# Accurate modelling of the optics of high resolution liquid crystal devices including diffractive effects

Mengyang Yang, Zijun Nie, Sally E. Day and F. Aníbal Fernández

Department of Electronic & Electrical Engineering,

University College London, Torrington Place, London WC1E 7JE

The optical behaviour of high-resolution liquid crystal (LC) devices or devices containing small features or LC defects cannot be modelled accurately with the simple methods normally used for traditional display configurations. In this work, an accurate modelling of the liquid crystal structure that yields the order tensor distribution over the complete structure [1,2] is combined with the electromagnetic modelling of waves propagating through the device, calculated using the finite difference frequency domain (FDFD) method.

One of the main difficulties with such an approach is that the numerical solution of the Helmholtz equation involves the solution of large and sparse matrix problems where the matrices are complex, indefinite and frequently, non-symmetric, particularly when absorbing boundary conditions such as the perfectly matched layers (PMLs) are used. The resultant global matrix is normally severely ill conditioned and this makes the most common iterative methods highly inefficient without adequate preconditioning [3]. In this work, a sweeping preconditioner [4] is constructed, specially adapted for this type of problems. The sweeping preconditioner takes advantage of a frontal numbering scheme that correspond to physical layers of the structure. An approximate solution can then be constructed by dividing the structure into subdomains of a few layers and successively finding the approximate solution for these subdomains when the rest of the structure is replaced by PML layers. The resultant preconditioner is then an incomplete block LDU factorization. This approach, to construct a sweeping preconditioner by moving PMLs is particularly appropriate for cases where propagation is mainly one-directional but will not be accurate in cases where there are large reflections or resonances. However, by applying the total-field/scattered-field formulation [5] to construct the matrix problem, this restriction is eliminated making this method effective for all types of problems. The resultant preconditioned matrix problem is then solved efficiently using an iterative technique such as GMRes.

The method will be demonstrated with modelling results for an LC microlens, an LC-based ring resonator and other examples of LC cells containing defects.

References

[1] R. James et al., “Finite-element modelling of liquid-crystal hydrodynamics with a variable degree of order,” IEEE Trans. on Electron Devices, DOI: 10.1109/TED.2006.876039, vol. 53, Nº 7, pp. 1575-1582, July 2006.

[2] E. Willman et al., “Modeling of Weak Anisotropic Anchoring of Nematic Liquid Crystals in the Landau-de Gennes Theory”, IEEE Trans on Electron Devices, ISSN: 00189383, DOI: 10.1109/TED.2007.904369, vol. 54, Nº 10, pp. 2630-2637, Oct. 2007.

[3] O.G. Ernst and M.J. Gander, “Why it is difficult to solve Helmholtz problems with classical iterative methods,” In Numerical analysis of multiscale problems, I.G. Graham et al. (eds), pp. 325-363. Springer, 2012.

[4] B. Engquist and L. Ying, Multiscale Model. Simul. vol. 9, pp. 686-710, 2011.

[5] K. Umashankar and A. Taflove, “A novel method to analyse electromagnetic scattering of complex objects,” IEEE Trans. Electromagn. Compat., vol 24, Nº 4, pp. 397-405, Nov. 1982.