ARCoptix

Achromatic switchable polarization rotator

ARCoptix S.A
Trois-portes 18
2000 Neuchâtel
Switzerland
Mail: info@arcoptix.com
Tel: ++41 32 731 04 66

Intorduction:

Liquid Crystal twisted nematic polarization rotator (TN cell) is very useful when one wants to rotate the orientation of a linear polarization by a fix amount of typically 45° or 90°. When light is traversing LC twisted nematic cell its polarization follows the rotation of the molecules (see figure below). The screens of any laptop computer are based on the same effect. In optical systems the polarization is often rotated by quartz retardation plates ($\lambda/2$ or $\lambda/4$ plates). Quartz plates shows high quality and good transmission performances especially in the UV region. However such plates present also some disadvantages: They are expensive, functions only for a narrow spectral bandwidth and have a small incidence angle acceptance (field of view less then 2°). The liquid crystal nematic cells have therefore a large acceptance angle, function over a very large spectral range from VIS to NIR (if they are thick enough) and are less expensive. Optionally, by applying a voltage on the TN cell, the polarization rotation can be "switched off". Also when placing a 90° twisted cell between crossed polarizers it can be used as a shutter.

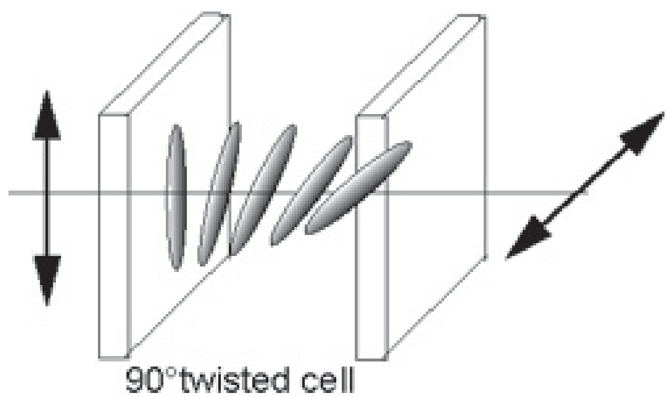
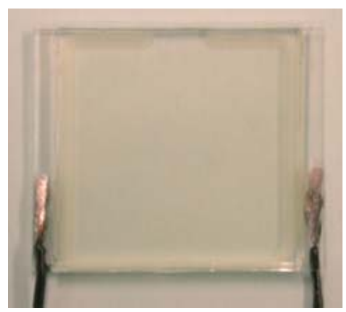


Fig.1: Twisted nematic liquid structure rotates the polarization of light.

Arcoptix offers several types of products:

Type of Product	Field of application	Properties
45° and 90° high end polarization rotators (scientific grade)	scientific applications	No spacers over the aperture. Minimal wavefront distortion $(\lambda/4)$ and AR coating
Industrial large series cells (industrial grade)	Industrial applications	Cost effective, industrial quality, compact, some wavefront distortion and spacers distributed over the aperture
Custom made	Scientific-industrial application	Optimized for minimal switching time, specific angle of rotation, specific size, specific wavelength.

Scientific grade cells
With housing



Industrial grade cells
without housing

How does it works and what cell does I need?

A twisted nematic liquid crystal cell consists essentially of a liquid crystal layer placed between two treated glass substrates.
The inner-surfaces of the cell is composed of two layers: The first layer is a transparent electrode (mostly ITO). It permits to apply an electrical field across the cell and switch the cell between the OFF and the ON state. The second layer is responsible for the homogenous alignment of the LC. It is generally a rubbed polyimide layer of about 100nm.
The liquid crystal alignment at both sides of the cell is hence defined during cell manufacturing. By careful control, any twist-angle can therefore be induced in the helical structure across the liquid crystal layer. With a twist-angle of exactly 90°, the standard 90° twisted nematic (TN) cell is formed. Twist-angles of less than

90° form the low-twist (LT) cell whereas by definition, super-twist cells are cells that possess twist-angles exceeding 180°.
The two glass substrates are separated by spacers with a well defined size (usually between 3µm and 20µm) and sealed with glue.

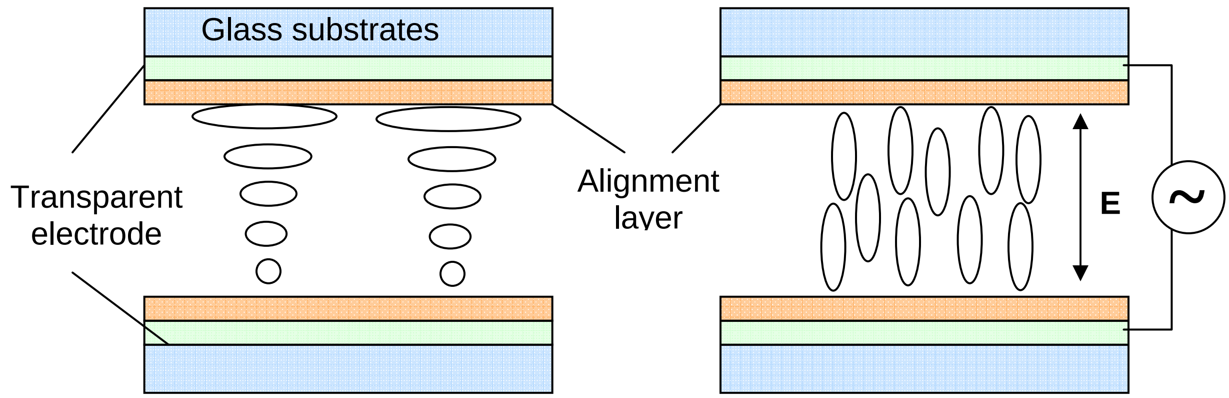


Fig. 2: OFF state (no applied bias) *ON state (applied bias) LC molecules are oriented along the electric field*

When the polarization rotator is in the off state, the helical structure formed by the LC molecules rotates the entrance polarization as shown in figure 1. In the ON state the polarization rotary power is suspended and the polarization state of the light entering normally to the entrance surface is not altered by the TN cell.

100% efficient rotation of a linear entrance polarization can only be obtained in the limit of large cell thickness and in general the exiting light becomes elliptically polarized with components oscillating in directions lying both parallel and perpendicular to the exit liquid crystal molecules. Furthermore, it is the *optical-path-difference* in the liquid crystal cell that affects the overall magnitude of the polarization efficiency for the TN cell. The optical-path-difference is given by the Δnd parameter, where Δn is the anisotropic index of refraction for the liquid crystal material and d is the cell-gap. The following equation shows the transmission of a TN 90° cell as function of a normalized retardation parameter u. It assumes that the TN cell is placed between two parallel orientated ideal polarizers.

$$T = \frac{1}{2}\frac{\sin^2\left(\frac{\pi}{2}\sqrt{1+u^2}\right)}{1+u^2} \quad \text{where} \quad u = 2d\frac{\Delta n}{\lambda}$$

Figure 3 shows this transmission for different optical path difference Δnd in function of the wavelength. We see that the best extinction (which means also the best rotation efficiency) is obtained with the highest optical path difference. So for optimal rotation of the entrance polarization over a broad spectral range it is better to use a TN cell with a high optical path difference (which means a large cell gap and a high anisotropy).

However one must be aware that higher cell gaps decrease drastically the switching time of the TN cell. So rapid switching times and high efficiency over a brad spectral range cannot be obtained. Notice that the curves shows some minimum and a custom made TN cell can be optimized to have a good rotatory efficiency (low transmission) and a rapid switching time (minimal cell gap) for a narrow range of wavelength (for example the blue curve with Δnd=0.7 around 800nm).

In application where switching time does not matter it is better to choose a TN cell with a high optical path difference.

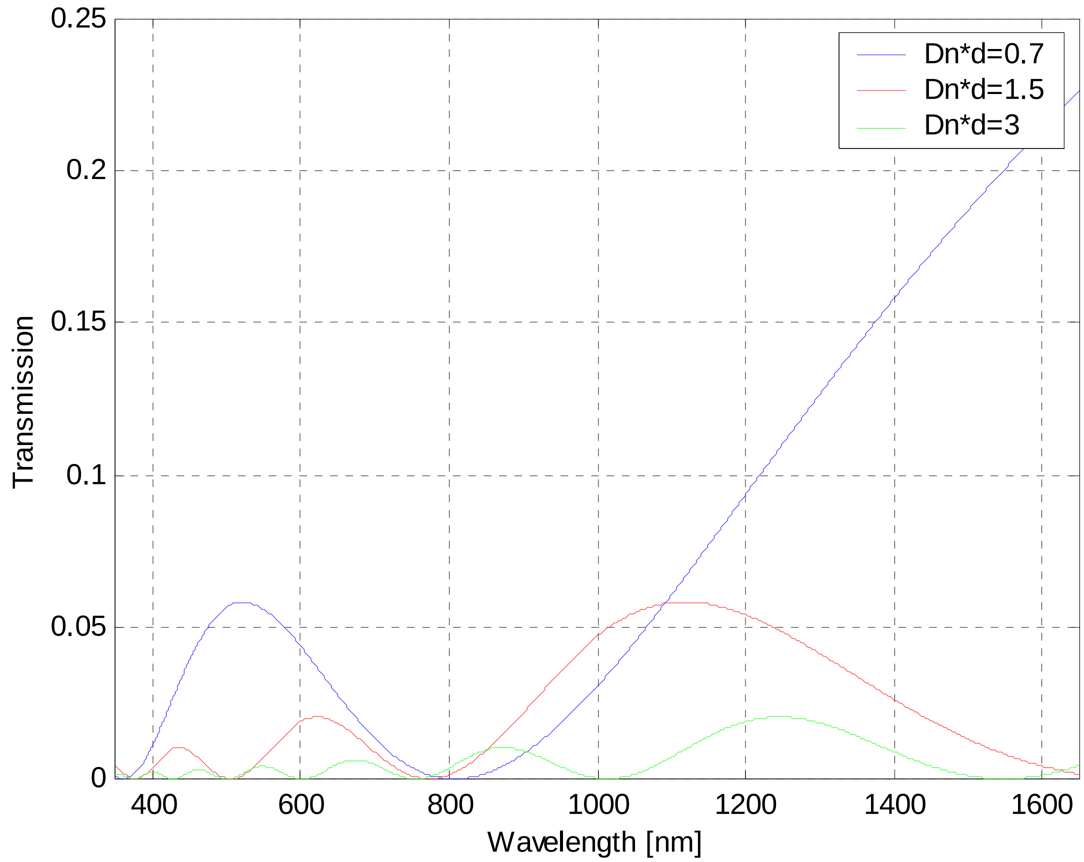


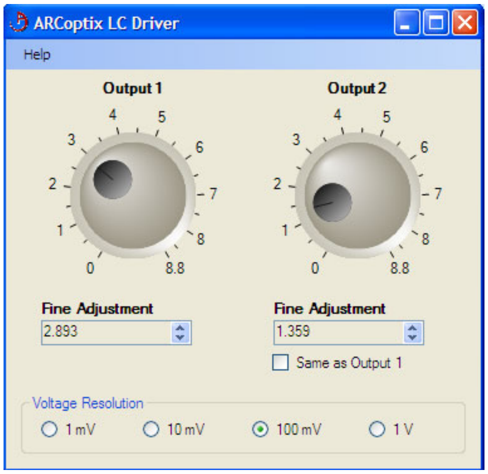
Fig 3: Transmission of a 90° TN cell placed between two parallel ideal polarizers. Lower transmission means better rotatory efficiency.

Electrical driving:

The polarization converter needs to be connected to an alternative (AC) power supply producing a square wave signal with change of polarity (oscillating between positive and negative bias). To drive the polarization rotator there are essentially two options:

1) Use the Arcoptix digital LC Driver that has two independent outputs that are computer controlled via USB and optimized for liquid crystal device driving (see figure 6). It generates a square signal of 1.6 KHz with variable amplitude between 0V and 9V. The LC driver produces a highly stable signal with a precision of 1mV. However only two levels are relevant for driving the cell 0V and 9V (e.g. minimal and maximal value) for switching off and on the TN cell. External trigger can be obtained on demand.

2) Use a standard labor generator with square wave signal. The should be somewhere around 0.1-1 kHz and the amplitude should be variable between 0 and 5V (almost no current).



LC Driver with two independent outputs that are computer controlled via USB.

LC cells are usually driven with AC square-wave voltages of between ±1.0 and ±10 volt whereby the polarity is rapidly switched at speeds of up to 1KHz (the frequency is not very important, typically more than 10Hz) in order to prevent impurity ion migration from occurring. A priory, it may be expected that activation of the LC cell with AC voltage might cause the molecules to rotate. However in practice interactions between the LC molecules themselves hinder this and if the polarity change is rapid enough (which is generally the case for a square wave) the molecules “do not have enough time to react”. Polarity reversal (when it is performed quickly) of the driving electronics will therefore have no effect upon the alignment of the molecules and the performance of the device is only dependent upon the root-mean-squared (rms) voltage and not on the polarity of the external field.

Notice that the phase shift stays constant when applying a square shaped function because of the slow reaction time of the LC molecules. Only slowly varying applied voltages below 50HZ may change the phase shift.

Specifications

The specs below are valid for all the models.

Twist	45° or 90° (custom twist possible)
Twist accuracy	±1°
Output ellipticity	Between 0.1 and 10% (depending of the model and the wavelength)
wavelength range	350-1800 nm
Active area	10 mm or 20mm (diam.)
Transmission	> 85% (VIS)
retarder material	Nematic Liquid-Crystal
Substrates	Glass
wavefront distortion	< lamda/4
temperature range	15°-35°
Anti-reflection Coating	Broadband VIS
Retardance temperature dependency	About 0.5%/°C (wavelength dependent)
Housing size	25 mm in diam. 15mm deep

Transmission:

Total transmission of the TN cells (including losses due to reflections) is given by the graph below. For lower absorption losses Anti-reflection coatings are necessary. The transmission is identical for all the models.

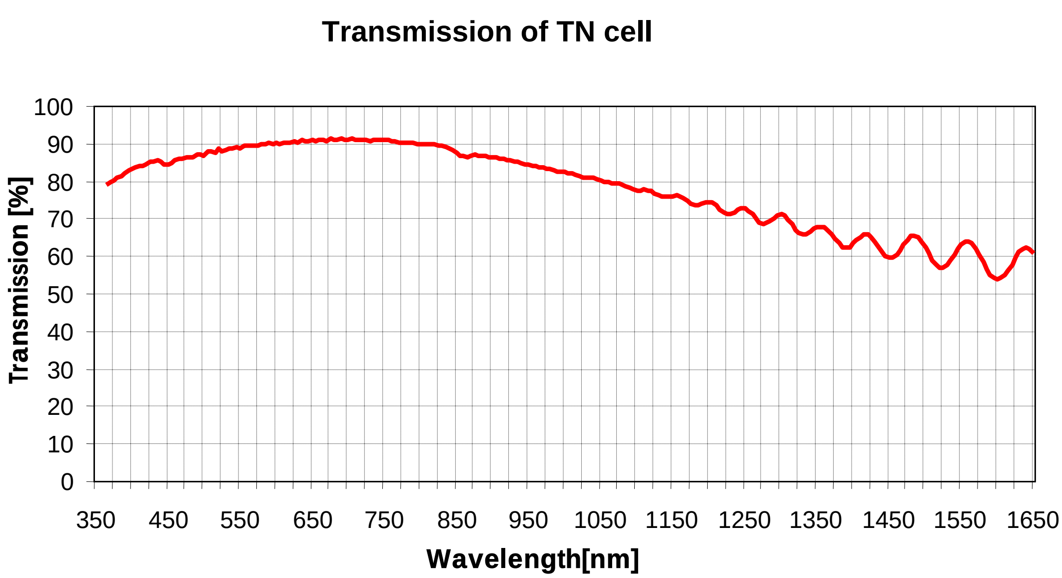


Fig. 5: Transmission of the TN cell (all models) without polarizers.

Rotatory efficiency:

As explained in the previous section, the rotatory efficiency can be quantified by measuring the transmission of the TN cell when it placed between two ideal parallel polarizers.

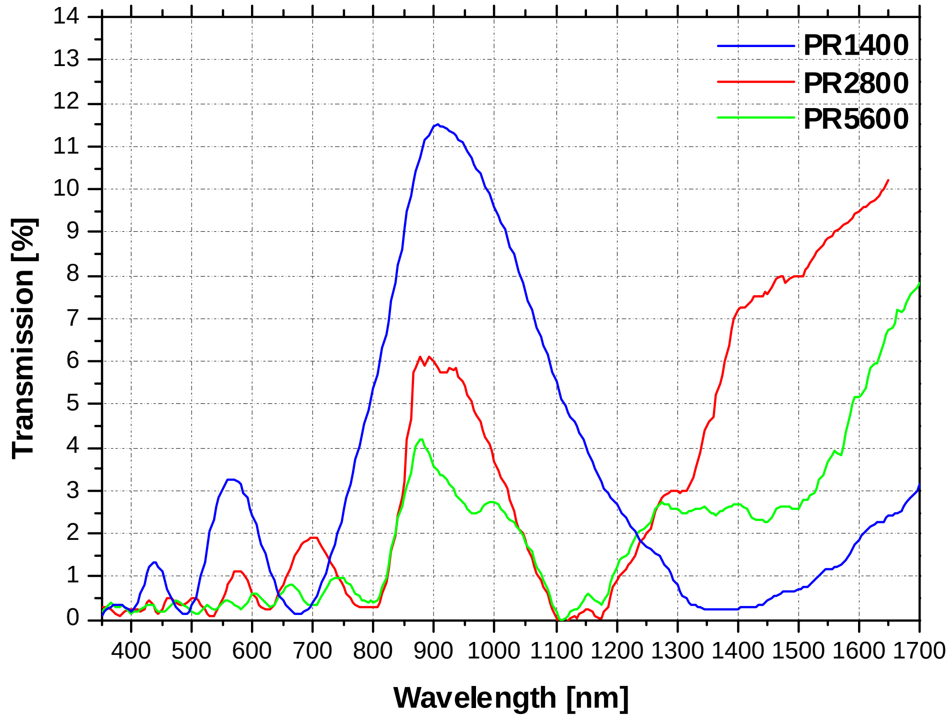


Fig 6: Measured transmission (when placed between two Glan-Thomson polarizers) for the three standard models

In summary the (extinction ratio) for the three standard models

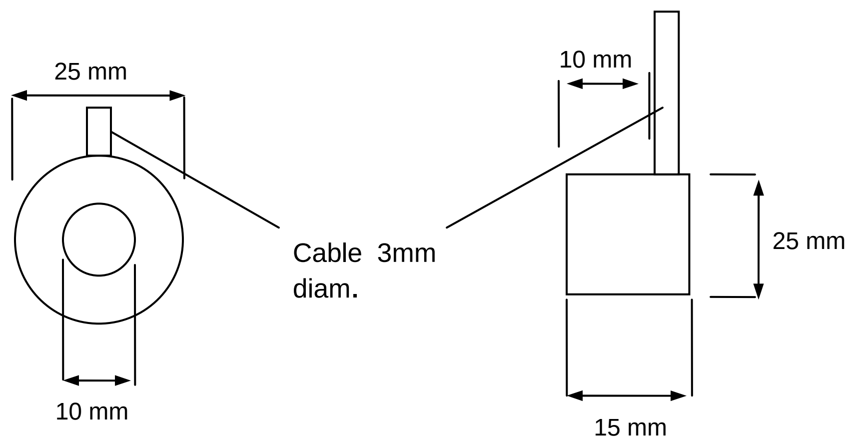
Model	Mean Extinction ratio 350-800nm	Switching time
PR1400	4%	25ms
PR2800	2% (1/500 at 633nm)	70ms
PR5600	Below 1%	150ms

Electrical connection:

The phase shifter must be connected to an alternative power supply providing a square wave of minimal ±6 V. The frequency of the bias must ideally be around 100 Hz and there should be a polarity inversion. LC driver can be supplied by ARCoptix if necessary.

Housing:

The Housing (for scientific grade only) is made of anodized aluminum. It has a diameter of 25mm. The optical axis is indicated by a stripe.



Custom Design

Design and quotes for custom specifications such as switching time, active area, twist angle, total size, housing can directly be asked by sending us an email at info@arcoptix.com.

Payment Terms

Payment terms are 30 days upon shipment arrival. Prepayment may be occasionally required for international orders (but generally not for universities, research institutes and other governmental institutions). Please ask for a quotation. Arcoptix do in principle not accept credit cards (please ask if this may be a problem).

Specifications

Listed specifications are accurate as of the publication date. Product improvements and design changes may alter product specifications without notice.

Warranty

All products in this catalog are warrantied against defects in materials and workmanship for a period of one year from the date of shipment. Liability of Arcoptix is limited to the defective product value only. polarization solution.

Shipping

We will use our best judgement regarding shipping
Method (mostly with DHL), unless a specific carrier is requested.
Freight charges are paid by the receiver.

Ordering information

Quotes can be asked by
e-mail: info@arcoptix.com.
By phone: ++41 (0)32 731 04 66 or 64
By Fax: ++41 (0)32 731 04 63.

Final order should be placed by sending use a signed fax containing the ordering details.