Parallel Calculation for Electromagnetic Field with Local Fourier Coupled Mode Theory

Sungjae Park, Jonghyun Lee, Youngjae Kim, Shin-Woong Park and Hwi Kim*

Department of Electronics and Information Engineering, Korea University, 2511 Sejong-ro, Sejong 30019, South Korea
E-mail: hwikim@korea.ac.kr

1. Introduction

Recently, as the display rapidly develops, a lot of research and development related to display technologies are being carried out. In particular, organic light emitting diode (OLED) display devices have complicated optical structures on the nanoscale and different luminescent properties depending on the polarization of light. To analyze this complicated OLED displays, the methods for Electromagnetic (EM) field analysis such as the finite difference domain (FDTD), the finite element method (FEM) and the rigorous coupled-wave analysis (RCWA) are generally used. In this study, we used Fourier modal method (FMM) [1] based on RCWA to calculate the EM field. However, to calculate the EM field of a large-area display using the FMM, it is necessary to use a high-resource computer or a special methodology for parallel computation. Therefore, we propose a method for parallel process of FMM that can perform calculations on general level calculation systems such as a personal computer (PC). Our approach is the derivation of the parallel FMM based on the coupled mode theory (CMT) [2] and free-space extension technique. This algorithm allows efficient calculation of the EM field of a large area display through parallel FMM.

2. General Instructions

To calculate the EM field of the large-area OLED display, we use the hybrid method of FMM calculation and angular spectrum method as shown in Fig. 1. Free-space, which is homogeneous, does not need to be computed by FMM because an analytic field model with low computation can be applied. The local Fourier coupled mode theory (LFCMT) computes total area through synthesis of field calculation for computed local EM field applying the hybrid analysis.

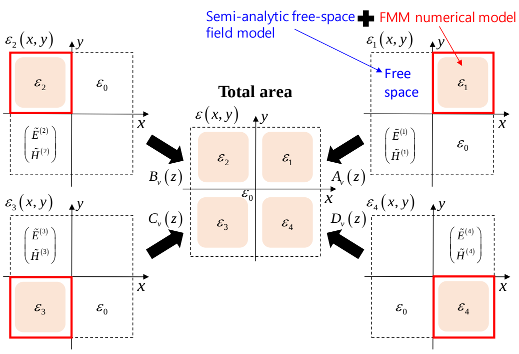

Fig. 1 Hybrid analysis method applying simultaneously FMM and angular spectrum method

This is an efficient calculation because the amount of computation is significantly reduced compared to the conventional method. The equation for global EM field is as follows,

$$\begin{pmatrix}\tilde{E}\\ \tilde{H}\end{pmatrix} = \sum_v \left[A_v(z)\begin{pmatrix}\tilde{E}^{(1)}\\ \tilde{H}^{(1)}\end{pmatrix} + B_v(z)\begin{pmatrix}\tilde{E}^{(2)}\\ \tilde{H}^{(2)}\end{pmatrix} + C_v(z)\begin{pmatrix}\tilde{E}^{(3)}\\ \tilde{H}^{(3)}\end{pmatrix} + D_v(z)\begin{pmatrix}\tilde{E}^{(4)}\\ \tilde{H}^{(4)}\end{pmatrix} \right]$$

Simulation result of the bidirectional LFCMT for the two-dimensional structure with five waveguides is shown in Fig. 3(a). The light is propagated through optical interaction which is the light spreads in both directions from a dipole located at the center. Figure 3(b) show the calculation result for the three-dimensional structure with a 2 by 2 wave guide. It can be confirmed that the light propagates in the z-axis through the optical interaction.

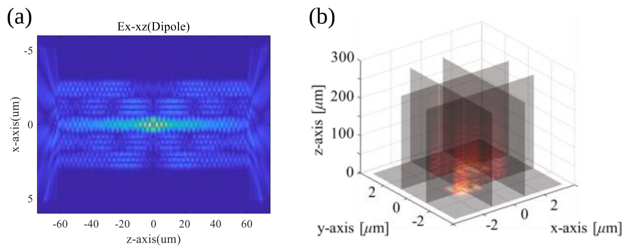

Fig. 2 The simulation results of EM field calculation for (a) 2D bidirectional structure and (b) 3D structure

3. Conclusions

The LFCMT proposed in this study is a new method to solve the difficult problems that have not yet been solved in the industrial field because it can calculate the large area EM field based on the CMT and the free-space extension method unlike the conventional method. It will also contribute greatly to the development of the ultra-high-resolution displays, a key issue for the next-generation displays.

Acknowledgements

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References

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[2] W.-P. Huang, "Coupled-mode theory for optical waveguides: an overview," Journal of the Optical Society of America A, vol. 11, no. 3, pp. 963-983, 1994.