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FPM series

MODEL OVERVIEW

The FPM (Fast Polarization Modulator) series is a range of liquid crystal (LC)-based polarization modulators/rotators that control the light polarization by an externally applied drive voltage. Compared to conventional mechanical modulators/rotators, LC modulators/rotators are electro-optical; they contain no moving parts, are completely vibration-free, and have a small footprint.

Most modulator/rotator models consist of a polarization modulator in form of a LC cell together with a linear polarizer. Applying the drive voltage reorients the birefringent LC molecules, changing the phase retardation of light passing through the LC cell. This results in a change in polarization of light passing through the full modulator/rotator structure. Some models employ two LC cells for achieving enhanced performance.

In order to meet a wide range of requirements for various applications, a series of modulator/rotator models possessing different electro-optical properties are offered in a number of standard sizes, all available with short lead times. Customers not finding their required modulator/rotator properties are advised that further optimization and custom designing are possible, both in terms of electro-optical properties and mechanical dimensions (up to 14”x16” size). As regards volume supply, any number from a single prototype up to several million units per month can be shipped.

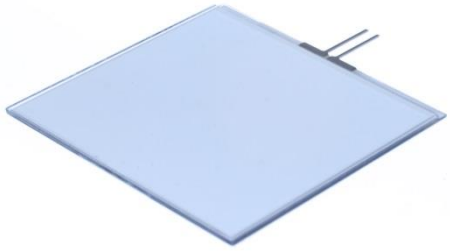
To purchase or for more information, please contact us at: info@lc-tec.se or +46 243 79 40 70.

Advantages

- Electro-optical
- No moving parts
- Vibration-free
- Small footprint
- Low power consumption
- Large design freedom
- Fast switching
- High contrast
- Excellent optical quality
- Ruggedized
- Reliable

Applications

- 3D projection
- Direct-view 3D
- Photography
- Industrial cameras
- Machine vision
- Polarization imaging
- Microscope
- Laser attenuation
- R&D
- And more…



Main electro-optical properties

Model	Number of polarization output states	Transmittance	Polarization contrast*	Response time** (T_{100}-T_{10})	Relaxation time** (T_0-T_{90})	V_D
FPM(L)	2	≥43.5%	≥60:1 ≥1,800:1	≤6ms	≤30ms	@ 4V
FPM(L)-NIR(1100)	2	≥40.0%	≥200:1 ≥300:1	≤5ms	≤15ms	@ 5V
X-FPM(L)	2	≥43.5%	≥20:1 ≥1,800:1	≤30µs	≤1.8ms	@ 24V
X-FPM(4L)	4	≥41.0%	≥120:1/≥30:1 ≥500:1	≤30µs	≤1.8ms	@ 24V
PolarSpeed®-M(L)	2	≥42.0%	≥20:1 ≥120:1	≤30µs	≤30µs	@ 24V
VPR	Continuous	≥41.0%	≥75:1 all outputs	all output changes ≥20°	≤10ms	@ 9V

Note: The values above are valid for the 2x2 size at room temperature, incident light is unpolarized. Transmittance and polarization contrast correspond to luminous data for all models except for the FPM(L)-NIR(1100), where the performance is measured at the design wavelength of 1,100nm, and for the VPR, where the performance is measured for narrowband operation. See detailed product specifications for further information.

*: Polarization contrast is defined as the ratio of the desired polarization output to its orthogonal non-desired component. The lower value corresponds to the polarization altering state, while the higher value corresponds to the non-altering state. The contrast of the polarization altering state is significantly higher around the design wavelength (normally 550nm).

**: Response time is defined as the time it takes to switch from the polarization altering to the non-altering state after the drive voltage is applied. Relaxation time is the corresponding time for switching from the non-altering to the altering state after the voltage is switched off. The PolarSpeed®-M(L) operates differently , offering fast switching in both directions.

Available standard sizes

Size	Outer dimensions	Clear aperture	Thickness
7x8	7.0mm x 8.2mm	5.0mm x 5.0mm	Model dependent, ranging from 1.3mm to 4.9mm
13x15	13.0mm x 15.0mm	9.8mm x 9.8mm	
1x1	25.4mm x 25.4mm	22.2mm x 20.2mm	
2x2	50.8mm x 50.8mm	47.6mm x 45.6mm	
D1 (circular)	25.4mm diameter	22.2mm diameter	
D2 (circular)	50.8mm diameter	47.0mm diameter	

Note: See detailed product specifications for available standard sizes for each model and for exact dimensions/tolerances.

Model descriptions

FPM(L) (Fast Polarization Modulator)

The basic FPM(L) model offers high contrast between two orthogonal linear polarization output states even at moderate drive voltage amplitude together with fast switching from polarization altering to non-altering state. It is suitable for customers seeking a general purpose modulator/rotator without having extreme requirements for fast switching.

FPM(L)-NIR(1100) (Fast Polarization Modulator - NIR Operation, 1,100nm optimized)

The FPM(L)-NIR(1100) provides near infrared operation and is design for optimum performance around 1,100nm. Custom designing for wavelengths up to 2,000nm is possible.

X-FPM(L) (Extra Fast Polarization Modulator)

The X-FPM(L) is the fastest single-cell modulator/rotator and differs from the FPM(L) model by having higher switching speeds, both response and relaxation. This modulator should be considered for applications in which high-frequency operation between two linear polarization states is desired.

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X-FPM(4L) (Extra Fast Polarization Modulator, 4 linear polarization outputs)
The X-FPM(4L) incorporates a dual-cell structure in order to achieve switching between 4 linear polarization states, oriented at -45°, 0°, +45°, and +90°, respectively. It is especially suitable for polarization imaging applications.

PolarSpeed®-M(L) (PolarSpeed® Modulator)
Based on LC-Tec's patented PolarSpeed® technology, this dual-cell modulator/rotator offers unprecedented 30µs symmetrical switching times in both directions. The PolarSpeed® modulator/rotator is especially suitable for demanding high frame rate applications, such as time-multiplexed stereoscopic 3D, and is compatible with up to 540 FPS operation. PolarSpeed® technology can be found worldwide in the DepthQ® polarization modulator, exclusively sold and distributed for 3D projection applications by our long-term partner Lightspeed Design, Inc. (US).

VPR (Variable Polarization Rotator)
The VPR differs from all other polarization modulator/rotator models by offering continuous analogue rotation of linear polarization output states between 0° and 180°.

Models under development

FPM(L)-LAS (Fast Polarization Modulator - Laser Operation)
By optimizing both the manufacturing process and material choice, the FPM(L)-LAS is compatible with laser operation without sacrificing product durability or lifetime.

Polarization output
The modulators/rotators are configured for linear polarization output states. Switching between other pre-defined polarization states is also possible, for example between linear and circular polarization as well as between left- and right-handed circular polarization.

Entrance polarizer
The modulators/rotators are supplied with an input (or exit depending on usage) polarizer as standard. For customers having linearly polarized incident light, the modulators/rotators can also be supplied without any polarizer, the 0P reference is then added to model name.

Variable retarders
If continuous analogue control of the phase retardation is desired, the X-FPM can be offered as a variable retarder (wave plate) with variable retardation from 0 to 2λ.

Electrical connections
The modulators/rotators are normally supplied with contact pins bonded to the device. Several other options are also available, including flexible flat cables (FFC) and soldered wires.

Top coating and AR (anti-reflective) cover glass
Most models are supplied with an anti-reflective, scratch-resistant hard-coating on the outer surfaces. For demanding optical applications, the modulators/rotators can also be supplied with an optical quality, high-efficiency AR cover glass laminated to both sides. This configuration minimizes surface reflection, beam deviation, and wavefront aberration, and is especially recommended for imaging applications. The suffix -AR is then added to the model name.

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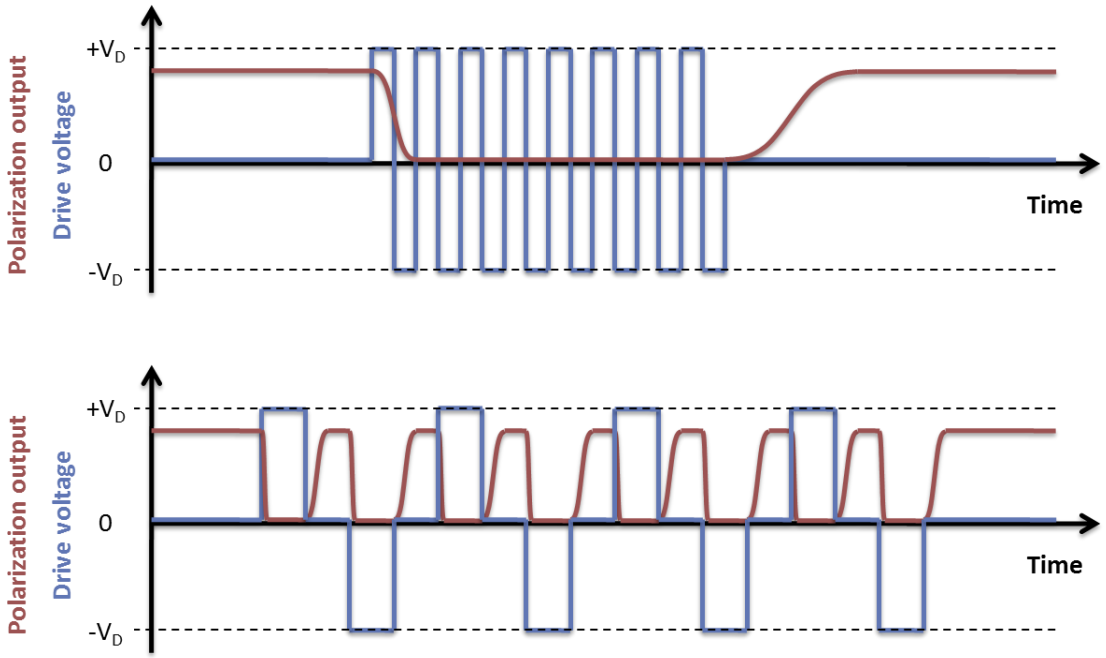
Drive voltage

The modulators/rotators possess mono-stable normally polarization altering operation, meaning that without voltage applied the modulator/rotator is in its polarization altering state*. Applying the drive voltage, V_D, switches it to a non-altering state**. This voltage must be kept throughout the duration of the time the modulator/rotator is required to be in the non-altering state. In general, increasing the drive voltage amplitude usually increases the contrast of the non-altering state and shortens the response time.

The polarization output of the modulator/rotator reacts to the RMS voltage. In order to prevent ion migration within the LC layer that might impair modulator/rotator performance and lifetime, it is recommended to ensure that there is no net DC bias present in the drive signal. This is best achieved via use of one of the two AC square waveforms illustrated below. When the top alternative is used, the recommended minimum frequency is 60Hz if visual flicker is to be avoided. The bottom option is suitable when cycled operation between different polarization output states is desired.

* The PolarSpeed®-M(L) model shows inverted optical response, i.e. non-altering without voltage applied. ** The PolarSpeed®-M(L) has a different operating principle and requires specific dual-signal drive voltage waveforms. For details, see the PolarSpeed®-M(L) specification.



Recommended controller

The LCC-230 is a flexible, full-featured liquid crystal controller specifically designed to drive all FPM, X-FPM, PolarSpeed®, and VPR models. The LCC-230 incorporates two independent LC channels, each with $30V_{RMS}$ of range and fully short-circuit protected.

The controller is operated by the LCDriver2 application via a full-speed USB 2.0 compliant interface. LCDriver2 permits dynamic editing of programs up to 96 lines in length. Three trigger modes (internal, line, program) determine how program lines are executed. Up to nine programs may also be pre-stored on the LCC-230 for stand-alone operation.

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