Reflective Liquid Crystal Displays: The Next Major Paradigm Shift in Display Technology

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Abstract

As requirements for display information burgeon in the future and as flat panel displays progress towards being the dominant form of electric media, a paradigm shift from emissive displays to reflective displays appears inevitable. Reflective liquid crystal display technologies are currently poised to accomplish this shift and will greatly expand the capabilities of today's highly successful and dominant self-luminous flat panel liquid crystal displays.

Introduction

In the vastly expanding information age, where high information content is the best selling commodity and display images define the 'personality' of the entire product, flat panel display have been phenomenally successful as the primary interface between user and product in many imaging applications. Flat panel displays have become an indispensable way to render information in any combination of text, graphics, still images, and video. The recent information explosion has resulted in significant research and manufacturing investment to develop novel electro-optical materials for flat panel display technologies. The commercial fruits of these investments are currently being enjoyed in products such as notebook computers, personal digital assistants (PDAs), wide screen projection systems, etc.

Today's dominant flat panel display technology is based on the electro-optic properties of liquid crystalline materials. Liquid crystal display (LCD) technology currently accounts for approximately 86% of the total world wide sales in the flat panel display market.[1] The technical know-how and infrastructure in place for LCDs is tremendous, and as the need for information grows in the future, LCDs are expected to capture even more the market share. Challengers to LCD technologies, such as plasma, electroluminescent, and vacuum flourescent displays, are predominately restricted to non-portable markets; for example, plasma displays for large direct-view applications. Newcomers to the flat panel display arena, such as field emission displays and organic electro-luminesensce displays, must overcome many of their own limitations and contend with the maturity and infrastructure of LCDs.

There are several major and consistent in information displays. First are the ever increasing demands for higher display resolution and information content. Second is the evolution towards thin, lightweight, low power displays for portable applications. Third is the ubiquitous use of color for information coding and imaging, coupled with the markets demand for full color, high performance displays systems. These trends are responsible for driving current display systems to the state-of-the-art. Today's display technology is dominated by self-emissive display devices such as cathode ray tubs (CRT's) for desk-top applications and the backlit active-matrix (AM) LCD for portable applications.

Color is vital for information coding and guiding visual search on complex information displays, and high-fidelity color displays are a prerequisite for most imaging applications. Rapid improvements in the quality and availability of color image capture and printing systems have further pushed the emphasis on full-color imaging. At the same time, steady advances in liquid crystal display (LCD) technology have not only made color displays pervasive, but have permitted the migration of color technology from our working environments to our leisure environments, homes and vehicles.

These trends place increasingly stringent demands on existing color display technologies, which are all either emissive devices (e.g., shadow-mask color CRTs, electro-luminescent displays, color plasma displays) or contain some internal source of illumination (e.g. transmissive color LCDs with integral backlighting). While self-luminous displays have evolved into highly capable devices for electronic color imaging, they suffer from a number of shortcomings which limit their future utility. First, self-luminous displays require relatively large amounts of power to achieve sufficient luminance for most visual tasks and many operating environments. As levels of ambient illumination increase, they typically exhibit degraded contrast and insufficient luminance. These adverse changes can be largely compensated by putting more power into the display, at least up to a limit. Second, the colorimetric characteristics of self-luminous color displays do not respond naturally to changes in the ambient environment. Natural objects and most reflective color reproductions exhibit predictable and consistent changes in their reflected spectral power distributions as the level and spectral composition of ambient illumination changes. This enables visual/ perceptual mechanisms of color constancy and gain control to adapt the state of the human visual system to prevailing conditions of illumination. As the level of ambient illumination increases, natural objects become more luminous and typically more saturated in color. In contrast, self-luminous displays do not inherently increase in luminance with increased illumination and color saturation is generally reduced via diffuse broad-band reflections. Third, self-luminous color displays tend to be large and heavy, although recent trends in flat-panel displays have resulted in dramatic reductions in weight and volume. Finally, self-luminous color displays remain relatively expensive, at least in part due to the large number of display components and the need to handle significant power levels.

The transition to reflective color displays represents the next major paradigm shift in the evolution of display technology. Advances in liquid crystal (LC) materials and optical configurations have already produced reflective monochromatic displays with dramatically improved reflectance and resulting display visibility. These new displays, which are just now beginning to enter the marketplace, represent a significant advance over the now commonplace twisted-nematic (TN) and super-twisted nematic (STN) LCDs.[2] High performance reflective color remains an elusive goal at present, as the technical challenges to achieving a large color gamut, high excitation purity and sufficient reflective luminance for a broad range of viewing conditions are formidable. Nevertheless, the prospects for such a display device are compelling, and the enabling display technologies and knowledge bases in color and vision science are well positioned for the development of high-performance reflective color displays.[3]

A review of the current state-of-the-art in reflective display technology will be presented.[3] An analysis of why existing approaches have at best produced only marginal results and attempt to define the colorimetric and visual requirements for effective color displays[4] based solely on reflective ambient illumination. An overview of a number of recent developments in LC materials and optics which provide the building blocks for the future generation of reflective color devices will be presented. Finally, a technical approach to the development of a high-performance reflective color display will be discussed.

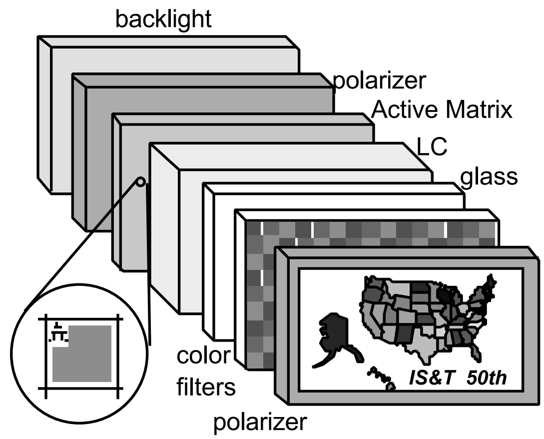

Figure 1: The optical stack for a backlit LCD. A standard configuration used in notebook computers. The liquid crystal serves as a spatial light modulator of the backlight.

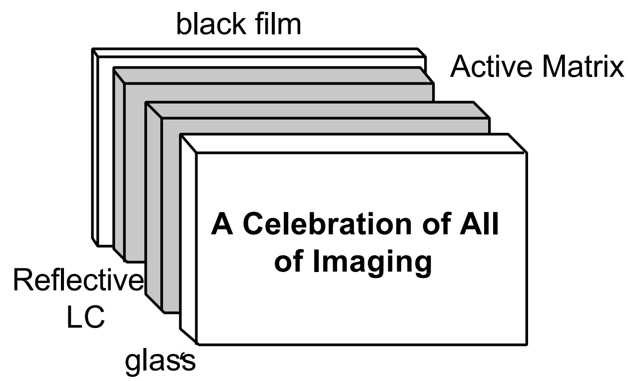

Figure 2: The optical stack of a reflective LCD. No backlight or absorbing elements are required. The display reflects the image to the user using the ambient lighting conditions. The reflective display is more compact, lighter, and uses less power than the transmissive display shown in Figure 1.

References

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4. L. D. Silverstein and T. G. Fiske, *Proceedings of the First IS&T/SID Color Imaging Conference*, **1** 149 (1993).