On the Development of LCD Simulator: ProLCD

Han Yong Lee, Se Chung Pang, Hyun Suk Kim, Mi Yu, Jun Sik Oh
Technology Division, Samsung Display Devices,
575, Shin-Dong, Paldal-Gu, Suwon, Kyungki-Do, Korea, 442-390

Abstract

We have developed the LCD Simulator, which is called "ProLCD", in order to reduce time and efforts for the design and analysis of LCDs. We describe the numerical models implementing the computation of LC directors and electro-optics, the graphic user interface and the visualization modules. Many applications show that ProLCD is a very useful, interactive design tool with good reliability.

Introduction

Recently, LCDs have been widely used for flat panel displays of monitors, TVs and mobile devices, etc. As they are required to have better performance such as higher resolution, wider viewing angle, or higher contrast, it becomes challenging to obtain the optimal design parameters by experiments due to phenomenal increase in design variables.

In order to reduce time and efforts for investigating the interdependence between design parameters of liquid crystal cells, we have developed in-house ProLCD , the LCD Simulator. In this paper we briefly present the theoretical background and the configuration of ProLCD.

Theoretical Background of Numerical Models

Many authors have studied numerical models for calculating the performance of LCDs [1]. Such numerical models consist of two steps. First, the distributions of LC director are calculated for applied voltages. We solved Euler-Lagrange's equations based on the minimization of the total free energy, the integral of the elastic and electric energy density over LC cell [2]. We also took into account back flow effects by Erickson-Leslie theory [3].

Next, Maxwell's equations are solved for a propagation of light in anisotropic liquid crystal media. For a normal incidence of light, we used the 2X2 Jones matrix method [4]. For an oblique incidence of light, we adopted the extended 2X2 matrix method improved by Yeh [5] for a fast computation and the 4X4 matrix method developed by Berreman [6] for an accurate computation including multiple reflection. A systematic review of these theories can be found in ref.1

Configuration of ProLCD

The LCD consists of several layers like polarizers, LC cells, retardation films, color filters, glass etc. Fig.1 shows the diagram of ProLCD describing the process of analysis and design of LCDs. From this diagram ProLCD is composed of several modules related to Preprocessor, Solver, and Postprocessor.

The graphic user interface(GUI) based on Windows 95 allows the user to interact with these modules user-friendly. Fig.2 displays the typical menu of Preprocessor. You can construct the structure of LC layers and make data files for material properties and cell parameters of liquid crystals, polarizers, and retardation films. You can also consider the thin-film multilayers like SiO2, PI, and TOP coating.

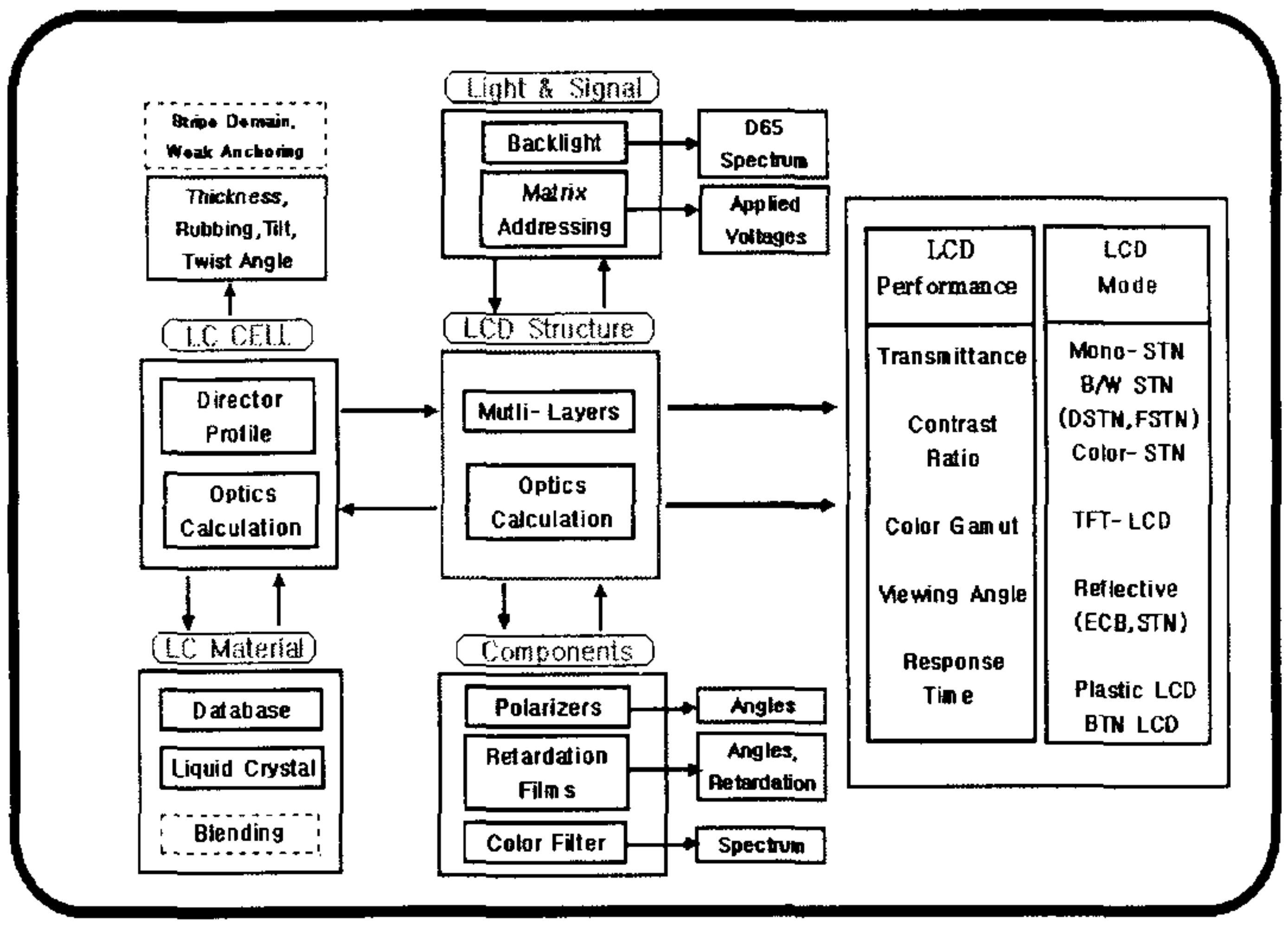


Fig.1 Diagram of ProLCD Software.

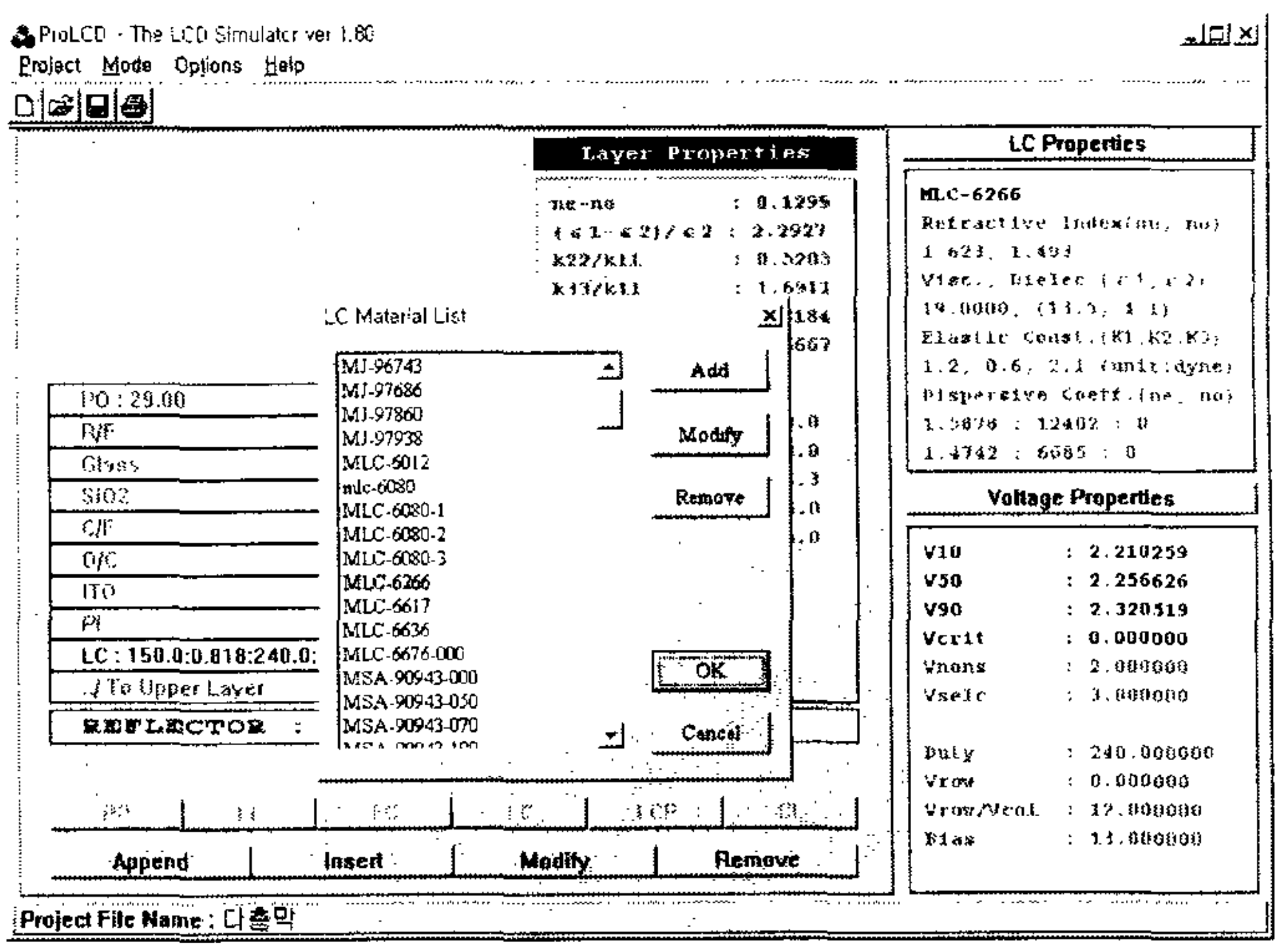
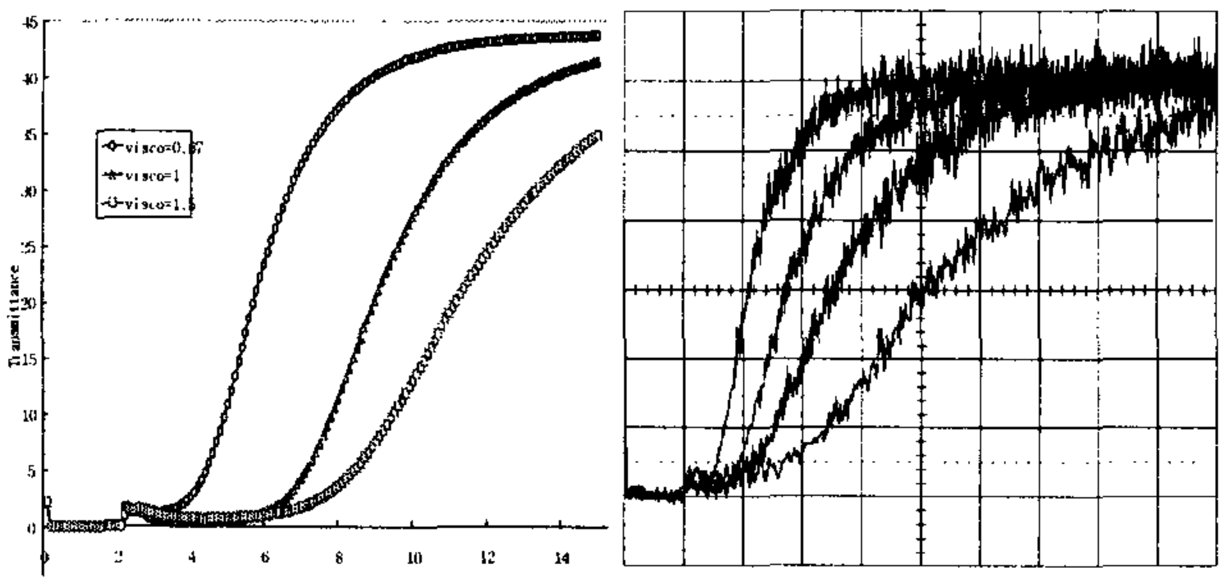


Fig.2 Typical menu for Preprocessor of ProLCD.

It shows several dialog boxes to indicate the LC database, Layer Structure, and Information related to LC, Layer, & Voltage.

Solver is made of many modules which can calculate the distribution of LC director al applied voltages and analyze a propagation of light through LC layers. In the postprocess the results obtained from Solver are visualized by graphics modules.

The electro-optical characteristics of LCDs are regarded as the transmittance, the contrast ratio, the viewing angle, the color gamut etc. According to them it has several dialog boxes which enable to



(a) (b)

Fig3. The transmittance vs. time with viscosities of BTN LCD. (a) Simulation results. (b) Experimental results.

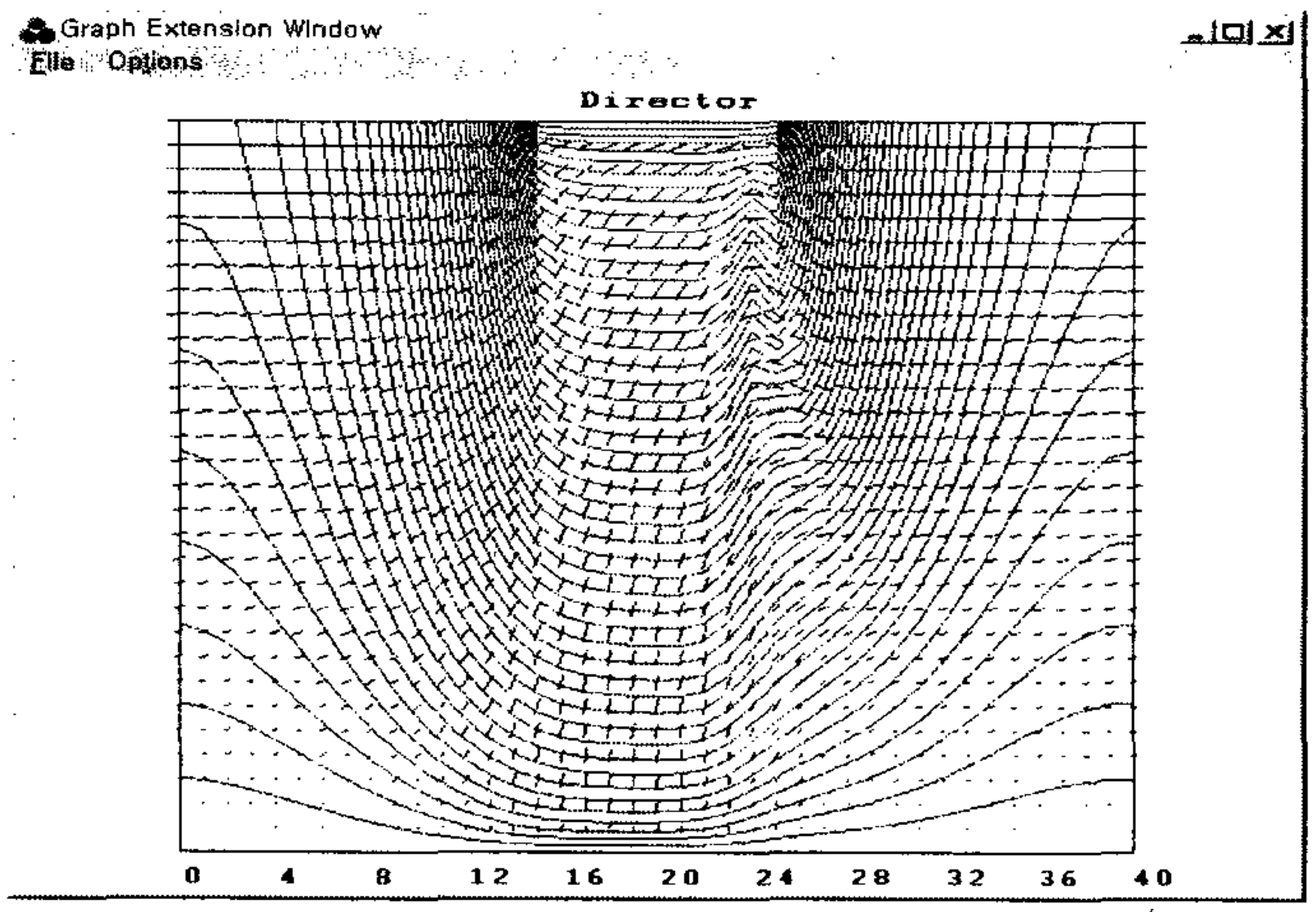


Fig.4 2-dimension simulation of LC cell.
The disclination near the right end of the upper electrode is observed by the distribution of equipotential lines and director deformation.

display the deformation of LC directors, the transmittance-voltage curve, the transmittance-wavelength curve, the contrast-voltage curve, the iso-contrast curve, the path in color triangle between on and off voltages.

Application and Discussion

ProLCD enables to perform the numerical analysis for both the transmissive and reflective types of LCDs. It can deal with TN-modes, STN-modes, ECB-modes, VAN- or HAN-modes, Multidomain-modes, BTN-modes. It allows the performance optimizations with material and cell parameters, respectively.

In ref.7, we carried out the optimization process to find the wide viewing angle by using several compensation films: one negative film, two symmetric negative films, crossed films for normally white TN and negative films, crossed films, one biaxial film for STN. Fig.3 illustrates an example of BTN LCD which has been done recently [8].

For high resolution displays, we need to deal with a 2-dimensional model of electrodes or spacers to analyze the fringing

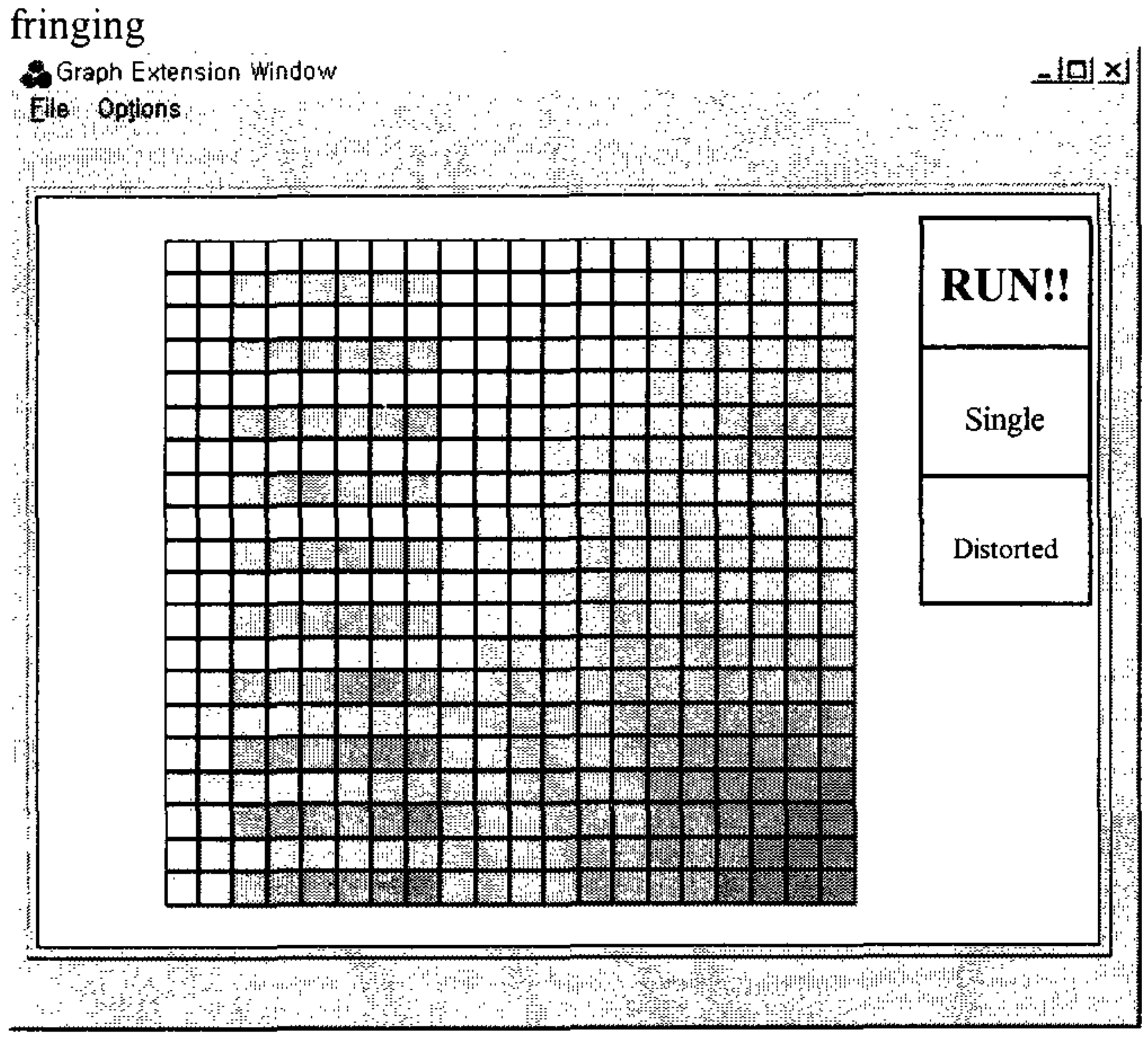


Fig.5 Crosstalk simulation example of the stripe pattern . Dark pixels indicate a severe voltage drop compared to bright pixels. Input parameters can be modified in the tool to minimize the crosstalk.

effects. Fig.4 shows the distribution of inhomogeneous electric fields and director deformation in a typical 2-dimenstional LC cell.

On the other hand the passive matrix LCD usually suffers from crosstalk and so we have developed the tool for the diagnosis of crosstalk by cell-electrical analysis as shown in fig.5.

From the functional viewpoint of programming, ProLCD can turn into each mode interactively without changing the interface despite of dealing with various LCD-modes,.

Conclusion

We have developed "ProLCD" as an interactive design tool of LCDs. It has been applied for developing the several new modes of LCDs to achieve the improved performance such as wide viewing angle, high contrast ratio etc. From these applications it has become a very useful tool with good reliability which can test many designs quickly and cheaply and speed the development of new devices.

References

[1] H. Wohler and M. E. Becker, *SID'98 Application Seminar A2*, 1998.
[2] D. W. Berreman, *Phil. Trans. R. Soc. Lond. A,* vol.309, pp.203-216, 1983.
[3] S. Chandrasekhar, *Liquid Crystals*, 2nd ed., Cambridge University Press, pp.85-98, 1992
[4] R. C. Jones, *J. Opt. Soc. Am,* vol.31, pp.488-493, 1941
[5] P. Yeh, *J. Opt. Soc. Am,* vol.72, pp.507-513, 1982.
[6] D. W. Berreman, *J. Opt. Soc. Am,* vol.62, pp.502-510, 1972
[7] B. H. Lee, S. Y. Lee, S. C. Pang, and H. Y. Lee, *SID'96 EuroDisplay,* pp.359-361, 1996
[8] J. S. Oh and H. Y. Lee, *IDW'99*, accepted.