Silicon-on-Insulator (SOI) optical waveguides with Liquid Crystals

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In a nematic liquid crystal, the orientation of the director can be switched by applying an electric field. In the past, Liquid crystals have been combined with glass fibres, photonic crystals and SOI waveguides. The appeal of SOI waveguides is due to the fact that they are fabricated using the same processes as those of complementary metal oxide semiconductor (CMOS) technology. Their most distinctive feature is high index contrast which results in tight optical confinement. SOI waveguides combined with liquid crystal could lead to tunable integrated optical devices.

In our studies we determine the full dielectric optical tensor of the liquid crystal upper cladding for a given applied voltage by using a finite element based liquid crystal hydrodynamics solver [1]. Next we use a finite element based fully anisotropic mode solver [2] to compute the modes supported by the whole structure. A TE (TM) mode is one for which the x-component (y-component) of the electric field is the most dominant of all three (x, y, z) electric field components. Consequently, the refractive index 'felt' by TE and TM modes depends on the orientation of the director in the liquid crystal cladding. We start with the director aligned along the z-axis; the TM and TE modes see the same index (ordinary refractive index, n_o) in the cladding. By applying a voltage between the bottom of the waveguide and the top of the liquid crystal we can switch the director so it now lies in the y-z plane. In this configuration, the TM mode feels a cladding index $(n_e(\theta))$ which is an average of the extraordinary (n_e) and ordinary refractive indices of the liquid crystal weighted with the angle θ between the director and the z-axis. In this case, the TE mode still feels an index n_o in the cladding. As such we can increase the refractive index of the TM mode while keeping that of the TE mode more or less constant. The refractive index of the TM (TE) mode increases (decreases) by an amount equal to about 20 % (3 %) of the liquid crystal birefringence. For a given waveguide geometry; as the applied voltage is increased, the cladding index felt by the TM mode increases. At a certain voltage, the TM mode starts leaking out into the cladding. When this happens the TM mode is said to be in cut-off; it isn't guided anymore. As such we realize an optical switch for the TM mode. Typically, depending on the liquid crystal used and the waveguide geometry the TM mode in the waveguide can be turned on or off by applying 0V or about 10V respectively. In a final step, we plan to set our studies on a firm footing by performing optical measurements.

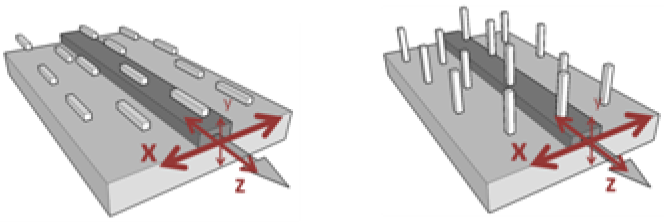

Figure 1: geometry of a rib waveguide with liquid crystal cladding

References:

[1] R. James et al. , *Finite-element modelling of liquid crystal hydrodynamics with a variable degree of order*, IEEE Transactions on Electron Devices, Vol. 53, pp. 1575-1582 (2006).

[2] J. Beeckman et al, *Calculation of fully anisotropic waveguide modes*, J. of Lightwave Tech., Vol. 27, pp. 3812-3819 (2009).

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