Lecture 19

Photonic Signals and Systems

- **An Introduction**
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- *Text Book Reference: N. A. Riza, Photonic Signals and Systems – An Introduction, McGraw Hill, New York, 2013.*

Liquid Crystal (LC) Variable Optical Attenuators (VOAs)

Topics:

- System design and working principles (electronic control as well as light polarization properties flow) of a 90 degree TNLC-based **analog-mode Fiber-Optic (FO) VOA**.

- System design and working principles (electronic control as well as light polarization and optical phase properties flow) of a BM-NLC **deflectors-based analog-mode compact FO VOA.**

- System design and working principles (electronic control as well as light polarization and optical phase properties flow) of a BM NLC Two Dimensional (2-D) Spatial Light Modulator (SLM)-based analog-mode **multiwavelength FO VOA.**

Liquid Crystal Analog Fiber-Optic (FO) Variable Optical Attenuator (VOA)

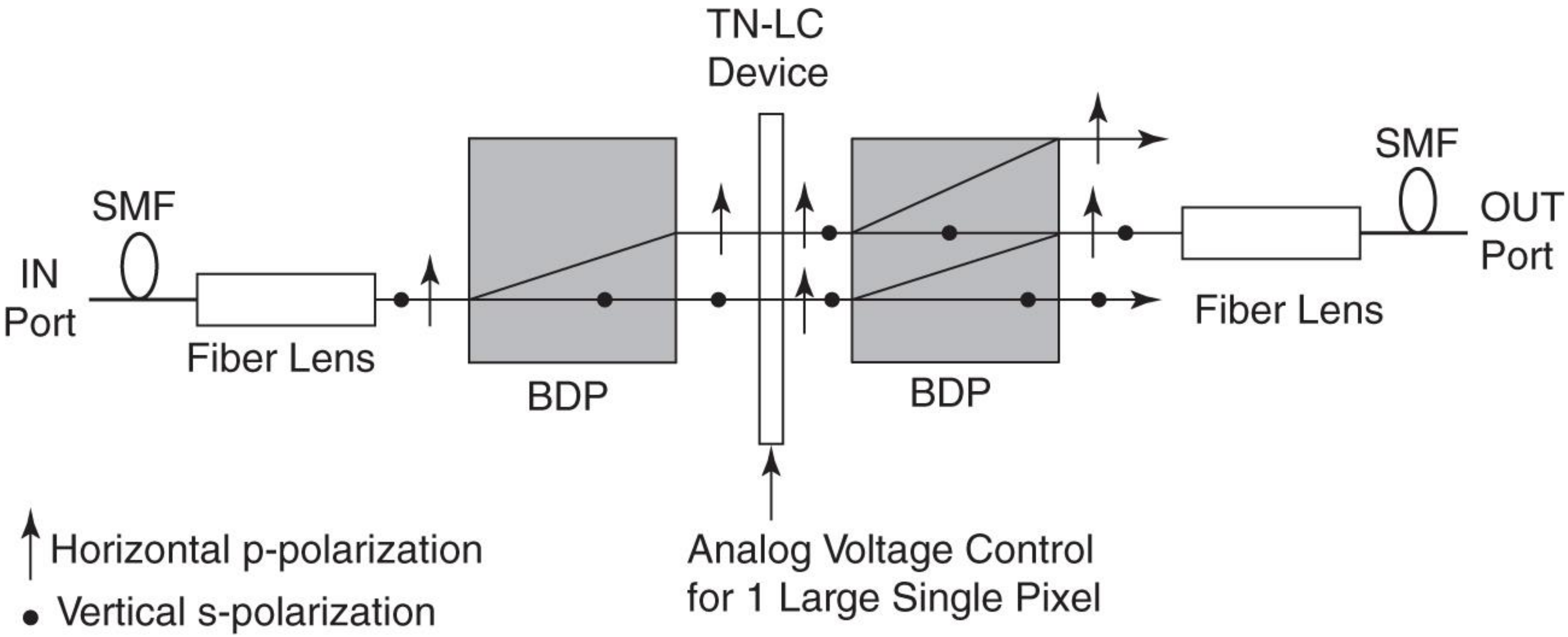

FIGURE 8.1 The liquid crystal analog fiber-optic VOA design.

Liquid Crystal Analog Fiber-Optic Variable Optical Attenuator (VOA)

Figure 8.1 shows the desired VOA using two self-imaging fiber-optic lenses, a pair of birefringent beam-displacing prisms (BDPs), and one TN-LC cell driven by an analog voltage-control signal to change the polarization control state of the TN-LC cell. Because the TN-LC device requires a linearly polarized input, the BDP is used to generate these spatially separated orthogonal p (horizontal) and s (vertical) components from the input light coming from the input SMF and fiber lens (FL).

The degree of input-light linear polarization rotation produced by the TN-LC device is controlled by the device voltage level and with zero voltage applied, all input linear polarized light is rotated in polarization by 90° that are spatially recombined by the output BDP and then sent into the output FL and SMF.

The **zero voltage state of the module becomes the zero attenuation state of the VOA.** As the voltage to the TN-LC device is increased, the two input linear polarizations directed through the TN-LC device suffer partial 90° linear polarization rotations producing both p- and s-polarizations for each spatially separated beam through the TN-LC device. When these beams pass through the output BDP, only part of these beams that have the correct linear polarizations are recombined by the BDP to be sent through the FL and output SMF. The remaining light using the output BDP is directed away from the FL and output SMF; hence, **forming an analog voltage-controlled fiber-optic VOA with a voltage-controlled attenuation setting.**

Liquid Crystal Deflector-based Fiber-Optic VOA

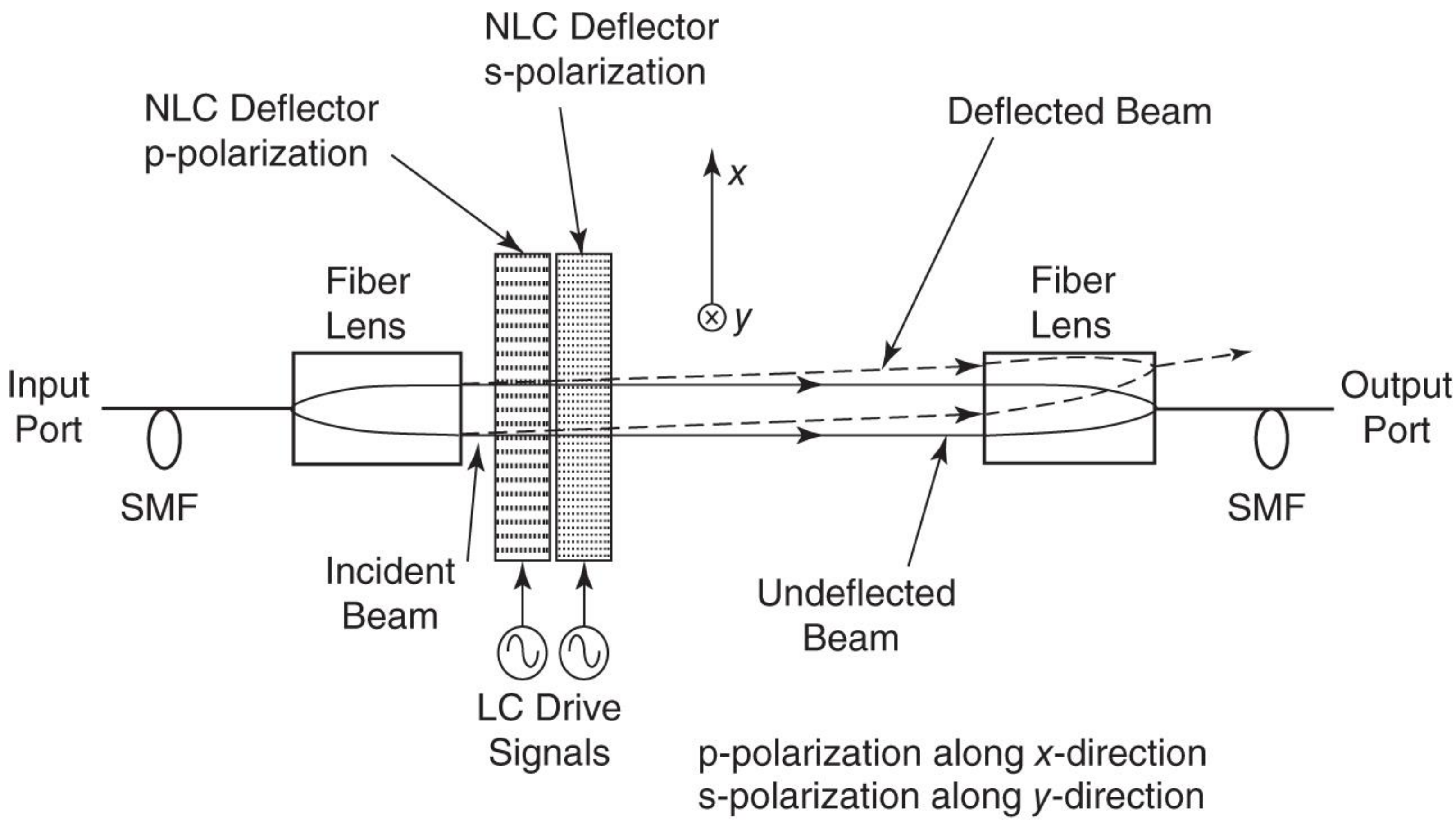

FIGURE 8.3 Liquid crystal deflector fiber optic VOA.

Liquid Crystal Deflector Fiber-Optic VOA

Light from the input SMF has both p and s polarization beams. Because LCs are polarization sensitive, two independent birefringent-mode parallel-rub nematic liquid crystal (NLC) 1D beam-deflector devices are deployed, **one to deflect the p-beam and one to deflect the s-beam.**

The distance between the output FL-SMF and input FL-SMF is designed such that the **NLC deflectors can produce adequate beam deflection to achieve no light coupling at the output SMF**.

The nematic director of the p-beam deflector is along the p-direction and the nematic director of the s-beam deflector is along the s-direction. **The NLC deflectors act as voltage programmed optical wedges to steer the input plane wave in one dimension**. The p-beam deflector moves the beam in the *x*-direction while the s-beam deflector moves the beam in the *y*-direction.

Because the SMF core is small (e.g., 9 μm at 1550 nm telecom wavelength in the fiber-based INTERNET), **only small angle (<2°) beam deflection is typically required** from the NLC deflectors to produce limited light coupling to SMF and, hence, VOA-based attenuation.

Because two separate drive signals control the VOA, a **Polarization Dependent Loss (PDL) compensator can also be realized**
By the same LC FO VOA hardware.

Multi-Wavelength Wavelength
Fiber-Optic VOA Using Liquid Crystal Controls

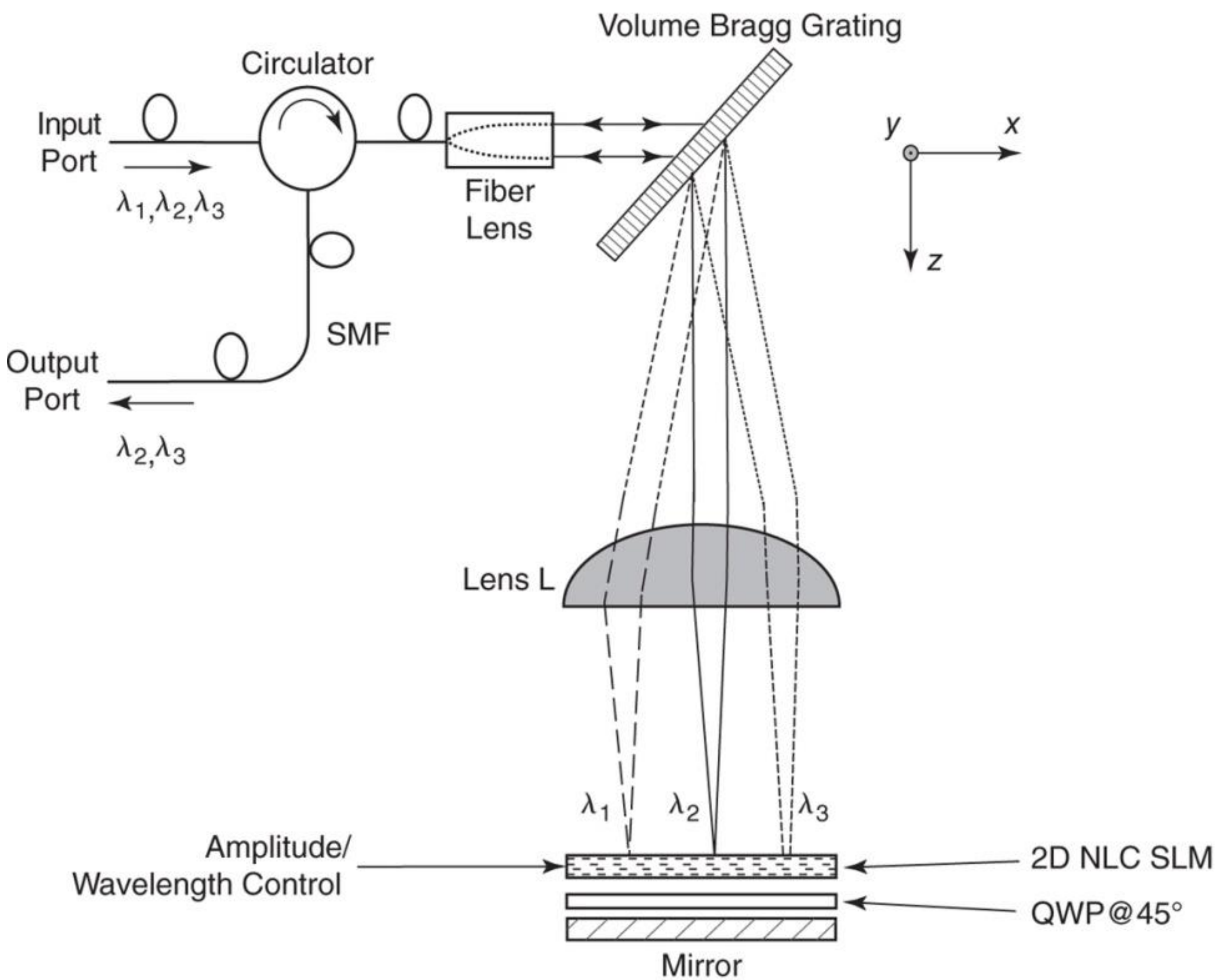

FIGURE 8.5 Multi-wavelength wavelength fiber-optic VOA using LC controls.

Multi-Wavelength Wavelength Fiber-Optic VOA Using Liquid Crystal Controls

To attenuate a wavelength, an optical wedge along the *y*-direction is created on the NLC SLM to steer the beam and, hence, **cause reduced coupling at the fiber lens.**

This operation can be done independently for all wavelengths.

Shown in Fig.8.5 is the case of 3 input wavelengths λ_1, λ_2, λ_3 and the optical phase in the NLC SLM is set such that the **λ_1 wavelength beam on the return path is completely decoupled from the fiber lens to produce wavelength blocking** while

λ_1 and λ_3 return fully Bragg-matched to the grating but with some attenuation based to the *y*-direction tilts received independently on the λ_2 and λ_3 beams on return to the fiber lens.