Polarization Rotators

Numerous technologies for modulating polarization for various applications

Boulder Nonlinear Systems (BNS) designs, develops, and manufactures liquid crystal devices (LCDs) for modulating light in a number of ways. LCDs can be designed to completely turn off a beam of light (Optical Shutter), vary the intensity of a beam of light (Beam Attenuator), rotate the polarization state of a beam of light (Polarization Rotator), delay the time of flight of a beam of light (Variable Waveplate).

These technologies can also be extended from single, large apertures to segmented, or pixelated, apertures – also known as spatial light modulators (SLMs). With an SLM one can spatially vary the amount of modulation to create a variety of optical functions. For instance computer generated holograms can be implemented, wavefront errors can be corrected, atmospheric turbulence can be simulated, beams can be steered, pulses can be shaped, or coherent images can be implemented for optical processing.

The following pages describe our available Polarization Rotator technologies. Please be aware that these are not off-the-shelf products, but instead are built to order. Therefore modifications and options are almost always possible for those applications with more demanding requirements. In addition, pricing and delivery times can only be determined after first establishing all customer-specific requirements

MS Series of Polarization Rotators

The MS Series of Polarization Rotators offers the maximum switching speed between two orthogonal output states. Depending on drive voltage and wavelength the switching frequencies can be as high as 5 kHz. Even higher frequencies can be utilized if rotation angles of less than 90° can be accommodated. Response times are approximately equal in both directions (positive polarity to negative polarity and vice versa) at < 100 us typically, but can be as short as 15 us with higher drive voltages.

This device behaves optically like a zero-order half-wave retarder mounted in a mechanical rotation stage. Varying the electric field is identical to rotating the mechanical stage. The rotation angle varies with both drive amplitude and polarity. The positive maximum voltage will give the maximum rotation in one direction, while the negative maximum voltage will give the maximum rotation in the opposite direction. Therefore both positive and negative drive voltages are required to achieve the full 90° rotation range. In addition, the drive signal must have a zero dc offset, implying with a typical square-wave drive the output will have a 50:50 duty cycle between the 0° and 90° states. However, pulsed drives with varying voltage levels can be utilized to change the duty cycle as long as the signal has no net dc offset, and as long as the threshold voltage of the device is not exceeded.

While analog polarization rotation can be achieved, the output is very nonlinear as a function of drive voltage. Response times will also vary significantly as a function of the rotation angle (drive voltage dependant).

XT Series of Polarization Rotators

The XT Series of Polarization Rotators offers the maximum polarization purity at the two orthogonal endpoints (500:1 for broadband, as high as 10,000:1 for narrow wavelength bands). Analog rotation is possible, but will result in elliptical polarization output, even circular at the midpoint (45°). The XT Series will give very fast response times (typically < 100 us, drive voltage dependant) in one direction (unenergized to energized), while the other direction (energized to unenergized) will be slower (typically 4 ms for visible, depends on operating temperature and wavelength).

A stable output rotation angle can be held indefinitely, but will vary with changes in drive voltage or operating temperature. The drive signal must be ac, with zero dc offset to prevent damaging the device. Typically a 2 kHz square-wave is suitable. Varying the amplitude of the square-wave (while maintaining a zero dc offset) results in changing the rotation angle. A voltage of 0 V yields the maximum rotation of 90°, while the maximum voltage (typically ±10 V) yields 0° of rotation.

The XT Series lends itself well to broadband applications. These devices can be designed to provide a very uniform polarization rotation virtually independent of the wavelength.

Table 1 - Typical Polarization Rotator specifications for devices designed for the visible wavelength range. These specifications represent data gathered from a small sample of designs. Actual results will vary as a function of the final design.

Polarization Rotators	*Transmission*	*Polarization Purity*	*Maximum Switching Frequency*
MS Series	*85 – 95%*	*200:1*	*5,000 Hz*
XT Series	*85 – 95%*	*500:1*	*120 Hz*

Above specifications are subject to change without notice. Please contact Boulder Nonlinear Systems for additional updates.

Device Construction

The Polarization Rotators can be constructed using one of two types of substrates. If the transmitted wavefront distortion (TWD) must be optimized then the devices should be constructed of polished optical flats. Typically this approach will yield a TWD of < λ/10 at 632.8 nm. However, if thinner devices are required, or price is more of an issue than TWD, thin sheet glass substrates can be utilized in place of the polished optical flats.

Devices built with thin sheet glass substrates require silica spacer beads distributed throughout the clear aperture in order to maintain a uniform liquid crystal layer thickness. This approach may not be appropriate for applications requiring a high optical power density. If the clear aperture is very small, or the substrates are polished optical flats the silica spacer beads can be placed only in the perimeter glue seal.

Devices can be delivered either with or without anti-reflection (AR) coatings. Eliminating the AR coating will typically reduce the price; however it will also increase reflections and reduce the overall transmission accordingly (unless the device will be index matched to another optic – *requires a low-stress approach to avoid damaging the polarization rotator*).

The devices will typically have two short stranded wire leads attached with the free ends stripped of insulation.

Devices are usually not mounted in a housing, but housings can be designed and delivered upon request.

Optical Damage and Temperature

While BNS has not performed any optical damage threshold testing, some of our customers have provided us with their information. Permanent damage has been noted with pulsed lasers at a peak power density of 1 GW/cm^2. With CW lasers damage has been noted at an average power density of 150 W/cm^2.

It should be noted that at power densities lower than the permanent optical damage threshold the device performance will begin to change due to thermal effects. Heating a polarization rotator above room temperature will result in faster switching speeds, but can also result in poorer optical rotation performance. For the MS Series the total rotation range will decrease as temperature increases. For the XT Series the rotation range will not decrease, but the peak operating wavelength will shift towards shorter wavelengths.

If the temperatures increase significantly the device will no longer operate until it is cooled down again. For the XT Series this isotropic temperature is approximately 90°C. For the MS Series the isotropic temperature is more on the order of 60°C. The MS Series is also susceptible to damage induced by thermal or mechanical shock. Thermal shock is when the temperature is changed very rapidly. If thermal or mechanical shock occurs, the MS Series device can often be recovered through a controlled thermal and voltage treatment procedure.

Company Profile

Boulder Nonlinear Systems, Inc. (BNS) is an innovative technology company specializing in dynamic liquid crystal polarization control solutions for both laser-based and imaging systems. Company strengths in scientific research and development are leveraged into OEM and standard product offerings targeted for astronomy, biomedical, defense, microscopy, optical computing, optical storage, and telecommunications applications.

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