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Optical Materials in CST STUDIO SUITE

This paper demonstrates the electromagnetic simulation of optical materials and explains how anisotropic and nonlinear material properties can be modeled virtually. Topics covered include birefringence, dichroism, magneto-optical activity and Kerr media. Using these material models, engineers can design and simulate photonic devices digitally, allowing them to analyze and optimize the performance of photonic systems before committing to manufacturing.

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WHITEPAPER
OPTICAL MATERIALS IN CST STUDIO SUITE

For many optical applications, materials are needed with anisotropic or nonlinear properties. Two important examples of such properties are birefringence and dichroism. Such materials exhibit different refractive indices and attenuation for orthogonal optical polarization states. They are used to alter the polarization state of the light for example in polarizers or polarization converters. A special case of a polarization dependent material property is magneto-optical activity. Magneto-optical active materials can also be used to alter the polarization state, but more importantly they can be used to build non-reciprocal components like isolators. Further, the optical properties can not only depend on the state of polarization but also on the electric field amplitude of the light wave. The optical properties can depend on the second, third power or even higher powers of the electric field. Here, the effects and applications are vast – amplification, frequency conversion, and all-optical switching to name but a few.

Optical components usually utilize weak optical effects that accumulate over distances a hundred or even a thousand times the optical wavelength. This is not an option for optical systems that are intended to be integrated on the chip scale. This problem can be mitigated by utilizing compact resonators which strongly increase the interaction with optical materials. However, due to the strong confinement of the light, resonance approximations often become invalid and simple theoretical predictions become cumbersome. Here, we demonstrate three examples of application of optical optical materials in integrated components. The direct numerical simulations help to understand the underlying mechanisms and demonstrate side effect not predicted by simplified theories.

In part I, we present birefringent and dichroic materials and show how strong anisotropy can suppress substrate leakage of ring resonators and waveguides. The 3D simulation shows that anisotropic materials should be considered carefully when all polarizations are present. The anisotropic material suppresses the leakage of the dominant polarization in the waveguide mode, but at the same time provides additional leakage channel for the orthogonal polarization.

In part II, we show how a magneto-optically active material can rotate the polarization of an optical wave. For integrated waveguides, strong birefringence prevents this rotation. Instead, the magneto-optical material is used to make the propagation constant of the guided wave direction



**PART I
BIREFRINGENT AND DICHRIC MATERIALS**

In birefringent materials the phase velocity of a light wave depends on the polarization and propagation direction. Mathematically this means that the permittivity of such materials is a tensor:

$$\mathbf{D} = \begin{pmatrix} \epsilon_{xx} & 0 & 0 \\ 0 & \epsilon_{yy} & 0 \\ 0 & 0 & \epsilon_{zz} \end{pmatrix} \mathbf{E}$$

Materials for which two of the components are identical are referred to as uniaxial. If all three components are different from each other the material is called biaxial.

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