Modeling methods for high-index contrast linear and non-linear nanophotonics

invited paper

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***Abstract*-We present several modeling methods for the study of nanophotonic devices: a non-linear eigenmode expansion method and a non-linear complex Jacobi method to model Kerr devices, and an RCWA-based model to study extraction of light from OLEDs using periodic structures.**

I. INTRODUCTION

We present several frequency domain methods for modeling nanophotonic devices.

Firstly, we will discuss modeling of Kerr non-linear devices, based on an iterative extension of the eigenmode expansion method [1].

Secondly, a different method of simulating Kerr devices will be discussed [2], which is based on an extension of Hadley's complex Jacobi iteration method. As Hadley's method is already iterative in its original, linear form, it does not require significant modifications to incorporate Kerr non-linear effects.

Finally, we will discuss the use of a model based on the rigorous coupled wave approach (RCWA) to study the extraction of light from an organic LED stack using periodic structures.

II. KERR EIGENMODE SOLVER

To model Kerr non-linear methods using the eigenmode expansion method, we discretize the non-linear parts of the structure to be modeled. Then, we perform a series of linear eigenmode expansion simulations, updating the refractive index in each cell according to the Kerr equation, until we get self-consistency.

The method is especially efficient for photonic crystal cavities, where the field is highly localized and therefore the region to be spatially discretized is small.

Fig. 1 shows the field profile of a self-localized mode in a non-linear photonic crystal structure without structural defects.

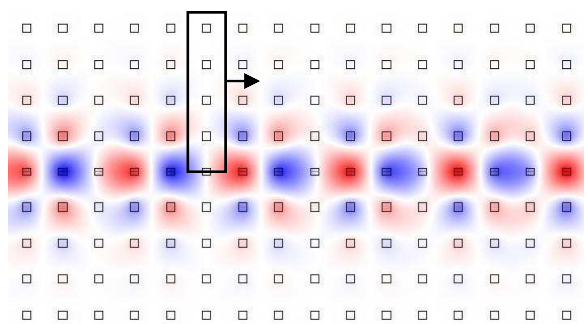

Fig.1: self-localized waveguide

III. NON-LINEAR COMPLEX JACOBI SOLVER

When the non-linearity is present in larger areas of the structure to be modeled, an extension of the complex Jacobi method becomes more suitable. As Hadley's method is already iterative in its original, linear form, it is naturally suited to incorporate Kerr non-linear effects, by updating the refractive indices according to the Kerr equation at each step.

Fig. 2 shows as an example the field profile in a non-linear grating coupler, which can be used as an all-optical flip-flop.

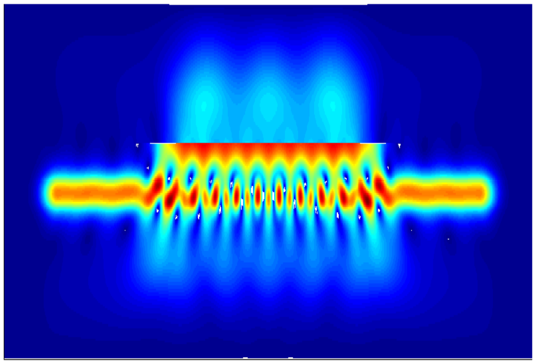

Fig. 2: Non-linear grating coupler

V. RCWA LED MODEL

We also present a comprehensive model to study light extraction from light-emitting diodes, more specifically organic LEDs. The model expands the field of the spontaneously emitting dipole into propagating and evanescent plane waves. The resulting field profile coming from the multiple reflections at the top and bottom mirror of the microcavity is then calculated.

These mirrors can include a periodic structure. The scattering properties of these gratings are calculated using the rigorous coupled wave approach (RCWA).

Finally, the influence of multiple reflections inside the thick substrate beneath the microcavity is taken into account by constructing a similar model, but this time using power densities rather than amplitudes in order to reflect the incoherence effects.

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