Design improvements for flat panel displays

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Displays built with time-multiplexed optical shutter (TMOS) technology are energy efficient and well suited for portable and avionics applications.

Today’s incumbent flat-panel display technologies enjoy dominance by achieving efficiencies of scale for traditional designs. LCDs and plasma displays (PDs) have steadily dislodged cathode ray tubes (CRTs), while newer technologies, such as organic light emitting diodes (OLEDs) and liquid crystal on silicon (LCOS) jockey for dominance in a changing marketplace. Each technology has a preferential size range beyond which economies of scale or compromised yields increase costs disproportionately. Most incumbent technologies are energy inefficient (a liability for portable deployment), require expensive retrofits to meet niche markets (such as avionics), and are limited by their core operational principles (see Figure 1).

Conventional color displays may have more than a million pixels, typically comprised of a red, blue, and green subpixel, each with its own control mechanism. (PDs can have more than three.) This tripling and miniaturizing of components reduces manufacturing yields. Historically, yield improvements arose from brute force rather than by reassessing the three-subpixel paradigm. Having reached the limits in this approach, interest in ‘exotic’ display technologies has been rekindled. These alternative approaches not only address existing limitations, but deliver new, previously unimagined functionality. Our research has focused on time multiplexed optical shutter (TMOS) technology.

TMOS combines field-sequential color (FSC) techniques with the principle of frustrated total internal reflection (FTIR). Red, green, and blue light is sequentially edge-injected (at high frequency) into a slab waveguide (glass or polymer). The evanescent field projecting from the waveguide provides the photon pool that is accessed with a simple micro-electro-mechanical-systems- (MEMS-) like structure for image generation. When a pixel is charged, a high-refractive-index membrane is propelled across a 250nm gap to the waveguide surface. Upon contact, light couples from the waveguide into the membrane and propagates to the viewer. Very rapid actuation of the membrane (response time of 650ns) permits pulse width modulation using binary encoding to generate color. The resulting system has fewer layers than an LCD, enjoys the benefits of large feature size, is transparent, and energy-efficient.

Using unicellular pixels simplifies the TMOS architecture and improves manufacturing yields. Unlike LCDs, the TMOS waveguide is not a backlight, nor do the pixels act as opaquing shutters (see Figure 2). It does not require color filters (as all but FSC-based LCDs do) or polarizers, improving efficiency. For example, in a 2.5in-diagonal 640×480 cell-phone display, the best LCDs deliver 260 nits (natural units of information) at 300mW, whereas TMOS can deliver 2,053 nits at 300mW.

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(or, conversely, 260 nits at 37.9mW). As the power efficiency of the drive LEDs improves, TMOS efficiency improves proportionately. Moreover, the impressive TMOS size limit of 112 in diagonal is practical, not theoretical.

Because it is transparent, TMOS is positioned to revolutionize device redundancy in avionics (see Figure 3). Instead of the backup display being adjacent to the main display, the two can be overlapped. Both panels could be 41% larger, and the pilot would see the backup display in the same location. As an added benefit, primary panels can be edge-injected and modulated to include non-visible infrared light. This enables the addition of information overlays such as autostereoscopic capability using FSC and a synchronous planar deflector. The absence of on-screen TFTs and Amperian loops provides immunity from electromagnetic pulses. Therefore, TMOS requires little retrofitting to ruggedize.

There is a common misconception that FSC-based technologies are not uniform. In fact, TMOS displays feature detuned pixels, tuned slab geometries, and mirrored edges with uniformity variations under 0.2dB across the display. Our work led to the resolution of FSC artifact suppression for Phase I and II Small Business Innovation Research (SBIR). Unlike other techniques, our approach attacks the source of motional artifacts: the unbinding of consecutive primary color image planes.

Displays based on FSC-FTIR principles hold tremendous promise for the future, and are ripe with application potential inaccessible to incumbent technologies. Our tests on earlier 32×32-pixel prototypes have corroborated theoretical predictions concerning performance, while tests on 120×160-pixel prototypes are imminent. We plan to expand our knowledge base for parameter optimization in order to deliver on the intrinsic scalability of TMOS and establish the viability of elegant new architectures over default traditional techniques.

References
7. USAF. Contract No. FA8201-04-C-0090