

Recent trends in digital imaging

Introduction

This paper looks at digital cameras, scanners, printers and display devices. It examines the markets, new and emerging technologies and issues in these areas.

Digital cameras

What is the state of the market?

The market for digital cameras has exploded over the last few years. Including cameras fitted in devices such as mobile phones, digital cameras have become the fastest selling consumer electronic device in history. This growth in digital sales has been matched by a decline in the sales of traditional analogue cameras to the extent where Kodak has announced its decision to stop selling these products in Western markets.

CEA market research has described the shift in the market as the move from early adopter stage to early majority stage. Digital camera sales have grown significantly year-on-year. This growth in the market has partly been driven by lower prices and these have in turn been kept low by increased sales.

The average price per megapixel has fallen each year since the launch of digital cameras: \$795 in 1998; \$346 in 2000; \$115 in 2002 with prices now below \$100 per megapixel (CEA market research¹). This reduction in prices coupled with the development of mainstream features in cameras has fuelled demand and given digital cameras broad mass market appeal. There is a wide choice of styles, specifications and price.

The trend for ever increasing resolutions has slowed over the last two years. Initially manufacturers were in a megapixel 'race' with camera resolutions increasing by about one megapixel a year. Resolutions have now reached a level which is 'good enough' for the majority of users needs so manufacturers have been concentrating on adding value, ease of use and better design (see *New technologies* page 2).

The market for cameras has divided into four key areas:

- a) **Entry-level/fun/fashion cameras (up to 2 megapixels) £20-£180 approx**
The recent emergence of 'fashion' cameras, which are driven by marketing, with an emphasis on style and size rather than picture quality/features, have increased sales in this sector. Cameras range from very inexpensive, low resolution, no LCD screen models, to sleek well designed 2 megapixel cameras.
- b) **Mainstream consumer models (3/4/5/ megapixels) £180-£500**
Over 40% of cameras sold are 3 megapixels or above. These cameras offer a range of features such as zooms, LCD screens, flash, automatic modes, video capture etc. These cameras meet the needs of the majority of users.
- c) **High end/enthusiast cameras (5+ megapixels) £500+**
Early adopters are now upgrading their cameras and there is a range of high end consumer cameras. These currently offer resolutions up to 8MP and a certain amount of manual control.
- d) **Prosumer/professional digital SLRs (6-18 megapixels) £850+**
Digital SLRs have dropped below the £1000 price point making them an option for serious amateurs/hobbyists. These have the option of full manual control, interchangeable lenses and superior optics and sensors.

These prices are very approximate as this is a fast changing area. Some lesser known brands offer certain specifications at prices considerably below the mainstream brands. It is important

to remember that megapixel counts are only one factor influencing the quality of camera outputs.

Increasingly, digital cameras are found in other devices particularly high-end wireless products such as notebooks, PDAs and mobile telephones. Indeed more cameras are sold in phones than as stand-alone devices. To take advantage of this phenomenon HP, Epson and Canon have created the Mobile Imaging and Printing Consortium to develop standards for printing from cameraphones.

The sale of cameraphones should have two effects on the digital camera market:

- i) as cameraphones have now reached 2 megapixels the market for low-resolution dedicated digital cameras should decline (except for 'fun' models);
- ii) Cameraphones will give consumers, especially young people, a taste of the possibilities of digital photography and help drive the sales of higher end cameras.

The emergence of cameraphones has had and will continue to have interesting sociological effects. These cameras have "an intimate, ubiquitous presence that invites a new kind of personal awareness" (Mizuko Ito, Okabe Daisukeⁱⁱ). This 'ubiquitous presence' whereby people will have digital cameras with them at all times could change the nature of photography and the way we see the world. '42.4 percent of camera phone users reported that they took photos of "things that they happened upon that were interesting."' (Ito/Daisuke) and "People with cameraphones start to have this consciousness that everything in their everyday life is potentially something shareable," (Ito). This ability could have possibilities in education allowing children to act as 'photojournalists' (schools in the US and Japan have used cameraphones in projects). The implications of these discrete, ever-present cameras in terms of social mores and invasion of privacy remain to be seen in Europe and some schools and local authorities have banned them. In Asia, where camera equipped phones are more prevalent, privacy problems and legal issues have arisen.

Memory cards/storage

The growth in digital cameras has been largely responsible for stimulating the memory card market. 60% of memory card sales are for digital cameras. Sales of memory cards more than doubled in 2003 and this trend is set to continue as the need for more memory increases. As prices have fallen and storage needs have increased users have been upgrading their cards. However, there still remains the problem of incompatibility and confusion between competing formats such as Compact Flash, Secure Digital, Memory Stick, MMC, SmartMedia and xD. This is set to continue as improved cards such as MMC4 are launched. These cards will offer much higher bandwidths for data transfer and capacities measured in gigabytes. There will be some competition from mini hard drives which tend to be less expensive per megabyte. Some schools use low resolution Sony Mavica cameras which have the convenience of recording to floppy disk or mini CD rather than memory cards. This offers quick, easy access for students who do not generally need high resolution pictures. A higher resolution device is useful for other needs such as art or publicity.

What new technologies/developments are there?

The digital camera market is a fast changing sector. In 2002 280 new digital models came to market in Europe. In 2003 this figure had reached 435 as opposed to 157 for traditional cameras. As has been noted the growth in megapixels has slowed but does still continue with 8 megapixel prosumers cameras available. Manufacturers have made cameras easier to use and include help menus and wizards in their devices. There has also been an effort to look at the 'digital chain' and improve the whole process of downloading, sharing and outputting photos through the PC. Manufacturers with an interest in printing services are looking for ways to push users towards their facilities rather than just printing at home. Features on models such as zooms, flash, anti-red eye, automatic scene settings etc have also proliferated to meet the expectations of consumers moving from film to digital. It is new features such as optical image stabilisation, and faster start-up/shooting times which are differentiating cameras.

CCD/CMOS

Initially CMOS sensors were used on low end digital cameras and CCD for higher resolution devices. However, improvements in CMOS technology has seen their introduction on high-end cameras and they could be set to replace CCDs altogether. CMOS sensors have several advantages over CCDs: the processing and capture chips can be integrated thus making CMOSs inexpensive to produce and more space and power efficient. CMOSs are produced in the same way as other chips and benefit from the manufacturing processes and economies of scale already achieved in the industry. CMOS based cameras are therefore smaller, more power efficient and potentially less expensive to buy. Currently, CMOS sensors are appearing on high-end SLR cameras or on very low resolution devices such as webcams.

Full frame

The majority of digital cameras uses interline CCDs where the image data is continuously moved to a shift register for output to the TFT-LCD display or for recording movies. The circuitry for this type of CCD reduces the active capture area of each receptor element. Many digital SLR cameras now use 'full frame' sensors without this circuitry to capture more data per pixel and produce images with greater dynamic range, colour and detail. However, full-frame CCDs are not able to produce real time previews on TFT-LCD screens or capture video. These are not major issues for professional/prosumers for whom image quality is paramount.

4/3 standard

This is a new 'common standard' developed by Olympus and Kodak for digital SLRs. It was developed to overcome the optical problems caused by the use of traditional lenses and bodies in digital SLRs and to make different manufacturers lenses and bodies interchangeable. The 4/3 standard uses a larger 4/3 ratio sensor (as opposed to the usual 2/3) and a standardised body where the lens aperture is twice as large as the sensor. This allows light to enter head on eliminating problems caused at the periphery of the sensor caused by using digital sensors with 35mm film lenses. The standard body not only allows 4/3 lenses to be interchangeable between manufacturers but also for the lenses themselves to be much smaller than the standard equivalent traditional lenses at any given focal length.

However, despite these advantages it remains to be seen whether the 4/3 standard will catch on. Professionals and enthusiasts have existing investments in lenses and cameras and may be reluctant to change to a new incompatible standard. Currently only Olympus have 4/3 products available.

New CCD designs

Resolutions and image quality have steadily improved yet the basic design of most CCD has remained unchanged with a matrix of receptors individually capturing red, green or blue. This has meant that interpolation is needed to output the final pixels, some cameras even adding a blur filter to counter any pixelisation caused by the interpolation. However, some new designs have appeared which help overcome these and other problems. Foveon's X3 sensor captures red, green and blue at each receptor thus no interpolation is needed. Sony has created a RGB+E sensor which captures emerald in addition to RGB offering more realistic colour. Fuji has a Super CCD SR which offers improved dynamic range.

All of these developments reflect the trend of manufacturers to emphasise factors other than megapixels in defining the quality of digital cameras.

OLED screens

Last year Kodak introduced the first camera with an OLED screen (see *Display technologies* page 8). This could be the start of a trend as OLED screens offer brighter, sharper images with a wide viewing angle and greatly reduced power requirements when compared to TFT-LCD.

Wireless

Wireless picture transmission is increasingly used by professional photo journalists linking their cameras to a portable device such as a laptop or PDA over 802.11b wi-fi. Standards are being developed for the wireless transmission of pictures and this feature could eventually filter down to consumer models.

Standards

There has been some development of standards to ease interoperability between devices, computers and photo finishers. The EXIF and DCF standards for exchanging and organising image files are becoming industry standards. The Imaging Industry Association is developing Common Picture Exchange environment (CPXe) and the Picture Services Network (PSN) directory service for sharing and printing photos online. Another standard, Pictbridge, is designed to allow cameras to print directly to any printer using the standard (see *Printers* page 6).

Issues

Privacy and child protection are major issues in schools using images. Schools need to implement a clear policy on the use of photographs of children, obtain consent before any publication and abide by data protection laws. The general rule is not to associate a photograph with a name. Guidance on this issue can be found at:

<http://www.teachernet.gov.uk/wholeschool/familyandcommunity/childprotection/usefulinformation/photosandvideos/?section=2924&CFID=5242418&CFTOKEN=4f7b4a9-5507d6e2-31ef-4d8d-8f71-96f57eb6515e>.

Advice on using photos on school websites can be found at:

<http://safety.ngfl.gov.uk/schools/pdf/d27.pdf>.

Scanners

What is the state of the market?

This section concentrates on mainstream flat bed scanners rather than specialist drum or 3D scanners.

Scanners became very popular in the late nineties as powerful PCs with graphics and multimedia capabilities became widely available. Prices for basic flat-bed scanners dropped to a point where they became commodity devices in the reach of the average consumer. They were a cheap, effective way for people to capture their photo collections onto their PCs for editing, storage and output. However, the recent popularity and penetration of digital cameras has decreased the sale of scanners. This continuing trend has also been driven by the rise in sales of all-in-one (AIO) devices that combine printer, scanner, and sometimes fax functions.

Scanners bridge the gap between the analogue and digital worlds. They allow users to make the transition from film to digital by archiving their existing photo collections to PC for storage and editing. In education their uses range from digitisation projects, and art/graphic applications, to simply adding images to pupils work.

As with digital cameras, the resolution and quality of low-end scanners has reached a point where they meet the needs of most users contributing to their commodity status. The increasing popularity of AIO devices has been helped by the fact that their integrated scanners have caught up in terms of resolution and the average user does not necessarily need the extra quality and features of dedicated products. In education the need for multi-function, space saving devices is less prevalent and schools are able to purchase stand alone scanners on price, suitability and quality.

Flat bed scanners can be divided into four main groups:

- a) **Low-end entry level:** inexpensive, designed for home use. Quoted resolutions and bit-depths look impressive but the overall quality of images does not match more expensive machines. Suitable for most users.
- b) **Mid-range:** higher resolution, better dynamic range. Extra features and software, eg automatic document feeders.
- c) **Document scanners:** usually with document feeders attached. Designed for scanning large quantities of text documents. They can be linked to document databases to automate the process of scanning and archiving.
- e) **High-end/professional:** for imaging professionals. High colour fidelity. Expensive.

What are the new technologies/developments?

There have not been any major recent advances in mainstream scanner technology but as with digital cameras image quality has improved and prices have fallen. Manufacturers have been concentrating on features, design and improved software. Optical character recognition (OCR) has improved greatly. Indeed the quality of software can have a significant effect on the overall quality of the final scan.

The designs of flatbed scanners have remained fairly consistent. However, recently manufacturers have made an effort to make their scanners smaller and more appealing. HP, for example, have introduced ultra-thin (spiral notebook size) and upright, clear sided scanners. Manufacturers have also made other minor improvements such as reduced warm-up times, integrated photo feeders and one touch buttons for email, copy, scan etc Scanning times have been considerably improved on many models. Some professional features such as transparency units (TPU) with moving light sources for better quality, faster scans, are making their way onto high-end consumer scanners.

USB, USB 2, SCSI and Firewire are the main interfaces; parallel interfaces are no longer commonly used.

High end imaging scanners now offer excellent image fidelity to professionals/high-end users. Improvements in CCDs and digital signal processors (DSP), coupled with image correction software and technology to reduce dust and light noise all improve the final results for demanding users. The cost of these scanners remains too high to justify their purchase for the majority of schools, especially as the quality of mid-range scanners is acceptable for most tasks.

One area which has improved is hand held scanners. Hand held scanners have largely been superseded by inexpensive flatbed models. However, pen-style scanners are versatile, portable devices for small ad-hoc text scanning jobs. These are now more accurate and include features such as OCR or even translation software.

In addition digital pen/electronic paper systems have been developed to capture handwriting. Some of these digital pens work independently, others use pre-prepared paper. Many of them have wireless Bluetooth connectivity.

Printers

What is the state of the market?

Until relatively recently printer sales were tied to the growth in the PC market. However, the printer market, especially for colour inkjets, has benefited from the boom in digital photography. The Canon Consumer Digital Lifestyle Index has found a correlation between the sales of digital cameras and printer consumables. Overall sales of printers, however, were down 2% in 2003 (GfK marketingⁱⁱⁱ). Analysts believe this decline will continue. The growth area has been in multi-function devices and photo printers.

All-in-one (AIO) devices have become attractive to many users. They offer added functionality, take up less space and are good value when compared to discrete devices. However, despite improvements, they cannot offer the same quality as dedicated products and may have support and long-term cost issues.

Colour printing has been a key trend with the rise in content and media rich documents and photos. In education colour printing is seen as a valuable tool for motivating pupils. However, the perceived high running costs of colour printers have reduced their widespread take-up. The take-up of colour laser printers has been slow despite the fact that networked colour lasers have cost and control benefits over individual personal inkjets. Many organisations do not know the true amount and cost of their printing and may not fully appreciate the long-term cost advantages of lasers over inkjet.

The printer market is very competitive. Manufacturers compete keenly on price and many are offering basic inkjets at extremely low prices relying on the revenues from consumables for their profit. These entry-level inkjets are intended to increase manufacturers' user base for their inks. Laser printers have also become increasingly affordable with monochrome devices starting at £150. Colour lasers have also seen significant price drops.

'Business inkjets' are designed for heavy users or small workgroups. They use larger print heads to increase speed and have bigger ink tanks to reduce costs. 'Single-pass' colour laser printers have improved speeds making them more attractive purchases. In general inkjet manufacturers are trying to increase speeds, improve drying times and reduce running costs. Conversely, laser products are aiming to converge with inkjets on price and image quality.

The ability to produce quality, colour documents on demand has meant many organisations rely on in house graphics and design to produce short-run brochures etc. This culture of 'just in time' printing has reduced the need to use commercial off-line printers.

The cost of A1 colour printers and plotters have fallen to price points (from £1500+) which make them attractive purchases for schools particularly those doing CAD/CAM.

Many manufacturers have been running consumable recycling schemes for environmental and commercial reasons. These schemes are partly in response to similar ones run by 3rd party suppliers. More value is being attached to this type of service by environmentally aware users and organisations.

Online storage and printing

The whole concept of how to share photos is changing. Although many users still appreciate the tactile nature and image quality of a print, online sharing, digital archives, email, picture messaging and CD-R slide shows are transforming the whole viewing experience. Portable digital image storage devices are becoming available. These are the picture equivalent of the MP3 player. This is part of the shift in ideas from the 'photograph' to the 'digital image' and the possibilities that represents.

Commercial printing of digital photos and online storage and sharing of photos has been growing (up 72% in US between 2002 and 2003). However, the general processing/printing industry has declined as a result of the rise of digital photography, hard drive storage and e-mail. It is estimated that only 20% of digital photos taken are ever printed. In order to counter this trend some manufacturers, especially those with a commercial interest in processing, have developed various strategies. These include the creation of new interoperability standards such as CPXe to help users find and easily use online photo printers. Many High street photo finishers now accept memory cards and can output to CD in addition to high quality photographic paper. Photo booths where users can download, edit and print photos from memory cards and mobile phones, are available and should become more common. The 'high-street' photo finishing industry is adapting to digital photography as revenues from traditional channels erode and trying to attract users away from home printing.

What are the new technologies/developments?

Inkjet printer technology has reached a point where major developments have plateaued. The droplet size is down to 1.5 Pico-litres from 10 a few years ago. Sophisticated print engines deploy precise amounts of ink in carefully controlled patterns. As has been stated, manufacturers are therefore concentrating on AIO devices and high margin 'photo' printers. Colour laser printers have become faster and less expensive but cannot yet match the photo quality of many inkjets. Conversely inkjets cannot meet the speed and cost per page of lasers.

'Photo' printers are inkjets with six or more separate coloured inks for improved colour rendition. The benefit of 6-ink photo printers over 4-ink counterparts has been questioned for the average user. Some manufacturers have added extra 'colours' to improve greytone or vibrancy. The trend of aiming printers directly at digital camera owners and allowing them to eliminate the PC from the process is highlighted by the inclusion of memory card readers on printers. Recently, many of these photo printers have also included a TFT-LCD screen to allow basic editing of photos before printing. These printers often have facilities for producing borderless 'photo-size' prints.

Wireless connectivity, such as Bluetooth and 802.11, is available but is often an optional extra. As more devices, such as cameraphones, become Bluetooth enabled this situation may change.

Pictbridge is an open industry standard developed by the Camera and Imaging Products Association (CIPA^{IV}) to ease interoperability between digital cameras and printers. The digital workflow, or getting photos from the camera to a hard print, has been problematic for many users. Manufacturers tried to solve this problem by enabling cameras to print directly to printers bypassing the PC. These proprietary solutions were limited to certain cameras and printers. The pictbridge standard allows any pictbridge enabled camera to print directly to any pictbridge printer, see: http://www.cipa.jp/english/pictbridge/DPS_WhitePaper_E.pdf.

One of the areas where online and high street digital photo printers claim to have an advantage is in the durability and longevity of their prints. Photos printed on inkjets can sometimes begin to fade in as little as two weeks. Inks with fade and smudge resistance have been developed by companies such as Epson with its 'Durabrite' range. Claimed fade resistance time of 70 years refer to photos printed

on special paper and kept behind glass. The goal of many manufacturers is to combine the colour reproduction and vibrancy of dye-base inks with the longevity and robustness of pigment inks.

Some companies have been developing 'erasable ink' for laser printers. Carbon-free toner is used that can be erased by heat from an 'eraser' machine. The paper can then be reused until it deforms. Toshiba are currently selling the technology in Japan where it is claimed to reduce paper costs by up to 60%. The environmental and cost savings could be significant as the paperless office still seems some way off.

Issues

The Office of Fair Trading investigated the market for printer consumables in December 2002. They found that 'printer manufacturers effectively control the pricing of ink-cartridges in their after-markets despite the presence of third party competitors.' It is difficult for 3rd party vendors to gain more than 15% of the market. Therefore they were not exerting pressure on prices. Manufacturers were also found to sell cheap printers subsidised by expensive inks. They found that consumers were not made aware of the on-going costs of owning a printer and that these costs varied widely between manufacturers and models. They advised that more transparency was needed in the market. The implementation of a standard test to identify the cost per page of each printer was recommended with the results being made available to purchasers.

The Waste Electrical and Electronic Equipment (WEEE) EU directive, which will be implemented in August 2005, is another contentious issue. The UK government has classified printer ink/toner as consumables and therefore exempt from WEEE. The refiller/remanufacturer companies oppose this as it allows printer makers to use 'killer' chips to prevent refilling, damaging their business and causing empty cartridges to be thrown away. This is counter to the situation in most of Europe where chipping will be banned. However, consultation is taking place between the interested companies and the government.

The cost of printing photos at home has come under scrutiny. A recent investigation by PC Pro magazine found that commercial printers could produce 6x4 prints for as little as 15p whereas home printing works out at between 28-80p. They also highlighted the fact that commercial prints were often better quality and were more fade resistant. However, for larger prints and for precise colour matching home printing has advantages. The convenience and creative control allowed makes printing their own photos attractive to many users. In education the ability to print in colour and include photos is seen as important in motivating pupils and developing ICT in schools. The on-going cost of this is the major barrier.

Display technologies

What is the state of the market?

The market is characterised by the transition from traditional CRT displays to flat-screen displays. Flat screen displays are dominated by TFT-LCD screens with plasma display panels (PDP) being used for large commercial displays and in the high end TV market. Several emerging technologies may eventually challenge the dominance of the TFT-LCD/PDP solutions.

TFT-LCD displays are the main technology for flat screens used in devices such as mobile phones/PDAs, notebooks, computer monitors and TVs. 15" TFT-LCD computer monitors have become a mainstream device with models for under £200. Until recently, 17" models were twice as expensive, but according to IDC^v recent price reductions have meant 17" displays could dominate sales by next year, especially as they are often bundled with computers.

Prices for TFT-LCD displays have been falling quickly. Fluctuation in prices due to supply has characterised the TFT-LCD market over the last few years. The general trend should continue to be downwards with production costs halving over the next three years. Analysts predict that by 2007 two out of three computer monitors purchased will be TFT-LCD. Revenues for TFT-LCD monitors

surpassed those for CRTs in 2003 and unit sales of TFT-LCD are expected to surpass CRT in 2004 (IDC).

This burgeoning market has attracted large investments in TFT-LCD production. This level of investment will probably ensure the future of TFT-LCD as the dominant technology over this decade as companies will want to recoup their investments before moving into next generation technologies. However, the Taiwanese and Koreans now have 80% of the market between them so Japanese manufacturers may take the opportunity to jump to next generation displays in order to compete with the Tiger economies.

Plasma displays currently dominate the large flat panel display (FPD) market. This remains a niche market for corporate displays and high-end TV enthusiasts. The high price of these displays has meant that in Japan, for example, where they account for 2% of FPD sales, they accrue 20% of the profit. However, plasma displays will begin to see direct competition from TFT-LCD panels. Plasma is expected to keep its dominance in the 40"+ sector to 2005 due to better cost and performance, but improvements in manufacturing have allowed TFT-LCD manufacturers to make larger screens for less. TFT-LCD screens of up to 50" can now be economically made. TFT-LCD prices are also falling faster than those for plasma leading DisplaySearch^{vi} to predict that PDPs could be pushed out of the 30"-50" market by 2006.

Growth in the LCD-TV market is also driving production. Profits on LCD-TVs can be twice that of computer monitors. Although, TFT-LCDs only have 3% of the total TV market at present this should increase to 16% by 2006. The profits and larger market that consumers represent have encouraged computer manufacturers like Gateway and Dell to enter the TFT-LCD-TV sector. It remains to be seen whether these IT names can compete with established consumer brands.

Sales of OLED displays (see *New technologies* below) were up 124% to \$262.7 million in 2003 with 17 million units shipped. They are currently being used on high-end, small devices. Larger substrates, manufacturing efficiency and increased reliability should help the OLED market. Analysts believe that these will not be ready for mainstream production until 2005 at the earliest.

The emergence of low cost, high performance projectors has fuelled demand in the market. Projectors have become user-friendly and light weight. The market is very competitive which keeps prices down and innovation up (see below). Sales were up 34% in 2002 and IDC predict continued growth.

What are the new technologies and issues?

The display market has evolved at a phenomenal rate and flat-panels are challenging the 60 year dominance of CRTs. Ironically, in displays up to 36", CRTs still offer the best performance and digital imaging professionals who require colour accuracy and video performance use nothing else. Their bulk, power consumption, heat production and aesthetic limitations however, mean their usage will continually decline. TFT-LCD screens offer better ergonomics, useful life spans up to three times that of CRTs, and reduced eyestrain. TFT-LCD displays are constantly improving with thinner, faster, high contrast displays being launched at increasingly large sizes. Higher Contrast ratios and response times of 12ms are now available allowing TFT-LCDs to compete with technologies such as CRT (8-12ms), particularly for video/games which used to be problematic.

Plasma, FEDs

Plasma is currently the main option for large screen displays. Their high prices have prevented widespread adoption. Although prices have fallen to £2500 for some lower quality models, they suffer from their high cost of production as the driver circuits account for 2/3rds of the cost of a screen as opposed to 50% for TFT-LCD. Manufacturers are trying to address this and other problems such as the graininess of some images and the large power consumption of the units. Another major problem for plasma displays is their limited life-span. They can have a contrast half-life of only four years and images can get 'burnt' into the screens.

Alternatives to plasma displays are being developed. Field Emission Displays (FED) use the same principle as CRT in that electron beams light screen phosphors. However, instead of electron guns FEDs use individual 'emitters' to direct electrons to each pixel. Development is concentrating on the use of carbon nanotubes as these 'emitters'. These displays, such as Motorola's nano emissive display (NED) promise cheaper, thinner, better quality screens. They use cheaper circuitry and involve fewer production processes than plasma. Plasma factories could be relatively easily converted to NED production. It remains to be seen whether this technology is commercially viable.

Micro display technologies

DLP: The Digital Light Processor was invented by Texas Instruments in 1987 but has only fairly recently become popular in digital projectors and rear-projection TVs. It uses a chip with microscopic tilting mirrors, one for each pixel. It offers bright, high contrast images suitable for high definition video. It also allows for smaller device sizes. However, the images tend not to be as sharp (particularly text) as TFT-LCD panels and the colour wheel technology used can cause visual problems for some viewers. DLP and TFT-LCD are direct competitors in the multimedia projector market and the image quality of both is constantly being improved. Prices of DLP projectors have dropped in the last two years making them a viable alternative to TFT-LCD especially for video playback.

LCoS: Liquid Crystal on Silicon is competing with DLP to replace LCD on rear projection displays and digital projectors. It should be increasingly prevalent as a HDTV solution. Liquid crystal is sandwiched between glass and a reflective layer over a silicon chip. The liquid crystals selectively block or allow light through to the reflective layer. They give high resolution images with a smooth, film-like quality similar to analogue displays. However, the devices are bulky, with limited lamp life and are lower contrast than DLP. Several manufacturers have slightly different implementations of this technology. It is expensive at present but big names such as Intel have invested in the technology and prices should fall with standardised and scaleable manufacturing processes.

Emerging display technologies

OLED/LEP

Organic LEDs and Light Emitting Polymers are seen by analysts as realistic TFT-LCD competitors in 2007/8. These technologies use organic semi-conductors which emit light when a current is passed through them. As they emit light, rather than selectively blocking it like TFT-LCD displays, a backlight is not needed. This lack of a backlight has significant impact on battery life for mobile devices. Notebook display systems currently take 40% of the total power. They can also have a 10-fold manufacturing cost saving over TFT-LCD. Manufacturing methods include using ink-jets to spray the organics onto flexible substrates. The possibility of roll-up or expandable low power screens could transform the mobile market. The screens are extremely bright with excellent resolution and wide viewing angles. However, there are still problems with the life-span and robustness of the displays. They have been initially used in small displays for cameras, hi-fis and phones and these will remain the initial markets. However, 21" screens have been demonstrated.

Digital paper

Digital paper aims to marry the qualities of paper with the advantages of an updateable electronic display. Reading times are 25% slower on existing displays when compared to paper. There are two main types of digital paper licensed from different companies: E-ink and Gyricon. Both these technologies are reflective so work from ambient light. E-ink uses liquid filled microcapsules filled with black and white chips that move to the top or bottom when a current is applied. Gyricon's paper uses bi-chromal microcapsules in liquid which rotate. Crucially, the displays maintain their image without power (bistable) having major benefits for mobile devices. They can be made from flexible materials using carbon polymer circuits and should eventually approach the resolution of printed paper. Although, Philips has managed to produce colour E-ink displays capable of showing video, the first commercial products (Gyricon's SmartPaper) have been monochrome, low resolution and with low

refresh rates. They been used in shop signage where the data displayed is fairly static and the ability to update it centrally is a big advantage.

In Japan, Sony is planning to launch E-book readers (E-ink) in May 2004 in conjunction with major publishers. Production prototypes of 5" roll-up screens have also been demonstrated. The ultimate goal is to have a networked, updateable, low power, flexible display. The potential for educational applications is enormous but it remains to be seen whether the technology will become commercially successful.

Other developments

DVI: The Digital Visual Interface is a connection that allows a continuous flow of digital data between the PCs graphics subsystem and a display without the need for analogue conversion. DVI is replacing VGA interfaces on newer, more expensive monitors. There are two main types of DVI: DVI-D (digital only) and DVI-I which can handle VGA signals as well. These interfaces also make monitor set-up and configuration easier. Currently 64% of TFT-LCD monitors are analogue only, 29% dual and only 7% purely digital (Stanford Resources). The growth of the DVI in Europe may be threatened by an EU proposal to class monitors with DVI connectors as TVs and impose a 14% import tax. For more information on the DVI standard see: <http://www.ddwg.org/dvi.html>

LED backlights: Most TFT-LCD displays use Cold Cathode Florescent Lamps (CCFC) as backlights. LED backlights enable a much brighter, longer lasting display which consumes less power and without the same environmental impact. These are initially appearing on some small TFT-LCD displays.

LED displays: The emergence of the blue LED in the late nineties allowed the creation of full LED displays. Due to resolution limitations these are only suitable for very large displays such as those used in advertising.

3D/holographic: Auto stereoscopic 3D displays are used in industry, medicine and the military. They can be coupled with VR technology that allows physical interaction with the display. This remains an expensive, specialist area. However, notebooks with 3D display technology have just been released and this could become a mainstream technology driven by the gaming industry. The notebook 3D displays (Sharp) do not need any special eyewear and work by having two slightly different images displayed at once. One image is for the left eye and one for the right. The brain then creates the illusion of 3D. However, the viewer is restricted in their available position. Major companies like Kodak are also developing similar 3D displays.

3D holographic projection *into air* has been demonstrated but remains only a distant future development. Toshiba have obtained a similar effect using existing projection technology again relying on the brain being 'fooled' into producing a 3D image.

Useful links

Digital cameras

Becta paper on choosing a digital camera: http://www.becta.org.uk/technical_paper

Choosing a camera: <http://www.pcmag.com/article2/0,4149,2400,00.asp>

Digital photography review. Provides technical, in-depth reviews of new digital cameras: <http://www.dpreview.com>

4/3 Standard: <http://www.four-thirds.org/en/index.html>

DCF standard: <http://www.exif.org/dcf.PDF>

CPXe standard: http://www.i3a.org/i_cpxe.html

PSN standard: http://www.pictureservices.org/pr_06_09_03.html

Pictbridge standard: <http://www.cipa.jp/english/pictbridge/>

Foveon X3 sensor: http://www.foveon.com/X3_tech.html

ZDNet reviews of a wide range of IT products, including digital cameras. <http://reviews.zdnet.co.uk>

News, reviews: <http://www.dpreview.com/>

Social impact of cameraphones: <http://www.thefeature.com/article?articleid=47795>

Memory cards

CompactFlash: <http://www.compactflash.org>

Memory stick: <http://www.memorystick.org>

MultiMediaCard Association: <http://www.mmca.org>

Secure Digital (SD): <http://www.sdcard.org>

Smartmedia: <http://www.ssfcd.or.jp/english/>

Scanners

Technical Advisory Service for Images: <http://www.tasi.ac.uk>

How scanners work: http://www.extremetech.com/print_article/0,3998,a=29391,00.asp

Selecting a scanner. Research Libraries Group: <http://www.rlg.org/visguides/visguide2.html>

Digital imaging tutorial. Cornell University:
<http://www.library.cornell.edu/preservation/tutorial/contents.html>

Digital pens/paper: <http://www.anoto.com/>

Digital pens:
<http://www.logitech.com/index.cfm?page=products/features/digitalwriting&CRID=1545&countryid=18&languageid=1>

Printers

PC Magazine guide to buying printers: Buying guide:
<http://www.pcmag.com/article2/0,4149,1766,00.asp>

Society for Imaging Science and Technology <http://www.imaging.org/>

OFT inkjet recommendations:
<http://www.ofg.gov.uk/nr/rdonlyres/eywvu2ox4uys7fototzs7ikecipuevt7nk6b5w3jrl66z7u2p5fjj4zikwwiyd2juonwwhed5rthe5n3ebfq4nypwpe/off610.pdf>

WEEE directive: <http://164.36.253.20/sustainability/weee/>

Erasable ink: <http://news.bbc.co.uk/2/hi/technology/3301003.stm>

Free Total cost of ownership printer tool: <http://www.charisco.com/tcoillustrator.htm>

Displays

PC Magazine buying guide for LCD displays: <http://www.pcmag.com/article2/0,4149,1457043,00.asp>

Projector guide: http://www.projectorcentral.com/buyers_guide.cfm

Projection technologies: http://optics.unaxis.com/en/Techno_531.asp

How Stuff Works (LCD): <http://www.howstuffworks.com/lcd.htm>

DLP: <http://www.dlp.com/>

http://www.projectorcentral.com/lcd_dlp.htm

LCoS: <http://www.projectorcentral.com/lcos.htm>

<http://www.intel.com/design/celect/technology/lcos/>

Digital paper: <http://www.eink.com/> <http://www.gyriconmedia.com/>

CNT: http://www.infoworld.com/article/03/12/04/HNnanotubes%20_1.html

http://www.motorola.com/mediacenter/news/detail/0,1958,2981_2436_23,00.html

OLED: <http://www.kodak.com/US/en/corp/display/overview.jhtml>

http://olight.com/techno_olight_technology.shtml

3D LCD notebook: http://66.132.145.25/products/pc_notebooks/actius/rd/3d/

Video Electronics Standards Association: <http://www.vesa.org/>

Health and safety: <http://www.hse.gov.uk/lau/lacs/16-1.htm>

References

ⁱ Consumer Electronics Association

http://www.ce.org/publications/books_references/digital_america/digital_imaging/default.asp

ⁱⁱ Mizuko Ito, University of Keio in Japan/University of Southern California;

Daisuke Okabe, Yokohama University

<http://www.itofisher.com/mito/>

ⁱⁱⁱ GfK Marketing Services

<http://www.gfkms.com/>

^{iv} CIPA Camera and Imaging Products Association

<http://www.cipa.jp/english/index.html>

^v IDC

<http://www.idc.com/>

^{vi} DisplaySearch

<http://www.displaysearch.com/>