White Paper

Zecotek 3D Display

"The solution to glasses-free, high-resolution 3D Displays."

Zecotek Photonics Inc. (TSX-V: ZMS; Frankfurt: W1I) **www.zecotek.com** is a Canadian photonics technology company developing high-performance crystals, photo detectors, lasers, optical imaging and 3D display technologies for commercial applications in the medical diagnostics and high-tech industries. Founded in 2004, the company has three distinct operating divisions: imaging, lasers, and 3D display systems with labs and production facilities located in Canada, Singapore, Malaysia, and Russia. Zecotek commercializes its novel, patented and patent-pending technologies both directly and through strategic alliances and joint ventures with multinational OEMs, distributors and other industry leaders.

In 2009, Zecotek was honored with the prestigious Frost and Sullivan award for 'Best Enabling Technology' for its MAPD (Multi-pixel Avalanche Photo Diode) and LFS (Lutetium Fine Silicate) scintillation materials. The Company has featured on Discovery Channel's Daily Planet, and in 2010 was cited as one of the top ten Canadian technology companies to be the next 'big thing' for its 3D display system.

Zecotek is presently seeking manufacturing and distribution partnerships to commercialize its 3D display.

Zecotek 3D Display System

Based on a patented array of matched dynamic lenses coupled with proprietary high-speed time-sequenced image projection, Zecotek's 3D display system offers a solution to the impasse of current 3D technologies as it does not require glasses or eye tracking, or other extraneous or viewer-dependent devices. The system operates by forming a very large number of perspective views which, together with its wide viewing angle, allows multiple viewers to have each their own unique 3D viewing perspective. This combination of views, viewing angle, and the 3D display's high resolution offer a viewing experience closest to the visual perception of real objects. Industry specialists have termed it "the best auto-stereoscopic solution available."

3D Technology Explained

The illusion of 3D is the result of our human binocular vision where each eye sees a slightly different image. This is achieved in the real world by our eyes being slightly apart, so that each eye has its own slightly different view. The brain processes these two images into one image having the quality of depth.

Glasses-based 3D systems produce a 3D effect by offering two views, with each view captured or digitally created to show an appropriately different angle or perspective. The glasses use either polarization filters or synchronized shutters to transfer only one view to each eye. The brain processes these images just as it would in real life, combing the two views to give the illusion of depth.

Glasses-based stereoscopic displays using polarization effect commonly contain a mask of interleaved polarizers with opposite directionality placed in front of the pixel matrix, so that each eye of the observer wearing glasses with the two similar polarizing elements will only see one of the sub-frames covered with a matching polarizer. Such systems suffer from a factor-of-two loss in resolution in one of dimensions (typically vertical) as well as from 50% loss in brightness because of polarization filtering. They do not need higher refresh rates required for shutter-glasses displays, but the manufacturing process of display panels with polarization masks is more complicated than the conventional technology.

Shutter-glasses 3D TV is based on repeated projection of a two-frame sequence, in which one of the frames is intended for the left eye and the other one, for the right eye. By using active shutter glasses, only one eye is allowed to view the image on the screen, for example the left eye, while the right lens on the glasses turns opaque to prevent the right eye from seeing the image. The speed of this switching on and off is linked to the refresh rate of the screen or display.

In a television screen or panel display, the refresh rate of the screen is defined by the speed and the frequency at which an image displayed on the screen is updated. The higher the refresh rate, the smoother the image perception is. An image updated every 17 milliseconds corresponds to a refresh rate of 60 Hz (*i.e.* 60 times per second). This rate can produce a satisfactory 2D image without a perceptible flicker. However, to produce two separate views the screen refresh rate is divided between the eyes, so that 60 Hz becomes 30 Hz for each eye, which may lead to visible flicker in the image and hence, to viewer discomfort. To reduce this flicker, display manufacturers have increased the refresh rate to a minimum of 120 Hz so that each eye experiences a refresh rate of at least 60 Hz.

Although visible flicker can be eliminated by increasing the refresh rate, the key problem with glasses-based systems, (or in fact any system, which relies on presenting only a few views), is the absence of motion parallax and the occlusion effect. Motion parallax is the apparent difference in the direction of movement or speed observed when the subject moves relative to his environment. Without motion parallax, everyone viewing the display (or on a theatre screen) sees the identical image no matter where they are positioned, or how much they move their heads. In a similar way, the occlusion effect is the blocking of one object by another opaque (non-transparent) object located in front of it, but where the hidden object can still be seen if viewed from a different angle, for example in side view. The absence of both motion parallax and the occlusion effect can create a sense of imbalance and dizziness, sensations commonly experienced when only two views are presented (and which are contributing to concerns over health and safety of 3D viewing, in particular by children during developmental).

Motion parallax and the occlusion effect are made possible only with a large number of views, (typically more than 5 and ideally more than 25) and which are then directed to an appropriate viewing angle at a speed which is undetectable by the human eye.

Auto-Stereoscopic Glasses-Free 3D Displays

The term “auto-stereoscopic” refers to displays, which can provide 3D effect without special glasses or other headgear worn by the observer.

It is possible to create an auto-stereoscopic display with only two views and, indeed, such devices have been proposed commercially, but the extremely small width of the ‘sweet spot’ from which depth perception is possible and severe visual artefacts outside of this observation zone put this approach at a disadvantage compared to the glasses-based systems. In order to address these problems in an auto-stereoscopic display, more views are necessary, and this is why multi-view auto-stereoscopic systems have been developed to improve visual comfort and perception.

In general, image quality (clarity) or any display is dictated largely by the resolution of the screen, which in turn depends on pixel density. The higher the pixel density is, the greater will be the image resolution. Current display panel technologies have achieved pixel densities that translate into very high resolution in 2D viewing. However, since 3D requires projection of multiple views at rates undetectable to the eye, this presents significant additional barrier to producing high-resolution 3D images using the same panel technologies.

At present, researchers and developers are pursuing two main classes of solutions. These can be broadly categorized as either a “space multiplexing (sharing)” approach or a “time sequencing (sharing)” approach.

Space Multiplexing (Sharing) 3D Auto-Stereoscopic Displays

Current commercial offerings using flat panel screens (3D Fusion, Fujitsu, Toshiba, &c) appear to achieve this by using lenticular lens arrays, parallax barriers, or some form of micro-lens arrays placed in front of a 2D panel. With this technology, groups of pixels in the screen are matched to a particular angle, so that they are projecting different views. However, this means that the total number of pixels in the screen must be distributed among the displayed views, so that pixel *density* of the resulting 3D image is divided by the number of views projected. Since resolution is proportional to pixel density, it means that high-resolution panels will only be able to achieve adequate resolution in 3D when the pixel density of those panels is increased by the same factor as the number of views required for 3D. Glasses-free, flat panel displays presently allow for up to 9 viewing positions. This means that the base HD resolution has to be divided by 9 for each view. In addition, the head movement in any one position is restricted to only few centimetres and distance from the screen may also be restricted in order to achieve the 3D effect (see the Appendix).

Even with only 5 views, in order to achieve HD (1920×1080) for each view, the total screen resolution must be 5 times HD, or approximately 9.5 million pixels (4096×2304). To provide for wide and continuous angle of view (> 40 views) and for an adequate viewing angle for multiple viewers, it is estimated that approximately 83 million pixels are required, or pixel densities more than 40 times those currently available. This sort of technology does not presently exist and, even if it became possible, manufacturing costs would be likely prohibitive.

At present, some industry players are working on developing UHDTV (Ultra High-Definition TV) with resolution of 7680×4320 pixels. This is expected to be available in 2022. ***Even with such high native resolution, the maximum number of views in 3D HD would be a meager 16, as opposed to the immediately available 40–90 views with Zecotek's display.*** With such UHDTV resolution, content and standards would be a serious issue (see the Appendix for additional detail).

Note: It is appropriate here to make some clarifications on terminology. One should not confuse number of “views” (perspectives) with number of “viewers”.

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Number of views is the number of adjacent angles of view from which a 3D object may be observed in the display. Multiple-view auto-stereoscopic 3D displays show many angles of view, giving not only the sense of volume but also freedom of movement for one or many observers. The more views are displayed, the larger viewing zone and the more freedom of movement the observer has. The viewing zone width is directly proportional to the width of each view, which latter cannot, however, exceed the inter-pupillary distance (the average distance between the pupils of the eyes), otherwise the observer loses 3D perception. Views are also correlated to the viewing distance (see the Appendix).

Number of viewers means the number of observers who can watch 3D image on a 3D display simultaneously.

Time Sequencing (Sharing) 3D Auto-Stereoscopic Displays: the Zecotek Patented Approach

Unlike space-multiplexed display systems, which must share pixel density and therefore resolution among views, Zecotek's system uses a proprietary time-sequenced technology combined with a patented dynamic system of multiple lenses. This results in display of more than 90 views at full native (base) resolution in each perspective. *It is this large number of views and the extremely narrow angle of each view* that give complete freedom of position for the viewers within broad viewing zones. Currently, Zecotek's prototype offer ~ 50° viewing angle.

Zecotek's time-sequencing approach also means that the HD resolution does not need to be divided between views. *Each view has exactly the same HD resolution as the base screen resolution*, because it is time, as opposed to space (see above), that is shared. Consequently, a frame rate of approximately 2,000 Hz is required, readily available from existing and well-known DLP back projection elements.

Back-projection 2D monitors and TV's have been available for many years and provide high-resolution, high-quality images. Their only trade-off is a thicker form factor compared to flat panel displays. (This extra depth can also be significantly reduced to almost flat panel form factor through use of special optics.)

Zecotek's 3D multiple-view auto-stereoscopic display with its time-sequencing approach can provide the most natural 3D experience, as it allows for a freedom of head movement similar to that required for seeing objects in the real world.

The consumer marketing limitation of 3D TV based on DLP and back-projection is that of form factor – DLP-based TV's are not perceived as being “flat panel” (even though with optical modifications form factors can approach conventional flat panel depths). While Zecotek's technology is fully adaptable to flat panel configuration, this will require matching flat displays delivering frame rates higher than 2,000 Hz. Such flat panel speeds are not yet available (largely because no demand existed to date), however many industry players have these in development for other applications. With rapid advances in OLED's (Organic Light Emitting Diodes) resulting in frame rates exceeding 2,000 Hz, and as manufacturing costs for these panels go down, Zecotek's patented technology would yield a flat panel configuration highly suitable for consumer markets *well in advance of those using space sharing systems requiring greater pixel density*, in particular as pixel density is directly related to production yield and therefore panel cost.

Manufacturing and Commercialization

3D is obviously desirable in a large number of applications beyond just being another value-added feature for consumer television. 3D technologies and applications have the ability to transform the urban landscape and to produce new tools and techniques for the full range of human activities. And while there is an enormous amount of exciting research and development being undertaken on 3D image capture and 3D applications, much of the enabling display technology is still based on *ad hoc* adaptation of legacy 2D panel displays as manufacturers struggle to adapt existing 2D technologies.

Market Approach

Zecotek is very clear about its market approach. While there is a reasonable expectation that a better and more realistic 3D experience provided by our technology will trigger consumer adoption of the DLP-based back-projection configuration and that a somewhat thicker form factor will be taken as a fair trade-off, the consumer market might lack traction until high frame rate flat panels become available. However, Zecotek is aware that its unique technology in the present DLP back-projection 3D display configuration can immediately cater to large specialized high-end markets.

These markets include industry, engineering, design, teaching, military and homeland security, museums, airport control systems, geological and marine analysis, and many areas of advertising or entertainment.

In order to address this opportunity, the Company is presently developing a desk-top DLP-based monitor to meet already identified customers and end users in specialized markets for a 3D high-definition auto-stereoscopic glasses-free display, where 3D imaging provides improved situation and process analysis, fast decision making, and problem-solving and where flat panel form factor is not a mission-critical issue. Since the system can be readily adapted to current DLP-based projection monitors, the Company is identifying potential applications and demand in these immediate specialized markets.

The Company has completed lab prototypes and is finalizing the documentation to transfer to manufacture. It is presently seeking partnership for market development and the pilot production of the first 50 units, targeted at immediate high-end applications and users. The partnership will then expand to large-scale production and sales based on the outcome of the pilot phase. An integral part of the program is to also work, in parallel, closely with developers of fast (OLED) flat panel displays.

Summary

Technology used by most 3DTV Manufacturers: glasses-based active switching technology, where an image is displayed successively for left and right eye, and users are required to wear active shutter glasses to see the 3D content.

Technology used by most glasses-free 3DTV manufacturers: space-sharing principle (see explanation above). In order to have multiple views, this approach requires hyper-resolution (an extremely high number of pixels) and intensive processing power to display them. This level of technology has not yet been reached and such devices would be very costly indeed, even when mass-produced. Even when available, it would only allow a limited number of views, below 16. This is far behind Zecotek's existing 40...90 perspective views in HD 3D.

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Patented technologies

Technology used by Zecotek Glasses-Free 3D: time-sequencing principle (see explanation above). In order to have multiple views, this approach requires normal HD resolution and moderate processing power. This technology is readily available and very cost-effective when mass-produced. There are two possible configurations: 1) **DLP back-projection**-based 3D monitor (ready as DLP's are mass-produced by Texas Instruments and other companies); 2) **Flat Panel**-based. This technology requires availability of high frame rate flat panels. Several industrial players should be able to produce fast OLED's at acceptable cost in the near future.

Zecotek 3D System Features

- High-resolution image (the same resolution for 3D and 2D modes);
- Simultaneous display of 3D and 2D content (at the same high resolution);
- Extremely small angle between adjacent views (hence, no viewing discontinuity or perspective "gaps");
- Complete freedom of position for the observer within the viewing angle;
- All the electronic components used in Zecotek 3D Display are currently available and supplied by major companies (*e.g.* Texas Instruments). The core design can be readily adapted to flat panel configurations.

The following table summarizes the important performance features of the Zecotek glasses-free auto-stereoscopic 3D display technology.

Parameter	Performance
3D image resolution per view, *pixels*	1920×1080 (full HD)
Number of views (perspectives)	Up to 90
Screen size, *inches*	10 to 54
Viewing angle, *degrees*	≥ 50
Number of color channels	3 (r, g, b)
Color depth	~20 bit (at 40 views)

Intellectual Property

All technology has been developed in-house by Zecotek scientists and technicians and does not rely on any licensed IP. **All IP is owned and controlled by Zecotek.** The Zecotek 3D Display has been granted Australian Patents under PCT. US Patents have been filed and published by the US Patent Office.

Awards

In 2009 Zecotek was honoured with the prestigious Frost and Sullivan award for 'Best Enabling Technology'. The Company has featured in Discovery Channel's Daily Planet, and in 2010 was cited as one of the top ten Canadian technology companies to be the next 'big thing' for its 3D display system.

Appendix

3D Image Resolution versus Number of Views

The diagram presented below shows 3D resolution *vs.* number of views for 3 different native (base) display resolutions (HD, 4K, and UHDTV) using space-sharing technologies. This is compared with Zecotek's 3D display using only the well-established native (base) HD resolution and time-sequencing technology.

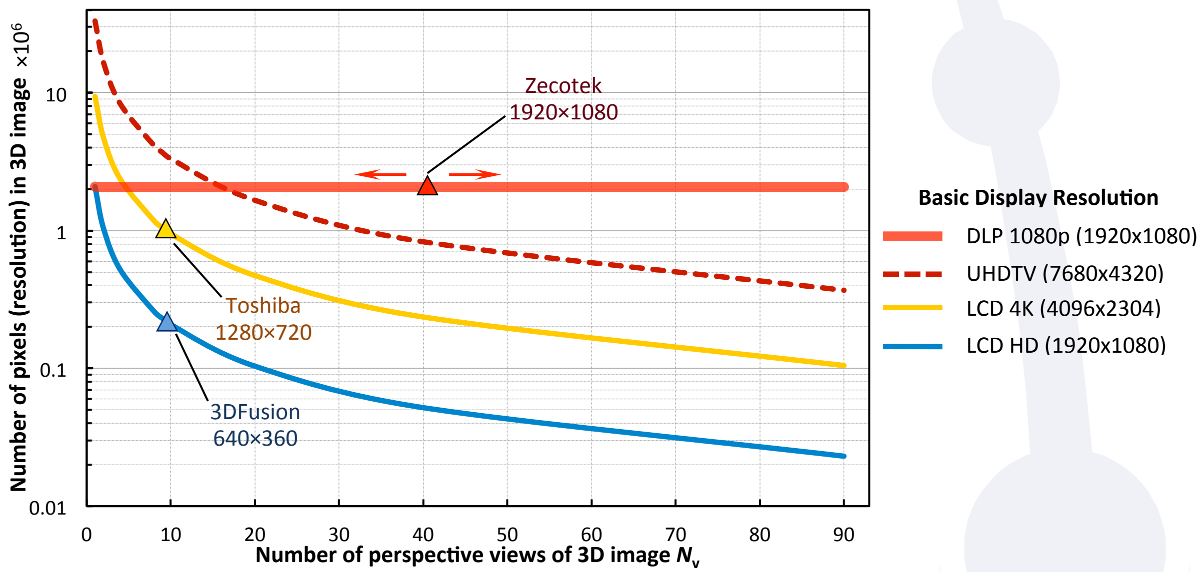

Fig. 1. 3D image resolution *vs.* number of views for different flat panel formats.

For space multiplexing (sharing) approach, one can see dramatic degradation in 3D resolution with increasing number of views, as opposed to a permanent, high (HD) 3D resolution for Zecotek's display. Even for the Ultra-High Resolution (UHDTV) estimated to be seen in around 2022, the 3D images using space-sharing technology can only provide 16 views in HD resolution per view. (The dashed curve intersecting with the red horizontal HD line corresponds to 16 views on the axis reading the number of perspective views).

For the recently announced Toshiba and other 3D glasses-free screens, using a 4K (4096x2304) LCD, the yellow curve intersects with the horizontal HD red line and corresponds to 5–9 views, only, on the horizontal axis reading the number of perspective views.

Maximal Viewing Distance *versus* Perspective View Width

A perspective view is a 2-D image of a 3D object (real or displayed) seen by only one observer's eye from a given angle to the object (screen). The longest possible distance D_v for observing an auto-stereoscopic 3D image is reached when the width of each perspective view is close to inter-pupil distance L_p. At larger distances, both eyes will be likely to see the image projected into the same perspective view. The angular viewing zone or the total viewing angle ϑ_v of the image is given by the equation:

$$\vartheta_v = W_v \times (N_v - 1), \quad (1)$$

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where W_v is the angular width of perspective views and N_v is the number of perspective views.

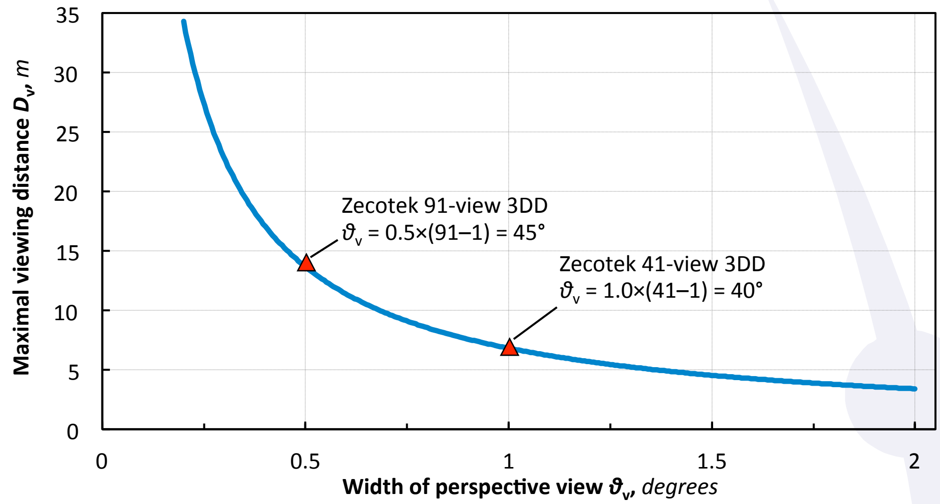

Fig. 2. Correlation between maximal viewing distance and the angular width of perspective views.

The curve in Fig. 2 above demonstrates the dependence of the maximal viewing distance upon the angular width of a single perspective view. Zecotek display technology inherently allows a wide range of these parameters, and two particular configurations corresponding to 91- and 41-view displays are marked in the figure.

Total Viewing Angle and the Number of Views

There is a linear dependence between the total width of the 3D display viewing zone and its number of perspective views. In the following diagram, two examples are given that correspond to the angular perspective view width of 0.5° and 1.0° along with specific points marked for different display configurations.

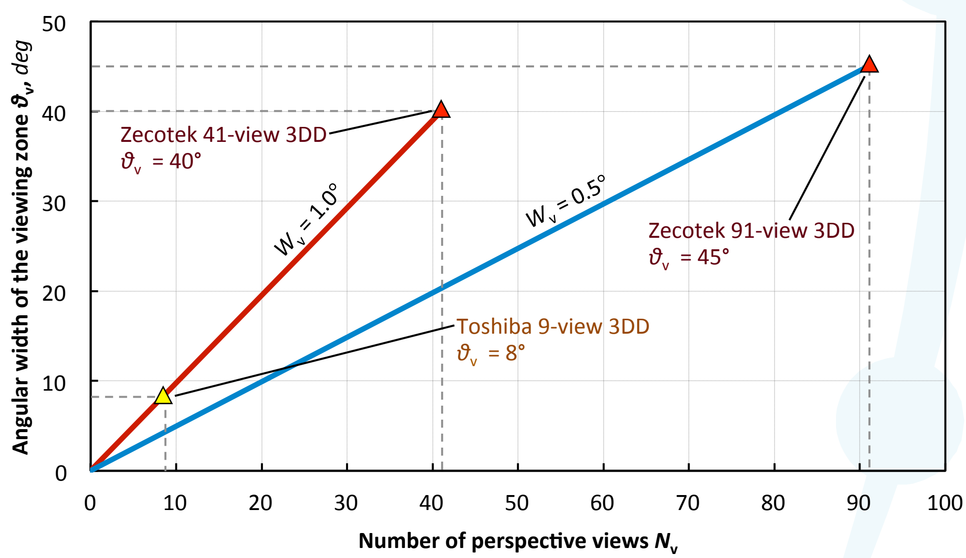

Fig. 3. Correlation between the total viewing zone angular width and the number of perspective views.

When a display manufacturer specifies a certain number of views N_v, it is possible to calculate the total viewing angle of this display (in case there is a single viewing zone) or the angular extent of a viewing zone (in case this viewing zone is repeated several times). This allows, in turn, finding the width of the viewing zone Z_v at the maximal viewing distance.

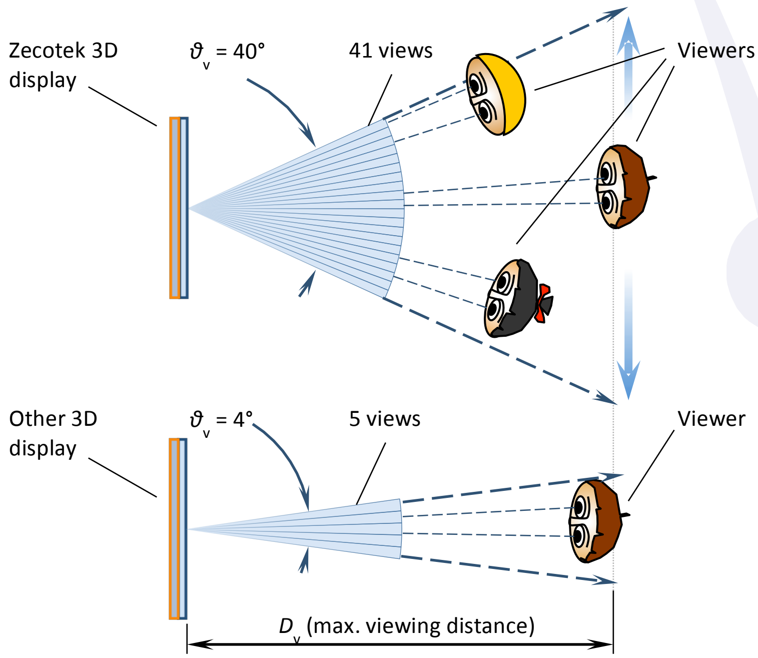

Fig. 3. Viewing capabilities and the number of perspective views for different displays.

For example, given that the inter-pupil distance L_p equals 6 cm, for a display with the number of perspective views N_v is equal to 5 the maximum width of the viewing zone is about 24 cm. This is almost the size of an average head. The image is lost within few inches of the head's movement. This is very limiting for viewing TV content.