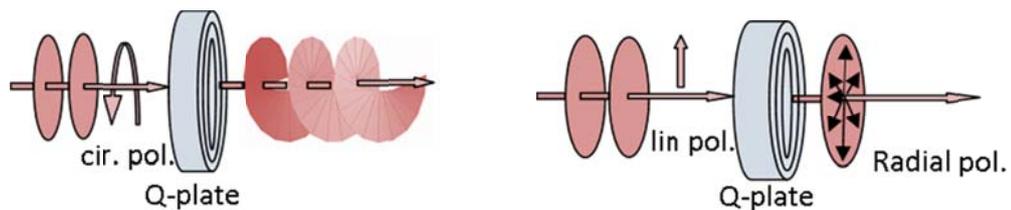
Figure 3: Retardation on the VSP in Pi and the input polarization is circular (left) or linear (right), giving respectively a spiral phase output or a radial pol. Output.

The table below summarizes all the settings necessary for four different functioning modes:

MODE	Retardation on the VSP	Input polarization	Output Polarization
Radial pol.	$\delta = \pi$	Vert. linear	Radial
Azimuthal pol.	$\delta = \pi$	Horiz. linear	Azimuthal
Spiral phase	$\delta = \pi$	Circular left/right	Circular right/left
Neutral	$\delta = n*2\pi$	any	same

For the first three modes described in the table above the retardation of the VSP needs to be set to half of the wavelength (or pi). This can be obtained by simply adjusting the bias on the VSP.

Notice that they are many other possible working modes (spiral, lemon,...) can be obtain by combining different retardations and input polarizations. A detailed description of this can be found in

Operating the device:

1) Put the clear aperture of the VSP in the path of your laser beam. Notice that there is no specific entrance or output aperture, the device is perfectly symmetric.

2) Make sure that the laser beam is perfectly perpendicular to the VQP input plane. A small tilt may already cause some deformations and unwanted effects.

3) The Spiral plate should preferably be attached a x-y positioning system in order to center the VSP with the laser beam. Notice that the center of the optical axis structure may not coincide perfectly with the center of the clear aperture.

4) Connect the cable of the VSP to one on the inputs of the LC driver (see electrical driving section).

5) Make sure that the input beam polarization is either Horizontal or vertical.

6) Vary the bias applied on the VSP (with the LC driver software) and observe the behaviour of the intensity pattern of the output beam in the far field (at least 1m for output plane of the VSP).

7) For a phase retardation close to Pi one should observe in the far field a little hole the laser beam intensity. The hole becomes the most visible when the phase retardation is Pi.

8) Adjust the bias on the VSP to obtain the most visible hole.

 Picture of a intesity distribution with the to lobes

9) Additional control can be made know with an extra polarizer placed just after the VSP. A double lobes intensity profile should be obtained.

10) By rotating the polarizer the two lobes should also rotate.

11) Adjust the bias on the VSP to obtain the most symmetric and best defines lobes. This should correspond to a retardation of Pi.

12) Also adjust the x-y position of the Spiral plate in order to center the two lobes with the beam.

Now your setup is aligned and adjusted in phase (with pi retardation). The different working modes (as described before) can be obtained by either entering the VSP with circular left/right or vert./Horiz. Linear polarization.

Electrical Driving:

1) Connect the LC driver to a PC with windows operating system

2) Connect the Lemo connector attached the VSP to one of the inputs (out1 or out2) of the LC driver.

3) The retardation on the VSP can know be adjusted by varying the output voltage of the corresponding output of the LC driver. (see operation of the IC driver section)

Notice that the retardation of the VSP is not linear with the voltage. The largest variation of the retardation is between 1 and 3,5 Volt. From 0 to 1 V there is almost no variation of the retardation.

Operation of the LC Driver (see also lc driver manual):

Before using the LC driver, make sure that the program and drivers are correctly installed on your computer. Notice that for the moment not possible to drive two different drivers from the same computer. When starting the program you get the following window (non-triggered version):
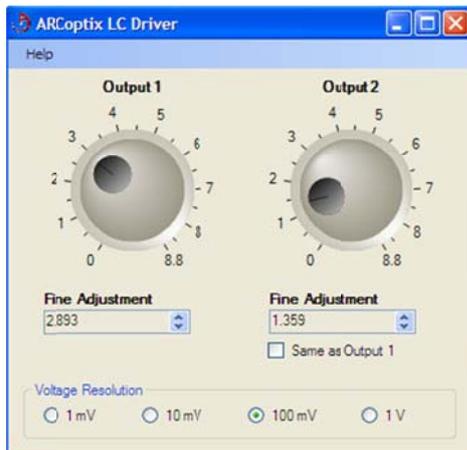
The output controls (output 1 and output 2) correspond to the two outputs on the LC Driver.
One can control output via
- The rotation button (rough control)
- The edit window just below the rotation button.
- With up and down arrows of the keyboard
- With the scroll wheel of the mouse (if any present)

For precise scanning of the voltage (if adjusting the phase of the variable phase retarder or phase compensator for example) with the up and down arrows or the mouse scroll wheel, one can set the precision of a single step with the voltage resolution selection.

To select the output controlled by the arrows or the scroll wheel of the mouse: click on the corresponding rotation button.
The maximum precision of the LC Driver is 1mV. And the maximum amplitude of the square signal is about ±8.8V. The constant frequency of the output voltage is 1.6 KHz
If the check box "same as Output 1 is checked then both outputs are identical and are both controlled by output 1.
Terminate the program by simply pressing the red cross button in the upper right corner (as usual for windows programs).

Troubleshooting:

The following question may help to solve eventual functioning problems of VSP:

1) Is the input polarization either horizontal, vertical or circular**?**
2) Is the VSP well aligned and perfectly perpendicular to the laser beam?
3) Do you see two lobes in the intensity profile of your laser beam when placing a polarizer after the VSP?
4) Do you see any change in the ouput intensity profile when changing the applied bias on the VSP?
5) Does the LC driver ouput change the voltage when changing the voltage in the software (check with a multimeter)?
6) Is the VSP correctly centered with the laser beam? What happens if the VSP is moved in the x-y plane?