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Coupled-Mode Theory for Complex-Index, Corrugated Multilayer Stacks

Hannes LÜDER^{1*}, Martina GERKEN¹, and Jost ADAM²

¹Institute of Electrical and Information Engineering, Christian-Albrechts-Universität zu Kiel, Kaiserstraße 2, 24143 Kiel, Germany

²Mads Clausen Institute, University of Southern Denmark, Alsion 2, 6400 Sønderborg, Denmark

*halu@tf.uni-kiel.de

We present a coupled-mode theory (CMT) approach for modelling the modal behaviour of multilayer thinfilm devices with complex material parameters and periodic corrugations. Our method provides fast computation and extended physical insight as compared to standard numerical methods.

Nanostructuring of multilayer thin-film devices, like OLEDs, is a common technique to manipulate the light out-coupling from and/or the field distribution inside the device. Recently, compound binary grating structures have been proposed for tailoring the angular emission spectrum of light emitting thin-film devices [1] and for increasing the sensitivity of refractive index sensors [2]. Here, we show a coupled-mode theory approach for modelling such devices. We first calculate the unperturbed waveguide modes (Fig.1), used as basis functions in the coupled-mode formalism. The waveguide corrugation is treated as a perturbation and leads to coupling between the modes. Expanding our previous work [3], we introduce perfectly matched layer (PML) boundary conditions, to maintain a discrete, complete set of modes [4], and allow for complex-index materials. These extensions, however, cause the resulting eigenvalue equation to be non-Hermitian, introducing two major consequences. First, the eigenvalues (i. e. the mode n_{eff}) have to be found in the complex plane (Fig. 2). Second, the classical mode orthogonality is no longer valid. We address both challenges by a combination of three complex-root solving algorithms, and by choosing a bi-orthogonal basis, obtained by solving the corresponding adjoint problem. With the once found modal solutions of the unperturbed waveguide, we can calculate the coupling coefficients, which describe the mode coupling caused by the introduced periodic corrugation.

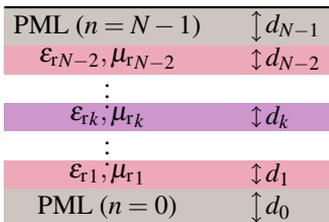


Figure 1: Multilayer slab waveguide with PMLs

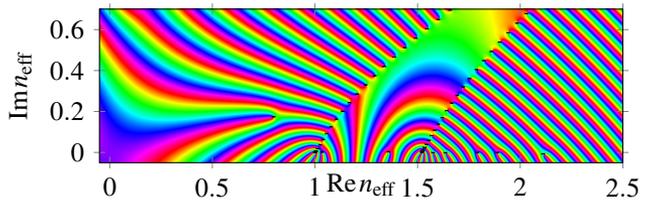


Figure 2: Phase portrait of a waveguide characteristic function f . The complex n_{eff} -plane is colored by translating phase $f(n_{\text{eff}})$ into color values.

References

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