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Autostereoscopic display technology for mobile 3DTV applications

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ABSTRACT

Mobile TV is now a commercial reality, and an opportunity exists for the first mass market 3DTV products based on cell phone platforms with switchable 2D/3D autostereoscopic displays. Compared to conventional cell phones, TV phones need to operate for extended periods of time with the display running at full brightness, so the efficiency of the 3D optical system is key. The desire for increased viewing freedom to provide greater viewing comfort can be met by increasing the number of views presented. A four view lenticular display will have a brightness five times greater than the equivalent parallax barrier display. Therefore, lenticular displays are very strong candidates for cell phone 3DTV.

Selection of Polarisation Activated Microlens^{TM} architectures for LCD, OLED and reflective display applications is described. The technology delivers significant advantages especially for high pixel density panels and optimises device ruggedness while maintaining display brightness. A significant manufacturing breakthrough is described, enabling switchable microlenses to be fabricated using a simple coating process, which is also readily scalable to large TV panels.

The 3D image performance of candidate 3DTV panels will also be compared using autostereoscopic display optical output simulations.

Keywords: 3D, display, switchable, microlenses, birefringent, coating, resolution, cell phone, TV

1. INTRODUCTION

Stereoscopic imaging has a long history of evolution of new display technologies that combine the latest progress in 2D image reproduction with novel optical elements. Historically many products have been held back by a combination of poor stereoscopic image reproduction and lack of source data. However, substantial changes are now occurring in the infrastructure on which the stereoscopic 3D marketplace can be built.

- Enabled by digital imaging and more formal implementation of 3D image capture and display protocols[1], reliable sources of stereoscopic image data can be produced in high volumes which meet currently understood demands for precision of image alignment, depth reproduction and control of viewing experience.
- The digital TV marketplace continues to evolve from the rapid introduction of mass market large flat panels to the home to the launch of mobile TV products worldwide.
- The cell phone is becoming a major imaging platform with significant computational resources and access to video image content.
- Optical components and materials continue to develop, driving the evolution of display optics.

We examine the design parameters of mobile 3DTV products with a particular emphasis on the requirements placed on the optical system. The convergence of display platforms, new optical components, materials and manufacturing methods together with the rapid growth in stereoscopic software systems, generates an opportunity for the first true autostereoscopic 3DTV products to be based around the mobile TV platform.

In most mass market applications, 3D optical components are required to switch to a high performance 2D mode. Displays with switchable barriers[2,3] and switchable lenses[4,5] have been previously discussed. In addition to high image quality and power efficiency, substantial demands on manufacturability are placed on these displays. Recent progress in manufacturing technologies to meet the demands of scalability, as well as thickness and cost reduction for mass market consumer products will be described.

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2. TRENDS IN IMAGE DISPLAY FOR MOBILE PLATFORMS

Traditional domestic telephones did not have a display, but with the introduction of portable handsets for cell phones, the need for an alphanumeric display to confirm the numbers “dialed” soon became apparent. The data capabilities of digital phones evolved the display panel into an essential tool for both the user interface and text services. The introduction of colour displays and camera functionality led to a worldwide explosion of picture messaging services. More recently, several trends in display evolution have emerged which are contributing to the use and exploitation of video applications on cell phones and which are key to the prospects for future mobile 3DTV products.

2.1 Increased resolution and reduced thickness

Demand for increased panel resolution in cell phones is driven by relatively short viewing distances for handheld devices, often with a youthful (high visual acuity) audience; the improved reproduction of Chinese character fonts; and the need to increase the functionality and appeal of the user interface by providing more detailed information on a small display.

Resolution improvement in cell phone displays has continued with 2.x” VGA (resolution 640x480) starting to replace widespread QVGA (resolution 320x240) use. Perceived display resolution can also be increased by the use of alternative pixel colour filter arrangements[6] in which knowledge of the human visual response function is used to modify the spatial luminance distribution on the panel and improve display appearance and/or brightness.

Cell phone thickness is currently a key differentiator in the marketplace. This has driven a reduction in display thickness, with the introduction of 0.2mm Liquid Crystal Display (LCD) glass substrate thickness recently reported[7], and overall display module thickness of around 1mm.

2.2 Video display

Cell phone network operators have a strong need to grow revenues from existing customers and video display is a good way to do this. MobileTV services based on more than one broadcast infrastructure have already been launched, and it is forecast that a broad range of video information will become widely accessible.

Cell phone video displays can suffer from slow frame update rate and motion blur. These can be reduced using fast response electro optic effects, increased update speeds, alternative addressing techniques and modified backlight schemes. Recent work on LCD cell phone displays has demonstrated reduction from 25ms to 16ms response times[8], with longer term targets from the large flat screen sector of 5ms.

Video operation places an exceptional demand on power consumption of TV cell phones compared to data phones as the display usage profile is much altered. Typically, data displays operate for a few minutes, and then revert to a low power mode, in which the backlight is dimmed. However, TV images are likely to produce extended viewing periods, so that backlight power consumption will have a much more significant impact on device operating times without a recharge.

2.3 Display efficiency

The increased contribution of display power consumption to battery operating time arising from changing usage patterns leads to a re-examination of the importance of display efficiency in cell phone handsets.

Displays using polarisers Transmissive LCDs & Organic Light Emitting Diode (OLED) displays have power consumption (albeit image dependent for OLEDs) at around 200 milliwatts for a 2.x” class display. Some types of OLED display rely on circular polarisers to increase the contrast by suppressing the reflection from the internal electrodes. Transflective LCDs combine a transmissive mode with a reflective mode which uses a mirror at the pixel plane to reflect ambient light. The reflective modes have historically been limited by low contrast and losses in the output polariser, but for 2.x” class QVGA (resolution 320x240) can have power consumptions in the in the range 2 to 20 milliwatts, less than a tenth of the backlight power.

Polariser-free displays Recently, new reflective display technologies which do not use polarisers or light emission from backlights/pixels have created a lot if interest. These polarizer-free displays promise substantially higher levels of efficiency and include interference mode displays[9], electrowetting displays[10] and electrophoretic displays[11].

2.4 Software infrastructure and TV for mobile platforms

Provision of content in 3D is no longer the barrier it once was as both real 3D images and converted legacy 2D stills and video can be played back in real time on cell phone platforms[12]. Legacy material conversion is well suited to cell phone platforms as it requires relatively small amounts of processing power and residual artefacts represent much smaller depth errors than when seen on larger display platforms.

Landscape format images are considered desirable for 3D, as they fit well with broadcast infrastructure and maximize the depth resolution that can be shown.

2.5 Implications for optical components in mobile 3DTV displays

The above analysis points to factors with which 3D optical component development must keep pace.

- Cell phone platforms are well suited to autostereoscopic imaging; glasses are not practical in this environment.
- Loss of text resolution in 2D will not be acceptable for cell phone users – optical components must be switchable.
- Video and image applications can accept lower spatial display resolution than 2D data applications particularly if temporal resolution (frame rate) is maintained; however the drive to higher resolutions is important for developers of 3D displays, as it enables an increase in the number of views presented while also optimising image quality.
- Optical components must meet the challenges of achieving required nominal viewing distance for higher resolution devices[13,14]. The reported move to 0.2mm thick glass display substrates is encouraging in this respect.
- Low efficiency optical components will not be acceptable; the efficiency of optical components in both 2D and 3D modes is critical for display users.
- Minimised device thickness is currently a differentiator for handset manufacturers.
- Technology development roadmaps must respond to both the immediate needs of polariser displays and the demands of future polariser-free displays.

3. SWITCHABLE MICROLENS ARCHITECTURES FOR CELL PHONES

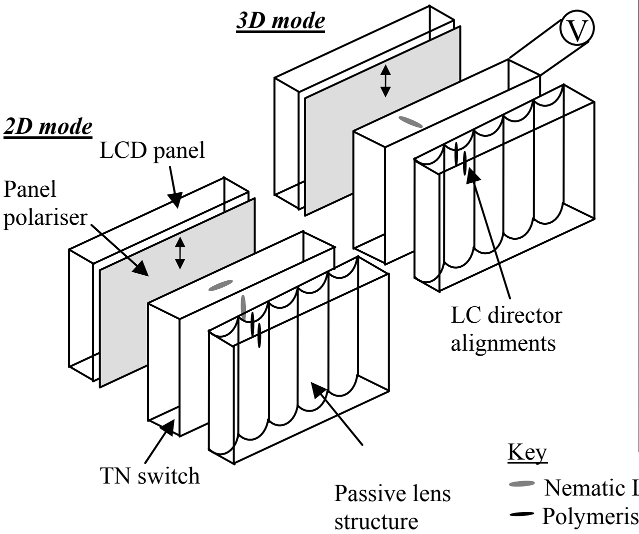
3.1 Polarisation Activated Microlens architectures for mobile 3DTV applications

Spatially multiplexed switchable autostereoscopic optical components can generally be divided between parallax barrier components which use arrays of optical apertures and microlens components which use arrays of lenses.

Switchable microlenses have key advantages for mobile 3DTV devices. In particular they are optically efficient, with brightness independent of the number of views presented. Polarisation Activated Microlenses^{TM}, in which the optical function of the microlens is modified by controlling the polarisation state of the light that passes through the lens and to an observer have been described previously[3]. Here, high efficiency, high contrast modes for LCD and OLED suitable for cell phone display are described.

- *LCD operation* As shown in Fig.1, the structure comprises the pixels and output polariser of the base LCD, a twisted nematic (TN) LC polarisation switch, and a Polarisation Activated Microlens, which has a surface relief structure formed in an isotropic material and an adjacent layer of birefringent lens LC material. In the 2D mode, the polarisation state that leaves the panel is rotated 90° by the switch LC material and is then incident on the normal refractive index of the lens LC. This has the same refractive index as the isotropic material so that there is an index match at the isotropic lens surface, and no optical function is produced. In the 3D mode, a voltage is applied to the TN switch which reorients the switch LC material so that it no longer has a polarisation rotating function. The output polarisation state from the TN switch is incident on the extraordinary refractive index of the lens LC, so that there is an index step at the interface to the isotropic lens, and the lens function is produced.

- *OLED operation* Polarisation Activated Microlenses cooperate with the circular polariser often used to cancel light reflection from internal electrodes as shown in Fig.2. Randomly polarised light from the panel enters the birefringent microlens and sees both the lensing and non-lensing functions of the lens array. In the 2D mode, the polarisation state corresponding to an index match at the lens interface is rotated by the TN switch and transmitted through the output polariser. In the 3D mode, the output polariser transmits the orthogonal polarisation state that passed through the lens seeing an index step.



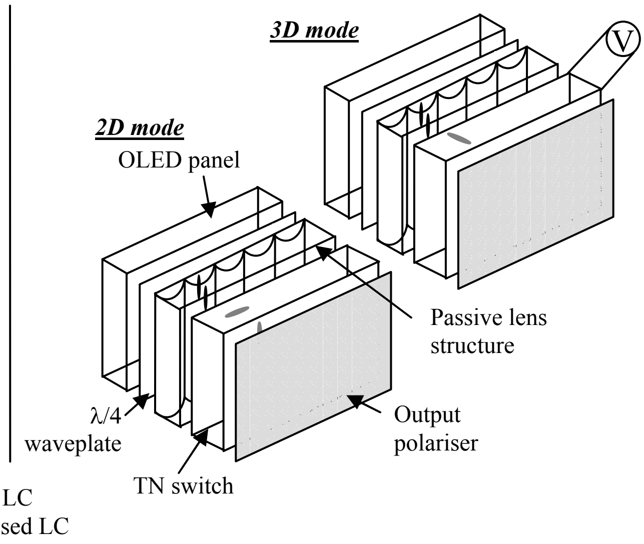


Fig.1 Polarisation Activated Microlens display with LCD panel

Fig.2 Polarisation Activated Microlens display with OLED panel

3.2 Thickness reduction of optical components in cell phone LCD & OLED displays

Polarisation Activated Microlenses use a passive liquid crystal (LC) surface relief material, so can be formed from a cured LC polymer material as previously described[13]. Such lenses are rugged with a wide operating temperature range. In section 4 of this paper, we describe developments in manufacturing methods which mean that these lenses are cheaper and easier to make than conventional nematic phase LC devices.

A significant further advantage of solid phase LC materials is that they can be used to reduce device thickness; a key trend for cell phone manufacturers. Early implementations based on nematic LC lenses used four 0.5mm substrates. Figs.3-6 show device structures based on standard 0.4mm glass substrates which have been recently demonstrated with thickness range 0.7-0.85mm. This compares to >0.9mm for an equivalent parallax barrier element where an additional polariser is required. Thicknesses of <0.45mm should be possible using the 0.2mm substrates being adopted elsewhere in the cell phone display industry.

In Fig.5, the aligning properties of the polymerized LC itself is used as an alignment surface for the switch LC, eliminating a polyimide alignment layer on this surface. As shown in Fig.6, to further reduce device thickness it is possible to replace the 0.4mm glass substrates of the LC switch with a plastic LCD. Fig. 7 shows a Polarisation Activated Microlens display component with a 0.26mm thickness plastic TN switch and 0.45mm solid lens on glass component fabricated in a joint development with the Swedish LCD centre[15]. Fig.8 shows a completed display retro-fitted to a Sharp GX30 cell phone handset. This is a promising early application for plastic TN-LCDs because the device is not required to analyse polarisation, merely to control the proportion of light in 2D and 3D modes. Therefore, manufacturing tolerances are not as severe as for high contrast display applications.

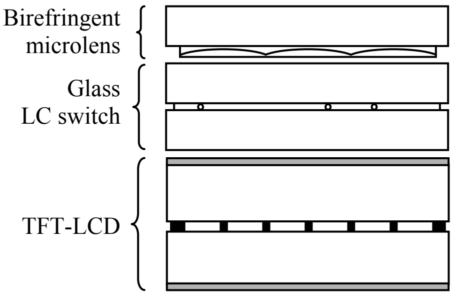


Fig. 3 Added thickness 1.25mm

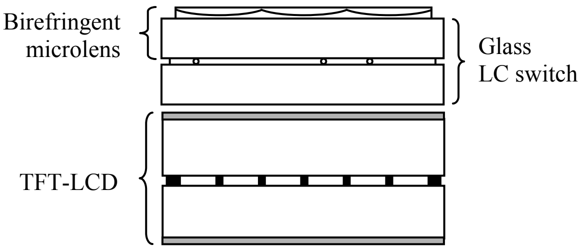


Fig.4 Added thickness 0.85mm

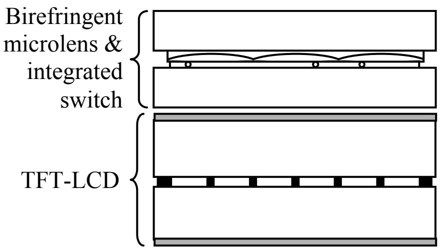


Fig. 5 Added thickness 0.85mm

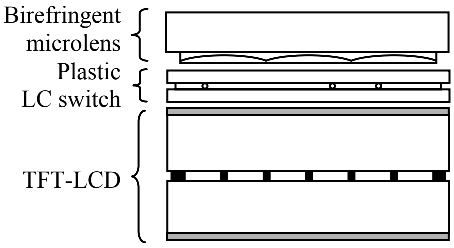


Fig. 6 Added thickness 0.71mm

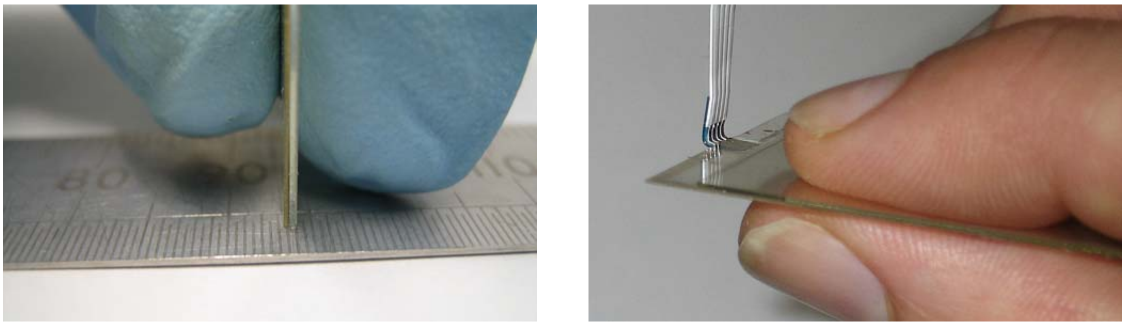


Fig.7 Integrated coated lens and plastic switch cell, total added thickness 0.7mm

Fig.8 Handset with Ocuity Polarisation Activated Microlens and Swedish LCD Centre plastic LCD

3.3 Optical structures for polariser-free displays

Ocuity have developed highly efficient architectures which can meet the needs of polariser-free display systems, as shown in Fig.9.

Although there is no panel output polariser, light leaving the display can be resolved into horizontal and vertical linear polarisation components. Each lens array comprises an ‘active’ LC microlens array, in which the director orientation within the lens is controlled by switching a voltage across the polymer and LC materials[16]. The alignment directions at the common interface are orthogonal in the adjacent lenses.

In the 2D mode of operation, both lenses are switched such that light from the display is index matched at both microstructured interfaces and no optical function results. In the 3D mode, both lenses are unswitched and the vertical polarisation state sees a lens function in the first lens but no optical function in the second lens. Light in the orthogonal polarisation state is unmodified by the first lens, but modified by the second lens. High precision alignment techniques developed by Ocuity mean that the optical functions for the first and second polarisation states can overlap, giving 2D and 3D modes for both sets of polarisation states from the panel. This basic structure can also be modified to provide a switchable 3D portrait mode as well as the standard 3D landscape mode, if this is deemed necessary.

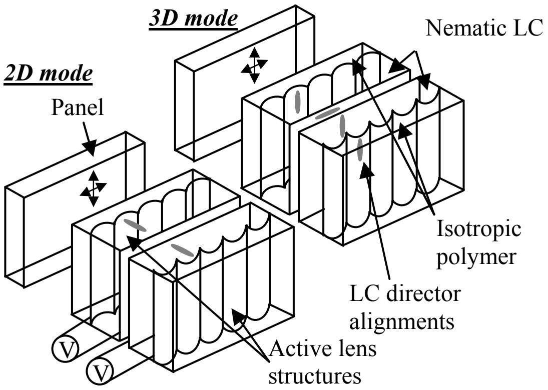


Fig.9 Switchable microlenses for polariser-free displays

Such a device shows the flexibility of switchable microlenses to meet the demands of future autostereoscopic display systems for mobile display platforms. By comparison, a switchable parallax barrier for such a display would need an additional pair of polarisers, and would suffer from light loss both on the way in and the way out of the reflective display.

4. BIREFRINGENT MICROLENS MANUFACTURING TECHNOLOGY DEVELOPMENTS

Recent developments at Ocuity in materials and fabrication methodologies reported here for the first time enable a step change to be made in low cost and large area birefringent microlenses.

4.1 Standard LC cell fabrication method

Most switchable optical elements for autostereoscopic displays use the birefringent properties of aligned LCs and can be fabricated using modifications of conventional LC processing technologies. A typical LC cell fabrication method is shown in Fig.10 with the analogous fabrication of a nematic LC microlens shown in Fig.11.

Much of the materials and capital equipment are common between the two processes, but several issues arise specific to LC lens fabrication which need to be considered:

- *Coating* The polymer material is required to be coated with an alignment material, and so must be compatible with the processing regime and solvents used for this material, and maintaining alignment properties over the required operating timescales and environments.
  Scribe and break In order to enable scribe and break, the lens polymer material should ideally be cleavable. The isotropic cured polymer material is mounted on a glass substrate which is scribed on the reverse side. To ensure that the polymer interface cleaves cleanly with the glass, the lens polymer material should be brittle, generally arising from a high degree of monomer conversion and cross-link density. Fig.12 shows a cross-section of such a scribed lens.
- *Edge sealing* Dispensing of edge seal adhesive to a polymer surface relief structure poses additional constraints on the adhesive material and method because of the increased cell gap and a tendency of the material to prefer to fill down lens channels. An adhesive which bonds successfully to both glass substrate and polymer surface relief structure is required. These two issues can be avoided by removing the polymer material from edge seal regions to improve seal adhesion and reduce spreading. This technique has been demonstrated using by UV laser processing as shown in Fig.13.
- *LC cell filling* To avoid air bubbles a vacuum must be applied to the lens polymer material during cell filling. Such processes generally have a long fill time so require filling equipment for many devices in parallel.

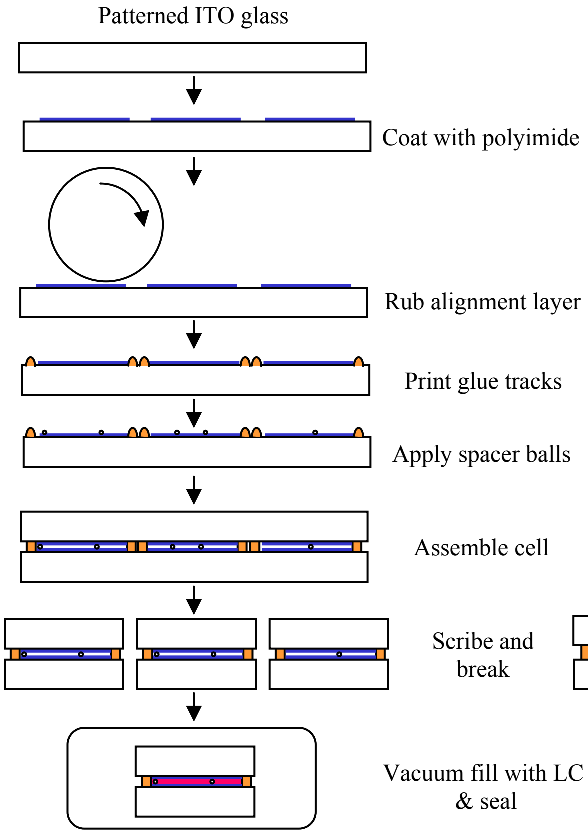


Fig.10 TN LCD assembly

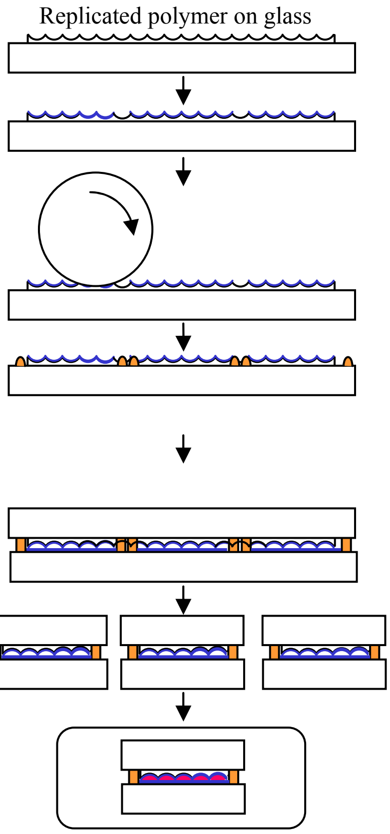


Fig.11 LC lens assembly

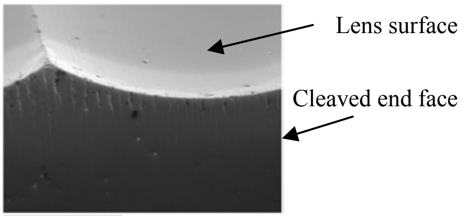


Fig.12 SEM of lens polymer material after scribe & break

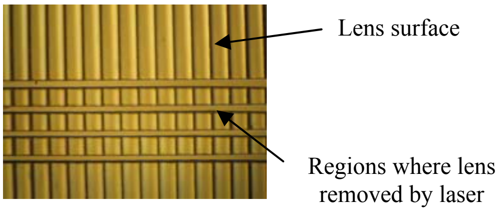


Fig.13 Results from laser removal of lens polymer material

4.2 Coatable solid phase LC microlens manufacturing method

A new fabrication method for solid phase lenses has been developed at Ocuity which provides substantial scalability and cost advantages over nematic LC lenses, based on replacing the filling method of conventional nematic lenses with a coating method. This means that the birefringent lens technology can be readily extended to TV size LCD panels.

Solid phase LC materials are rod-like molecules with a central mesogenic core to which flexible polymerisable spacers are attached. When used with polymerization initiators and activated by heat or electromagnetic radiation, they can form dense cross-linked networks. This means that the alignment of the materials can be set for the monomer and then fixed by polymerisation.

Polymerisable LC materials have previously been used commercially for fabricating waveplates in which they are dissolved in a solvent and coated onto a single alignment layer[17,18]. With a material birefringence of ~0.15, such waveplates are a few microns thick. By contrast, birefringent microlenses are typically 20-60 microns thick and the lenses need to be “full” once the solvent has been evaporated. For many practical applications, a twist in the device is also valuable[19]. It would be desirable to use alignment on both surfaces of the LC layer to provide alignment energy and twist, precluding the use of a standard solvent carrier.

Both 100% monomer LCs and LC gels in which non-curable and curable LCs are mixed have been used in combination with commercially available and proprietary isotropic polymer materials to produce filled cured lens cells. To obtain repeatably good quality filled lenses over a whole lens area, particular issues to be considered include uniformity of mixture, amount of photo initiator, temperature of processing and time of processing at temperature.

With recent LC monomer material formulations available for example from Merck and BASF, long-lived supercooled nematic phases have been demonstrated. These materials are generally crystalline at room temperature but after heating in to the nematic phase and subsequent cooling below the nematic transition temperature, they maintain their nematic phase for extended periods of hours to days. The availability of reliable supercooling LCs has made a substantial difference to the ease of processing for mass production and has led to the development of a proprietary coating-based fabrication method for solid phase birefringent lenses as shown in Fig.14. A replicated polymer on glass lens is coated with an alignment layer such as polyimide and in this case rubbed, as for standard nematic phase microlenses. Heated and vacuum degassed LC monomer is then applied to the lens surface under a polymer film in a rapid coating process when compared to capillary or vacuum filling. Though the LC polymer supercools to room temperature, coating on to a heated bed helps speed up the flow of material. Note that for clarity of illustration the lens axis is shown orthogonal to the typically used coating and rubbing direction.

A key point is that large substrates can be efficiently coated in a short time minimising any unwanted thermal polymerization. The alignment properties of the monomer are controlled by the surface of the polymer film as well as the rubbed polyimide layer. The polymer film alignment properties do not need to meet the performance of a switching cell for anchoring properties, endurance or lifetime; the function is only required for the duration of coating and cure.

Following coating, the LC material is cured with UV light using an array of fluorescent tubes. The polymer film is then peeled off, revealing the surface of the birefringent material. By controlling polymer film and polymerised LC surface energy as well as degree of cure, the delamination process has been engineered to be both mechanically simple and reliable. Examination of the removed top sheet films in polarized light after delamination confirms that no material from the active area transferred to the film. Scribe and break has been shown to have similar properties as for standard glass and produces cleaved surfaces of polymer and LC film, as shown in Fig.15.

This method has key advantages:

- Low cost, low thickness, robust and high quality surface relief birefringent elements can be easily fabricated
- The process is potentially scalable to very large sizes, making it suitable for 100” class flat panel TV, LCD backlight and projection apparatus.
- The birefringent lenses may be made on a large motherglass sheet and readily cut to the required panel size. This contrasts with the earlier fabrication technique where each individual lens cell needed a filling process.
- The capital equipment requirements and process time is reduced
- Material costs and consumption are reduced

4.3. Preliminary endurance testing results

Unlike standard nematic LCs, once cured the variation in optical properties with temperature for polymerised LCs is essentially fixed, which helps produce a very wide operating temperature window. Solid lenses have demonstrated remarkable endurance in preliminary testing.

- Samples have been subjected to both -80°C and 90°C for 3 weeks with no apparent degradation.
- Samples have also been temperature cycled ten times between -27°C and +70° C with 2hr at each temperature and 10 seconds transition between temperature with no observed degradation.
- One sample has been subjected to 120°C for 5 days with no apparent degradation.
- One sample was heated to 180°C for 2hr resulting in a slight yellowing, however the film remained intact and functional.

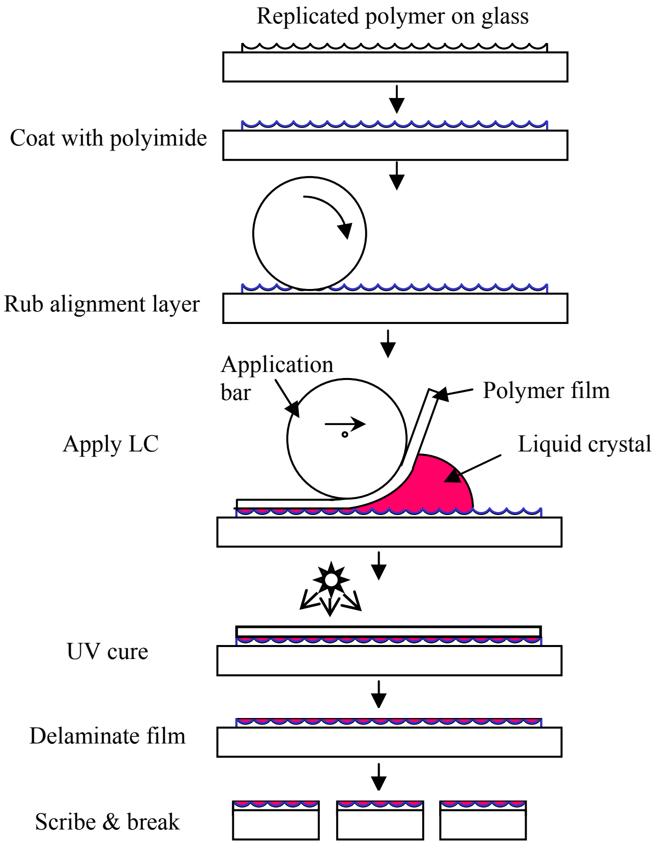


Fig.14 Solid LC lens fabrication

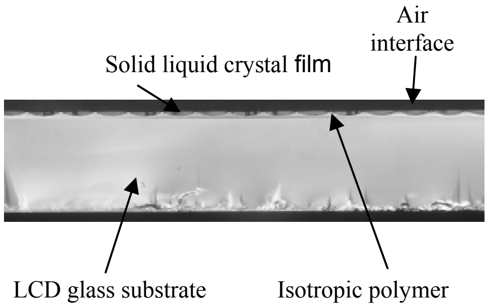


Fig.15 Cross-section of fabricated device

5. RESOLUTION CHARACTERISTICS OF MOBILE 3DTV DISPLAYS

5.1 2D and 3D pixel structures

In most common autostereoscopic displays, a parallax optical element such as a lenticular screen or parallax barrier is positioned in registration with a set of pixels of the display. In such spatially multiplexed displays, each view comprises a sub-set of image pixels.

In displays with extended usage times such as 3DTV, some users report that an increased viewing freedom compared to two view displays is desirable. The viewing freedom may be increased from less than 50mm to approximately 200mm using four views. Therefore, it is helpful to compare resolution performance in equivalent displays that provide this viewing freedom.

3D pixel arrangements depend on several factors including the window structure, the number of views required, panel orientation, required viewing distance and the particular optical element used.

5.2 Comparison of 3D image appearance

Techniques for analysing resolution trade-offs in multiview displays have been investigated previously and used to assess the performance of QVGA 2.x" class panels[20] used in many current cell phones. Here, the image simulation has been extended to include VGA (640x480) 2.x" class panels, likely to be popular in future mobile TV cell phone panels.

Sampling comparison Luminance frequency performance of 3D pixels can be quantitatively compared using reciprocal space coordinates, and Nyquist boundary structure for the green pixels. The sub-sampled 3D frequency gamut is smaller than the 2D gamut; each configuration having a different area and shape of frequency gamut that can be represented on the display. Increasing base panel resolution from QVGA to VGA doubles the horizontal and vertical frequency gamut of the display and thus improves image appearance as would be expected.

Colour sub-pixel visibility In some configurations, the separation of red, green and blue pixels increases as resolution falls, and it can be possible to resolve the separate colour channels[12,20]. As the red, green and blue channels have different luminance functions, this can appear as a luminance modulation imposed on the image. The visibility of this function is determined by the Human Contrast Sensitivity function. Typically, QVGA panels in 2D mode have no visibility of this error at normal viewing distances (say 300mm), but an increase of separation in 3D mode becomes visible or very visible. Arrangements in which the colour pixel separation is the same in 2D and 3D are thus preferable, such as landscape mode orientation on portrait mode cell phones. When the base panel resolution is increased resolution to VGA, the pixel separation is halved and this artefact is substantially reduced.

Image simulation The appearance of a single view of a 3D image was compared for different equivalent multiview 3D configurations in QVGA and VGA resolutions by simulating the 3D pixel layout for real images and printing the result onto a panchromatic transparency using a RGB laser scanner. The colour saturation of the red, green and blue pixels was reduced in VGA images because of the limitations on optical spot size in the laser scanner. However, they were considered a satisfactory representation of image quality that may be expected in such panels.

Fig.16 shows photos of transparencies for some important configurations simulated for 2.2" QVGA and VGA panels. These were observed by a group of experienced display users on a LCD backlight lightbox from 300mm. In a like-for-like comparison between transparency simulation and the equivalent actual autostereoscopic display, this technique has previously been shown to be a good representation of 3D image appearance.

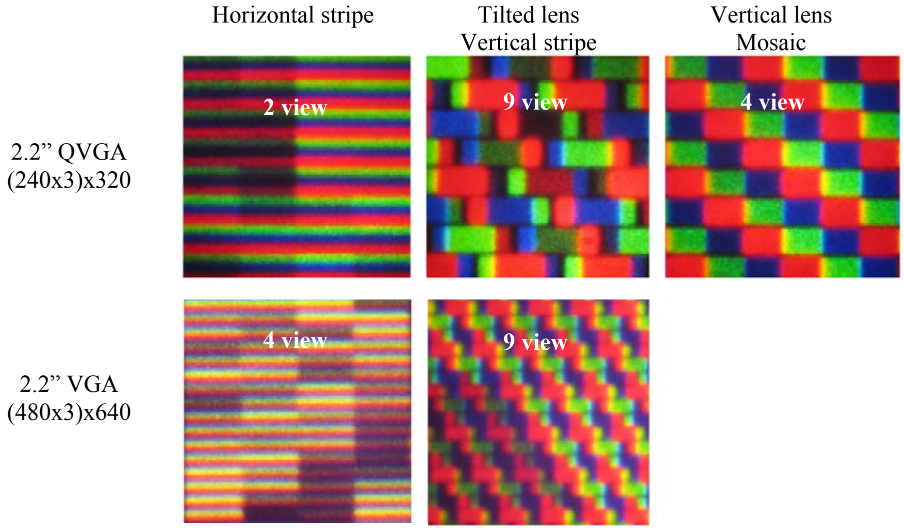


Fig.16 Simulation of appearance of 3D pixels on QVGA and VGA panels using RGB laser writer onto panchromatic transparency

Simulation results The observed artefacts in transparency images were subjectively ranked as shown in Table 1 by four experienced 3D display users. Table 2 provides a comparison between the various 3D pixel simulations for 2.2" QVGA and VGA images. Minimum viewing distances were calculated assuming thicknesses of 0.5mm for LCD glass, 0.15mm for polariser and 0.4mm for additional spacer. Calculated minimum viewing distance in a 4 view or 9 view tilted display is nominally 1/3 of nominal viewing distance. Typically minimum achievable cross talk values are given on the basis of previous reported results for each type of switchable optical system.

Table 1. Subjective ranking scores

Artefact ranking	Subjective appearance
4	No visibility
3	Just visible artefact
2	Clearly visible artefact
1	Very visible artefact

Table 2. Qualitative ranking of resolution artefacts and display performance

#views	Resolution	CF [1]	Optic	Block artefact ranking	Stripe artefact ranking	Typ.min. achievable cross-talk	Minimum viewing distance
2	QVGA	HS	Vertical lenticular	3	4	<1%	<300mm
4	VGA	HS	Vertical lenticular	3	4	~3%	<300mm
4	QVGA	VS	Vertical lenticular	2	1	~3%	~300mm
4	QVGA	M	Vertical lenticular	2	3	~3%	~300mm
9	QVGA	VS	Tilted lenticular	1	3	>20%	~300mm
9	VGA	VS	Tilted lenticular	3	4	>20%	~600mm
4	QVGA	VS	Barrier	2	1	~5%	~300mm
4	QVGA	VS	Step Barrier	2	2	~5%	~300mm

[1] Colour Filter HS: Horizontal stripe VS: Vertical stripe M: Mosaic

At QVGA resolution, 2 view horizontal stripe and 4 view mosaic patterns showed the best performance, with increased blockiness from the 9 view tilted lens arrangement as previously reported. For VGA resolution the delta pixel arrangement of the 9 view tilted lens arrangement showed good natural image appearance with blockiness artefacts reduced. However, tilted lens displays show high levels of cross talk throughout the viewing zone and use portrait orientation pixels so that they have a long viewing distance[13]. By comparison, the 4 view horizontal stripe arrangement combines acceptable viewing distance characteristics with low artefact visibility and low cross talk.

It should also be noted that the interlacing of the image data on 2 and 4 view stripe displays is far less computationally intensive than for tilted lens implementations, and so can be done in real time on the cell phone processor itself without the need for an additional custom interlacing chip.

It was therefore concluded that the two important configurations for mobile 3DTV applications are:
- For 2 view displays, QVGA landscape mode.
- For extended viewing freedom 4 view VGA landscape mode.

6. CONCLUSION

Mobile TV is now emerging as a significant new application of cell phones. This is driving a variety of developments in the base display including increased resolution, reduced thickness, video capability and increased display efficiency. With the introduction of infrastructure and software to enable the generation of high quality 3D images in real time from a 2D image stream, these devices offer a viable platform on which to deliver the first mass market 3DTV displays.

To be successful, enabling optical technologies must deliver a variety of key characteristics including:
- High efficiency to optimise battery lifetime
- Full 2D performance
- Comfortable glasses-free 3D images including minimal pixel artefacts, low cross talk and short viewing distances
- Low thickness and high ruggedness
- Low cost and scalable manufacturing technologies

Polarisation Activated Microlens™ technology is a strong candidate to meet the many demands of these platforms, especially when combined with recent advances in a LC coating technology which does not require sealing or vacuum processing.

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