A 4k projection display for D-cinema, medical imaging and simulation

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Abstract— **Liquid Crystal on Silicon (LCOS) combines two very well-known technologies, namely the IC/CMOS and the Liquid Crystal (LC) technologies. As both of these are very mature, it is obvious that LCOS has a huge potential for very high-end applications, more than any other (projection) technology. The aim of the FORK project is the development of a LCOS microdisplay device for very diverse applications in simulation, medical imaging, control rooms and digital cinema. These applications require or benefit from very high pixel counts, high contrast ratio's, very high light fluxes and very good colour and brightness uniformity, analog pixel addressing and high response times. A few microdisplay devices have recently been marketed for the applications mentioned above although none of these devices which meet all of these criteria.**

Index Terms—**LCOS, Liquid crystal, projector, IST**

I. INTRODUCTION

FORK: Development of a 4k compatible LCOS microdisplay device for D-cinema, medical imaging and simulation applications" is a 2½ years IST EU project, started in February 2006, whose main aim is to develop a very high resolution projection display. Indeed, FORK stands for 4k, i.e., 4096 lines. A 4k standard with 4096×2160 pixels is able, for example, to display simultaneously four HDTV images side by side. The design and manufacturing of the display – and the associated optics, electronics, cooling, etc.– are on the front-edge of current technological possibilities. Only JVC and Sony have quite recently started the production of devices including 4k displays based on LCOS technology [1]

High resolution projectors are aimed at a number of specific applications: digital cinema, simulation, and medical imaging. The system requirements for these applications are not the same in all cases. The aspect ratio for digital cinema, for example, is quite elongated (over 16:9) while medical imaging customarily requires 4:3, and simulation would even prefer square formats in many applications. Light output, on the other hand, must be high in cinema and medical imaging, while contrast has to be maximized in applications developed in dark environments, i.e., cinema and simulation.

II. THE APPLICATIONS

A. Simulators

Simulators for training of pilots and other professional activities employ a well-controlled set of environmental conditions, usually with low ambient light (Fig 1). These conditions allow maximization of the display contrast. The required light output is relatively low (2000-5000 lumen), but the requirements for high contrast ratio (5000:1) and a fast response time (full black to white and white to black response time below 2ms) are challenges that must be met. One of the proposals is to use a 4 LCOS panels to make an RGBK [2] (Fig. 2) light engine instead of the more familiar 3 LCOS RGB light engine.

B. Medical imaging

Medical imaging is currently managed in many hospitals and medical centers through Picture Archive and Communication Systems (PACS). Images are generated either in digital format (computed tomography, CT, nuclear magnetic resonance, NMR, most of the ultrasound devices, US, gamma-cameras, direct radiography, DR and computed radiography, CR etc.) or in analogue format (*e.g.*, conventional radiography) which is eventually scanned and stored. Images are displayed to the physician by current PACSs in 1k or at most 2k monitors.

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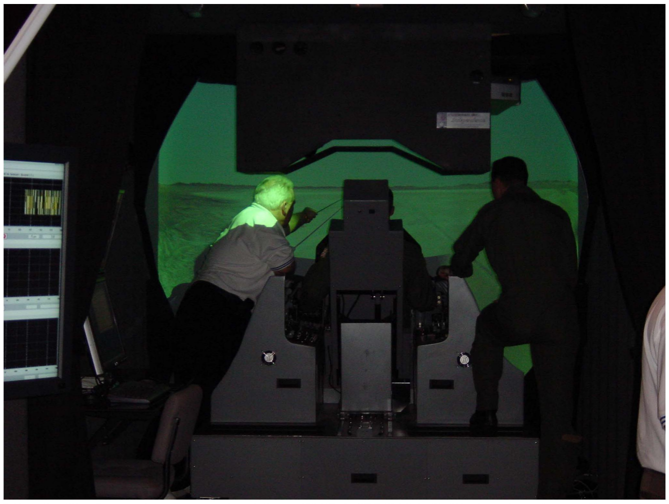

Fig. 1. Dark environment inside a SEOS PRODAS flight simulator. In order to simulate night flight and landing a contrast ratio >5000 between the bright and dark state is needed. In order to simulate the lights on the runway the transitions times from dark to bright and vice versa have to be less than 2ms.

This resolution is acceptable for most digital images (CT, NMR, US), but insufficient for radiographies in any format (CR, DR or conventional). At present, radiography customarily avoids the use of radiographic film. Images are acquired onto radiographic plates coated with photosensitive phosphors that are eventually laser-scanned to retrieve a digital image. The resolution of the images generated through this process is close to 4k standard, and large area radiographies (e.g. thorax, Fig 3) require a full 4k × 3k resolution. Performance of conventional radiography, by far the most used imaging technique, is therefore limited by the resolution of current displays.

C. Digital cinema and Virtual and Augmented Reality

At present, Digital Cinema (D-Cinema) resolution is well below its analogue counterpart. The market is led by micromirror-based digital light processors (DLP, Texas Instruments), offering 1024 (1k) lines maximum. However, the granularity of a standard 35mm film, which ultimately determines the sharpness of the cinema image, is close to 4000 lines, although the image may be somewhat blurred by the mechanical vibrations of the camera and the projector.

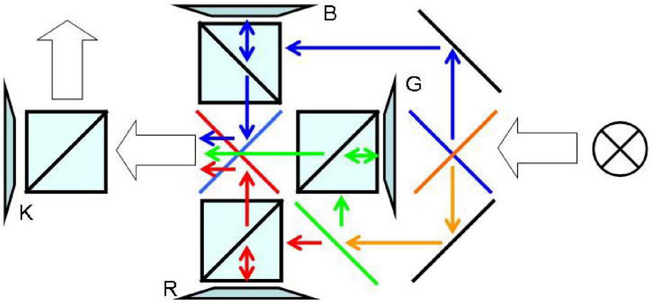

Fig. 2. The principle of a 4 panel RGBK: The light source emits white light which through dichroic mirrors is split into RGB colours. The colours are then modulated individually by 3 separate LCOS panels each with its own colour optimised polarising beam splitter cube. Finally the colours are recombined and the image is projected onto a fourth LCOS panel, which adjusts the brightness of each pixel. Using 4 LCOS panels make it possible to achieve contrasts which exceed 100k.

Fig. 3. An example of the use of digital radiography showing the thorax. This application has two very important needs: an elevated number of grey levels and very high resolution needed for visualising all the details, .The original version of this image occupies 15 megabytes.

D-Cinema Virtual and Augmented Reality (V&AR) displays require more light output (10000 – 20000 lumen), than both the medical and the simulation applications but they are less stringent specifications towards contrast ratio (2500:1). The high light output requirement will lead to a larger form factor. In order to achieve such higher light outputs it can be beneficial to have a larger LCOS device in order to reduce the light flux density on the panel and therefore the lifetime.

III. THE CHALLENGES

FORK displays will be based on LCOS technology. LCOS is very well suited for large image formats, since it is easily scaleable. However, a number of technical challenges are foreseen. The size of the display has to be considerable in order to leave space for the 8M+ pixels. Moreover, very high light fluxes, including UV, will have to be withstood by the LC material and the package. Thermal and UV aging test of selected LC materials are scheduled, whilst a novel ceramic package will be developed.

A. Silicon processing

The main challenge from silicon processing point of view is the expected die size of the LCOS display. 4k×2k pixels have to be placed on the display area surrounded by logic circuitry. The chip diagonal exceeds the maximum diagonal allowed by any standard lithographic equipment, hence in order to build such a big die, it has to be constructed by stitching. A process in which the final lithography is separated in to parts with a slight overlap. The overlapping regions will be exposed twice during the photo-lithographic processes, and thus have to be designed accordingly.

One objective is the development of a fast stitching technology suitable for small volume production. Another objective is to develop design rules or transformation algorithms for chip layout generating software tools that are tolerant for the stitching seam areas and take into account overlay area effects such as line width variations.

To comply with the extremely high quality demands of the envisaged applications, a reduction of micro and macro range in-homogeneity of the chip topology is targeted.

Finally, an integrated spacer technology will be developed, taking into account the interaction with the alignment layer process.

B. *VAN technology*

Vertically aligned nematic (VAN) LC technology, *e.g.* [3], will be used in the LCOS panels. This kind of LC has a so called negative dielectric constant, by which is to be understood that the material birefringence (hence the dielectric anisotropy) at the frequency of visible light has the opposite sign to the dielectric anisotropy at low frequency. This means that the molecules tend to align their larger refractive index perpendicularly to the applied electric field (Fig. 4).

In order for the panel to meet the specifications for the different applications a number of challenges to the actual LC panel have to be met:

In an augmented reality system where left and right eye images are sent alternately, the refresh rate of the panel is going to be 120Hz. This means that the frametime becomes 8.3ms and thus the grey to grey transition times have to be very small (<2ms). In order to achieve this very thin cells (1.5-2.2μm) are being employed.

The VAN has technology has one particular inconvenience, the so called delay time. This is the time it takes for the relaxed, dark, cell to begin to respond to any external field. This time is primarily a function of the pretilt (90-γ) (Fig. 4). The larger γ the lesser the delay time. Research into the link between delay-time and pretilt has to be undertaken, remembering that the residual plano-birefringence originating from a non-zero γ-value will compromise the dark state and thus reduce the contrast of the display.

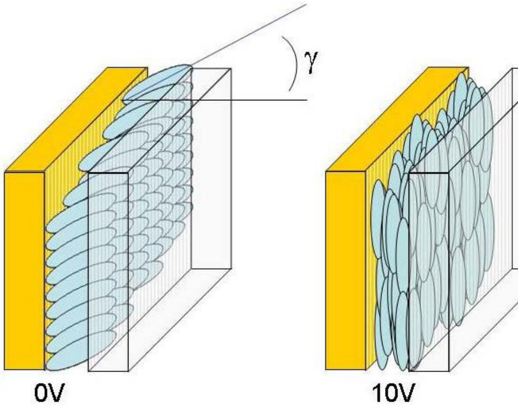

Fig. 4. The principle of a VAN liquid crystal display. At 0V the molecules, (hence the optical anisotropy) is aligned quasi perpendicularly to the display normal (γ<5°). Upon applying a field, *e.g.* 10V, the molecules tend to orient themselves in plane with the cell (perpendicularly to the electric field). Placing the display between crossed polarisers aligned at 45° with respect to the switching plane makes the display turn on or off as a function of the applied voltage. The internal liquid crystal cell surfaces are treated with alignment agent in order to control the switching plane and the pretilt angle (90°-γ)

C. *Liquid crystal alignment and material*

Typical alignment conditioning for liquid crystal displays are customarily based on the deposition of organic polymers such as polyimides or polyamides (Nylon). However, both the thermal stress and high lighting levels required in this project,, are incompatible with organic layers and thus the alignment technology will be based on the e-gun deposition of inorganic materials (SiO_2). E-gun deposition makes it possible to precisely control the γ by adjusting the inclination between the substrate and the E-gun. Experimental procedures for precise measurement of γ angles and cell thickness are being developed. The method should also include a standard protocol to test homogeneity of these two parameters over the display area.

Eventually an analysis of the trade-off between delay-time and contrast has to made, and the possibility of making more than just a single conformation of the display has to be considered.

The liquid crystal material itself is also subject to thorough investigation. The current commercially available VAN-materials have all components that are sensitive to UV-radiation. This means that using a setup in which the luminance reaches 20k lumens the LC material risks photodecomposition, unless specific UV filters are being used. In order to assure that the LC will not be the limiting factor in the device lifetime, synthesis of LC materials similar to the existing commercial ones, but without UV susceptible components, is taking place. At the same time research into materials with higher birefringence is being looked into. The motivation for this is that a partially switched highly birefringent LC can reach the same retardation as a fully switched less birefringent LC, while the response time is substantially lower, Hence a faster device can be obtained without compromising light intensity. The drawbacks are that higher birefringent materials, will give more residual birefringence at a given pretilt –hence lower contrast– and that high birefringence materials tend to be more viscous than the lesser birefringent counterpart. Obviously high birefringence can lead to thinner cells, and hence higher speed without compromising the dark state additionally. However in order to keep manufacturing yields at an acceptable level cell thicknesses below 1μm should be avoided. In thinner cells there is an increased risk of shortcuts between the electrodes, and the relative variation in thickness becomes more significant.

IV. THE CONSORTIUM

The FORK project consortium gathers European competence centres, each having expertise in one or more of the technology fields mentioned above. The consortium has undertaken the ambitious task of making the world leading light engine to be used in demanding applications ranging from medical imaging and simulation to digital cinema and virtual and augmented reality displays. The consortium includes experts on all the levels of light engineering, spanning LC synthesists, LC characterisation specialists, semiconductor designers and producers, and light engine and simulator manufacturers.

V. ACKNOWLEDGMENT

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