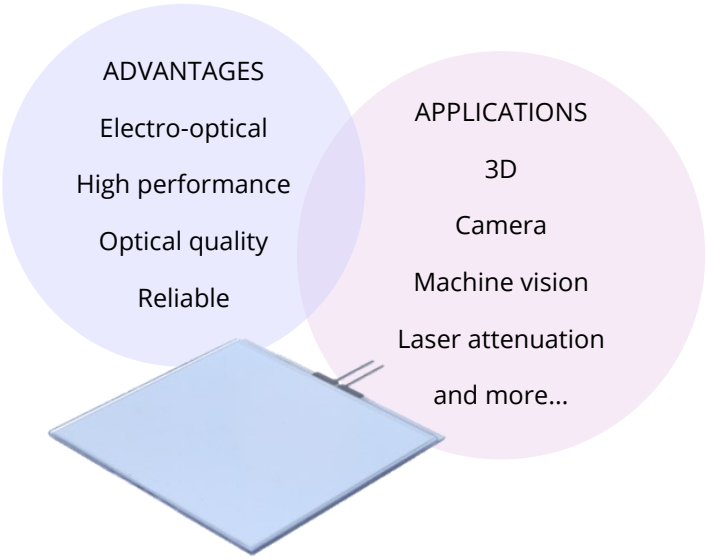
FPM series model overview

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, LC modulators are electro-optical; they contain no moving parts, are completely vibration-free, and have a small footprint.

Most modulator models consist of a LC cell together with a linear polarizer. Applying a 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 structure.



Standard models and sizes

In order to meet a wide range of requirements for various applications, a series of modulator 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 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.

Standard size	*Outer dimensions*	*Clear aperture*	*Thickness*
7x8	7.0mm x 8.2mm	5.0mm x 5.0mm	Model dependent, ranging from 1.35mm to 4.85mm
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	

Top coating and anti-reflective (AR) cover glass

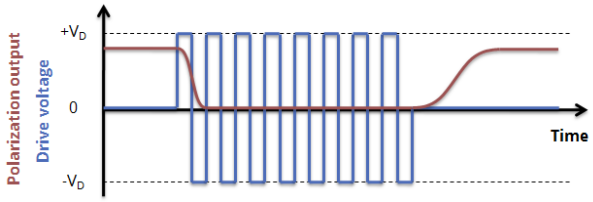
Most models are supplied with an anti-reflective, scratch-resistant, hard-coating on the outer surfaces. For demanding optical applications, the modulators can also be equipped with an optical quality, high-efficiency AR cover glass laminated to both sides. This configuration minimizes surface reflection,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

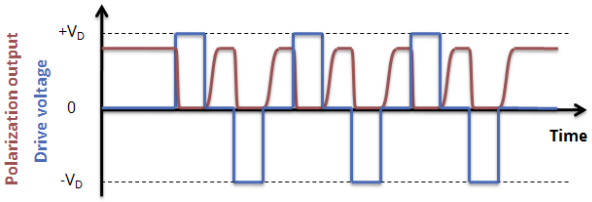
Electrical connection

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

Drive waveform

The modulators possess mono-stable normally polarization altering operation, without voltage applied the modulator 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 is required to be in the non-altering state. In general, increasing the drive voltage amplitude increases the polarization contrast of the non-altering state and shortens the response time. The polarization output of the modulator reacts to the RMS voltage. In order to prevent ion migration within the LC layer that might impair modulator 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 left alternative is used, the recommended minimum frequency is 60Hz if visual flicker is to be avoided. The right option is suitable when cycled operation between two 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) requires specific dual-signal drive voltage waveforms. See product specification for further information.

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FPM(L) (Fast Polarization Modulator)
The basic FPM(L) model offers high contrast between two orthogonal 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 polarization modulator without having extreme requirements for fast switching.

FPM(L)-NIR(1100) (Fast Polarization Modulator - Near Infrared Operation, 1,100nm optimized)
The FPM-NIR(1100) provides broadband visual-near infrared (up to 2,000nm) operation and is designed for optimum performance for wavelengths around 1,100nm.

X-FPM(L) (Extra Fast Polarization Modulator)
The X-FPM(L) is the fastest single-cell modulator 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.

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.

X-FPM(L)-LAS (Extra Fast Polarization Modulator - Laser Operation)
The X-FPM(L)-LAS is compatible with laser operation without sacrificing product durability or lifetime.

PolarSpeed®-M(L) (PolarSpeed® Modulator)
Based on LC-Tec's patented PolarSpeed® technology, this dual-cell modulator offers unprecedented 30µs symmetrical switching times in both directions. The PolarSpeed® modulator is especially suitable for high frame rate applications, such as time-multiplexed stereoscopic 3D, and is compatible with up to 540 FPS operation.

PolarSpeed® technology can be found 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 models by offering continuous analog rotation of linear polarization output states between 0° and 180°.

Polarization output
The modulators 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 are supplied with an input (or exit depending on usage) polarizer as standard. For customers having linearly polarized incident light, the modulators can also be supplied without any polarizer.

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
X-FPM(L)-LAS	Under	development				
PolarSpeed®-M(L)	2	≥42.0%	≥20:1 ≥120:1	≤30µs	≤30µs	@ 24V
VPR	Continuous	≥41.0%	≥75:1 all outputs	≤10ms all output changes ≥20°	≤10ms all output changes ≥20°	@ 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 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.

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