TV Displays

— a progress report

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In the 5 years since my first Technical Review article on television displays [1], we have seen the domestic TV environment change out of all recognition, as Liquid Crystal and Plasma displays have essentially displaced the CRT (Cathode Ray Tube) completely, in terms of sales.

This article covers the latest developments in the displays market, as we move into a world where manufacturers are prototyping a variety of different technologies and where 3D displays are also starting to appear.

In the domestic market, ***Liquid Crystal Display*** (LCD) and ***Plasma Display*** technologies have continued to evolve. Average screen sizes have now moved beyond 32 inches diagonal, and 37 or even 42 inches is foreseen as the biggest market segment in the very near future. Simultaneously, the largest practical sizes for domestic use have risen from 50 inch to 57 and even 65 inches over the past five years. The market has also evolved to provide higher resolution panels. Whilst most larger panels 5 years ago were 768-line devices, now no manufacturer can avoid the pressure to advertise “Full HD 1080” or some such wording.

Whilst the EICTA / DigitalEurope HD-ready logo had found widespread acceptance as a guarantee that a TV set would display an HD signal when the broadcasts started, the next step – the HD-ready 1080 logo – appears not to have achieved the same acceptance, which is unfortunate. Whilst a manufacturer’s own “Full-HD” logo indicates that the display has indeed got 1080 lines of pixels, it does not go as far as to guarantee that the TV will be compatible with 1080p50 signals from a set-top box or 1080p60 from a games machine.

Current trends

With plasmas also now tending to offer 1080-line resolution at most sizes, it might be thought that they would be well placed to compete with LCD in the larger screen sizes, but the plasma panel

1. R. Salmon: **The changing world of TV displays — CRTs challenged by flat-panel displays**
EBU Technical Review, April 2004
http://tech.ebu.ch/docs/techreview/trev_298-salmon.pdf
Also published as BBC R&D White Paper, WHP 089.

manufacturers are finding it hard to justify investment in the current climate: this year sees Pioneer (who had already absorbed NEC) and Fujitsu Hitachi pulling out of plasma panel manufacturing, leaving Panasonic as the only Japanese plasma panel manufacturer. However, Panasonic has made the investment required to bring the next generation of Plasma displays to the market, and the NeoPDP results in a big cut in power consumption, and thinner and lighter panels, all increasingly important factors.

But cutting the display power consumption has also been on the agenda for LCD manufacturers, and their massive dominance in the market remains, with recent investment in new plants now coming on line. With the ever-reducing manufacturing cost remaining the main focus for LCD panel producers, Sharp put a $3.2bn factory into production [2] in March 2009, which can produce eight 57-inch panels from a single 2.8m x 3m substrate, bringing still greater economies of scale. However, that will be Sharp's last Japanese factory; in April 2009 the company announced that, in the future, investment in new manufacturing capacity will be through partnerships outside Japan which, given the relatively high costs of both labour and land within Japan, can hardly be a surprise.

With the 42-inch market becoming increasingly competitive, manufacturers are introducing models in the 46 - 47 inch range – to bridge the gap below 50 inches. The inexorable rise in average screen size appears set to continue, which really is the main driver for broadcasters to invest further in HDTV.

Whilst the rear-projection TV was never a big feature of the European market, it was starting to achieve a small foothold about 3 years ago, thanks to its ability to offer large screens at low cost. With the flat-panel technologies having cut their costs, and the marketplace demanding flat panels to the exclusion of anything else, rear projection is now almost dead even in its traditional stronghold of North America.

A big growth market for displays has been in advertising panels, where the ability to have a moving or changing image is much more attractive to advertisers than a traditional poster, particularly in high-value locations. Whilst this has no immediate bearing on the TV market, it is another outlet for the manufacturers, enabling economies of scale in the larger display sizes, where the TV market has been constrained in the past by significantly higher prices.

The “new” technologies

A variety of new technologies have been shown in prototype form over recent years. Prior to the economic downturn, several of them looked set to give Plasma and LCD a run for their money. However, now that the money has itself run away, no company is really in a position to invest in new technologies on the scale required to make a significant inroad into the TV display market.

What has happened to TDEL and SED?

Thick-film Dielectric Electro-Luminescent (TDEL) technology looked very promising five years ago, with an impressive 34-inch full-colour prototype on show from iFire [3]. Capital investment was however not forthcoming to set up the planned pilot manufacturing plant but, towards the end of 2008, the iFire technology was sold by Westaim to a Canadian-Chinese joint venture, CTS Group. Further developments are now awaited.

Surface-conduction Electron-emitter Display (SED) technology also looked very promising until two years ago but patent/licensing problems caused the suspension of the Canon-Toshiba joint venture, and a loss of impetus. The legal wrangles are apparently now solved (in December 2008,

2. http://kn.theiet.org/news/jan09/sharp-LCD-centre.cfm
3. http://www.ifire.com/

Applied Nanotech announced that they would not be appealing against the court decision that ruled in favour of Canon in July 2008), but the opportunity to go into production has been lost and we wait to see whether this technology will eventually be able to fulfil its evident potential.

Abbreviations

1080p/50	High-definition progressively-scanned TV format of 1920 x 1080 pixels at 50 frames per second
1080p/60	High-definition progressively-scanned TV format of 1920 x 1080 pixels at 60 frames per second
CRT	Cathode Ray Tube
DLP	Digital Light Processing
EICTA	European Information, Communications and Consumer Electronics Technology Industry Association Now known as *Digital Europe* **http://www.digitaleurope.org/**
FED	Field Emission Display
LCD	Liquid Crystal Display
LTPS	Low-Temperature Poly Silicon
OLED	Organic Light-Emitting Device (Diode)
SED	Surface-conduction Electron-emitter Display
TDEL	Thick-film Dielectric Electro-Luminescent
VFD	Vacuum Fluorescent Display

The other new technologies (FED and OLED)

The last couple of years have seen a resurgence of interest in **Field Emission Displays** (FEDs) – similar in many ways to SEDs in that electrons are accelerated across a small gap to emit light from a phosphor. In particular, electron emission from Spindt tips has come to the fore again (FED has its origins in 1958, with Spindt emission dating from 1968, so maybe this does not really qualify as "new technology"!).

FET Inc [4], a spin-off from Sony, was set to purchase Pioneer's old plasma display factory earlier this year, but lack of financial backing caused this development to be abandoned in March 2009. This is very disappointing, since Ikegami had demonstrated a very promising prototype monitor based on a prototype FET Inc panel.

Futaba [5], known for their Vacuum Florescent Display (VFD) modules (which are not a candidate for TV displays) have their own research into Spindt-based FEDs, and are reported to be continuing this line of development.

Although Samsung has demonstrated a 40-inch **Organic Light-Emitting Device** (OLED) display, and has hinted at a 50-inch version this year, the company does not expect OLED to become a mainstream product for 4-5 years. The major problem is how to create the larger screen sizes needed for TV. Because OLED is an emissive technology, the electrical current required to generate the light has to be supplied via the active matrix backplane technology. (In an LCD, the main power dissipation is in the backlight, not in the display matrix.) LTPS (low temperature poly silicon) is therefore the usual backplane technology, but is limited in the substrate sizes achievable to twenty-something inches, and larger displays have typically been made by "tiling" several panels together. However, OLED displays have recently been demonstrated on amorphous-silicon / micro-crystalline-silicon backplanes [6, 7].

The development of Organic LED displays has matured to the extent that OLED TV displays have made it into production. Marketed as 3mm-thick "Organic" panels, the 11-inch diagonal Sony XEL-1 is on sale in Japan *(as pictured in Fig. 1),* and in the USA with a low-key presence in the European market [8]. Also demonstrated as a prototype viewfinder for Sony's HD and CineAlta cameras, the

4. **http://www.fe-tech.co.jp/**
5. **http://www.futaba.com/**
6. T. Tsujimura et al: **A 20-inch OLED Display Driven by Super-Amorphous-Silicon Technology** SID Digest, Vol. 34 (May 2003), pp. 6 – 9.
7. F. Templier et al: **Development of nanocrystalline silicon thin film transistors with low-leakage and high stability for AMOLED displays** IDMC2006 Digest, p. 1705.
8. **http://www.sony.co.uk/product/tvp-oled-tv/xel-1**

Figure 1
Sony XEL-1 11-inch OLED on sale in Japan

OLED panels are impressive and attractive, but are still some way from making a major impact in the TV market.

Developments in Plasma Display Technology

Whilst the Panasonic NeoPDP design is aimed at ensuring a continued competitive position for Plasma, there is also a radical new plasma display from Shinoda. This display consists of an array of vertical tubes, each one acting as a column on a conventional display – but with better separation and greater flexibility, both in manufacturing and in the display configuration, thus enabling a semi-circular display to be formed in a continuous curve.

The demonstration so far has been of a 125-inch display, just 1mm thick. Not intended at present for TV applications, the initial market will clearly be for digital signage, but it is a very interesting development none the less. News of how the development of a product is progressing however has been hard to obtain, so this is another "wait and see" situation.

3D displays

Significant interest has been shown in 3D displays in a variety of configurations, with many stereoscopic 3D-ready back projection and plasma screens already sold in the US market, and 3D-equipped cinemas now using DLP projectors with, usually, polarizing glasses.

3D displays may be divided into a number of different categories:

1) **Volumetric displays** – a real image is formed in 3D space, providing an infinite number of simultaneous views. This avoids many of the issues with 3D viewing which are frequently experienced with other technologies, but is a very difficult technique to use for television.

   Wave-front reproduction (often called a holographic display) might be thought of as the ultimate form of 3D display, but practical implementations which are able to give high-quality images are some way into the future.

Integral Imaging is part-way towards this, and is essentially a multi-view display with a very large number of views, of which HoloVizio is one example [9].

2) **Auto-stereoscopic displays** fall into two varieties, both allowing the viewer to see “parallax” as the head is moved.

   - **Head-tracking displays** which provide an image to each eye appropriate to the viewer’s head position. Head-tracking displays for a single user are already feasible, and research on tracking and providing images for multiple viewers is advancing. Fraunhofer’s Heinrich-Hertz Institut (HHI) [10] is heavily involved in leading the collaborative work in this area.

   - **Multi-view displays** allow the users to move their head within a certain zone, and their eyes see different views depending on where they are within that zone. Until displays become available with vastly greater pixel counts than are available at present, multi-view systems suffer from relatively low resolution in each view. Philips has had a 9-view product [11] in this area, and has shown a 46-view prototype based on a 4k horizontal-resolution panel. However Philips has recently announced that it is ending commercial activity in this area, but is continuing with collaborative research projects in this field.

3) **Stereoscopic displays** present two views, one for each eye, and are the major market at present. There is a variety of different techniques.

   - **Barrier or micro-lens based techniques**, essentially the same technology as multi-view displays, but with only two views, where the viewer is required to keep their head still, but does not need to wear special glasses.

   - **Glasses-mounted micro-displays**, with individual displays dedicated to each eye.

   - **Spectral separation with glasses**. The simplest form is the old-fashioned red/green anaglyph, but more sophisticated versions giving better colour reproduction are now being demonstrated. It is possible to obtain full colour reproduction by using two spectrally-separated primaries for each of red, green and blue, with notch filters or interleaved comb filters in the glasses matched to separate pairs of primaries. Currently the preserve of digital 3D cinema systems, such a technique could be applied to domestic installations.

   - **Polarization separation** – either diagonally or circularly polarized for each view, with appropriate polarization in the glasses. Zalman [12] (in the games area) and Hyundai/Arisawa [13] (for TV) are the most readily-available polarizing displays. These are usually based on LCD technology.

   - **Time-sequential with synchronized shuttered glasses**, such as those from LG, Mitsubishi and Samsung. Early displays of this type were back-projection DLPs, but now plasma is dominant in the domestic environment, with a substantial number (a few million) such displays sold in the USA.

The last two types of stereoscopic display, both with glasses, are the most common types in the market at present, although not yet widely marketed in Europe. In both cases the quality of the 3D effect depends largely on the level of perceived crosstalk between views (i.e. visibility of the right view to the left eye and vice-versa), and is dependent on the display and the glasses, in combination. If the display knows the characteristics of the glasses, then some cross-talk can, to an extent, be pre-corrected in the signal.

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9. http://www.holografika.com/
10. http://www.hhi.fraunhofer.de/
11. http://www.dimensionalstudios.com/philips_20_3d_4you_display.html
12. http://www.zalman.co.kr/eng/
13. http://www.arisawa.co.jp/en/product/3d.html

This present survey of displays cannot go into the many issues surrounding 3D TV. For more details on the challenges of bringing 3D to the domestic TV market, the reader is referred to BBC R&D White Paper 173 [14].

Aspect Ratio

Just as everyone is getting used to 16:9 widescreen, we have from Philips the launch of a "Cinema 21:9" [15] Ultra-widescreen 56-inch diagonal LCD screen (with the same height as a 16:9 screen of 45-inch diagonal), *seen in the publicity photo above*. It is understood that the intention is that TV material will be presented on it with a non-linear horizontal stretch (although the user will have the choice of how to display such images).

As screens get larger, it seems inevitable that TV formats in the future will continue the progression towards wider images since this better matches the human field of view and suits the horizon position for a screen occupying a significant proportion of a domestic room wall. However this new Philips model is not in the largest size category, and is clearly aimed at the home-cinema market, and so viewer reaction to its use for TV viewing, and the market reaction from other manufacturers, will be interesting.

Conclusions

The current economic conditions will probably result in a period of relative stability in terms of display technology. LCD appears secure in a dominant position. It is not only potential new entrants to the field which find it hard to match the huge economies of scale and market dominance which LCD has

14. BBC R&D White Paper WHP173: **The Challenges of Three-Dimensional Television**
S. Jolly, M. Armstrong and R. Salmon, January 2009
http://www.bbc.co.uk/rd/pubs/whp/whp173.shtml

15. **http://www.cinematicviewingexperience.com/press.html**

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achieved, but even plasma display technology finds itself under pressure, following the effective demise of back-projection displays from the TV market.

OLED technology appears the most likely challenger for the future, but is unlikely to seriously challenge LCD for some 5 or even 10 years to come.