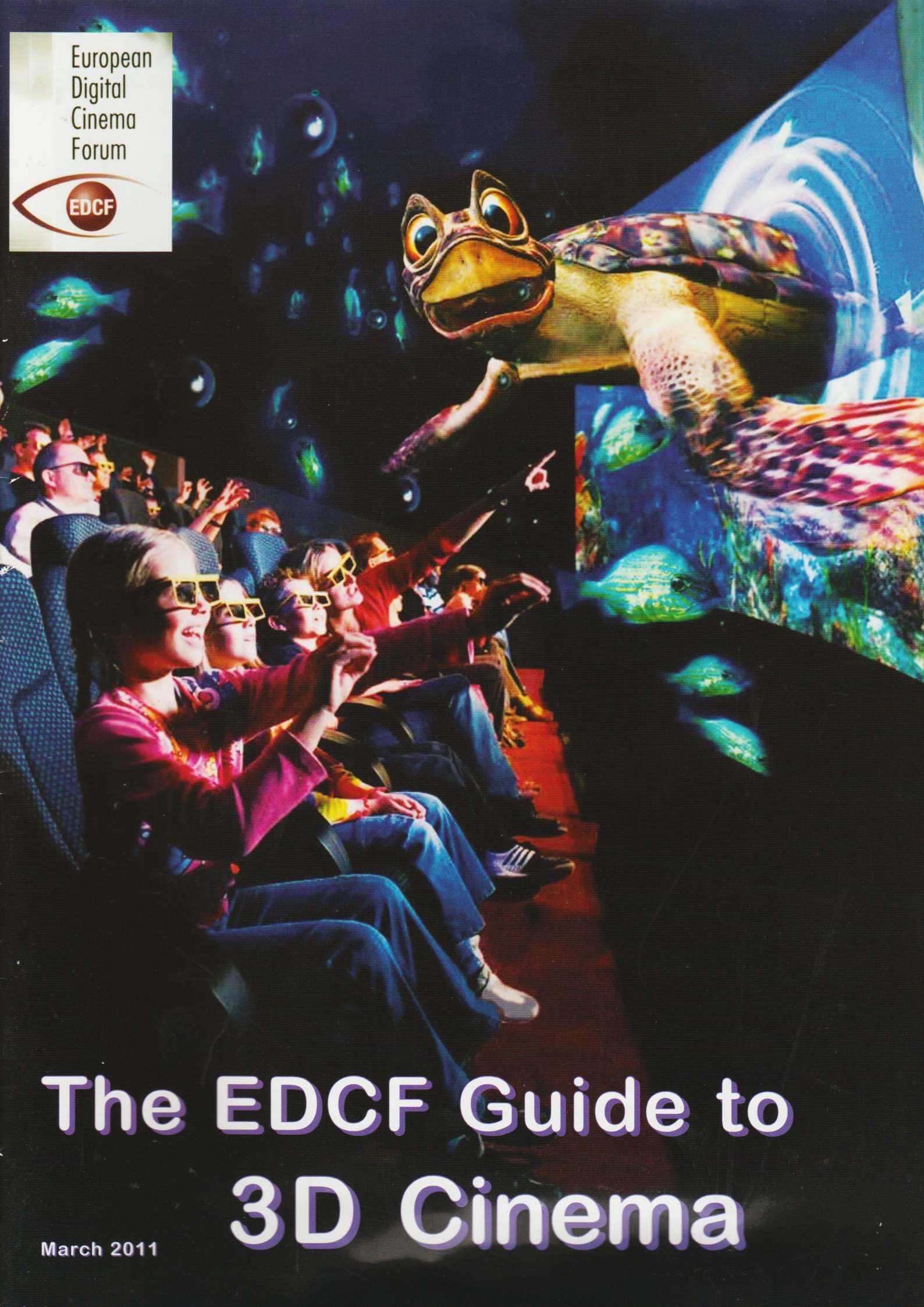


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The EDCF Guide to 3D Cinema

March 2011

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The EDCF Guide to 3D CINEMA

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The European Digital Cinema Forum



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Forum

THE EDCF GUIDE TO 3D CINEMA has been created by the EDCF Technical Support Group, chairman Peter Wilson. The aim of the Guide is to provide a tutorial, preliminary information and guidelines for those who need to understand the techniques and processes involved.

This Guide has been a long time in the making and during this time improvements have been made to the 3D systems in the market, and these improvements continue.

The Guide sets out to describe the technologies and explain the issues. For those making purchasing decisions this Guide should be read alongside the latest information from the manufacturers.

The EDCF is extremely grateful to the companies who have sponsored the publication of this guide
March 2011

EDCF is the leading networking, information sharing and lobbying organisation for digital cinema in Europe, providing a vital link between Europe and Hollywood Studios. For more details visit www.edcf.net

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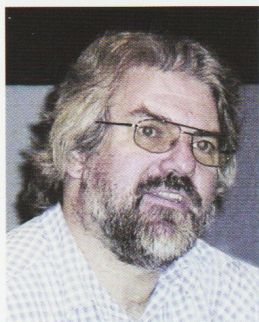
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Cover picture courtesy of Robert Simpson, Electrosonic. A 4D Cineffex 'experience' theatre with a 7 metre wide curved screen and effects including water sprays, air blasts, vibration seats and leg ticklers!

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1. Introduction to 3D Digital Cinema Exhibition



Peter Wilson
Director of the
EDCF Technical Support Group
and Board Member



3D is here to stay this time

It's very tempting to start this introduction with a comment about how quickly 3D cinema has arrived. After all, the first public demonstrations using Digital Cinema technology took place just 5 years ago at ShoWest when Texas Instruments assembled a group of movie directors and technologists to demonstrate what had already become possible with 3D digital projection. With positive encouragement from James Cameron, George Lucas, Robert Rodriguez and other leading directors the stage was set for an exciting future. But then looking back at the true history it actually took quite a long time to take off.

It was way back before the last century that scientist and inventor Charles Wheatstone produced his historic 1838 paper on the 'Phenomena of Binocular Vision'. He not only accurately described the perception of stereoscopic vision but also assembled the first Stereoscope to demonstrate his work. Since that time photographers of all forms have tried to create stereoscopic picture experiences. Apart from the very early experiments in the early years of film, the first commercial realisation of stereoscopic movies began in the 1950s. After the initial releases, stereo faded from movie deployment until the second wave of excitement in the 80s. These early attempts at broad usage were thwarted by both technique and technology. It was too tempting to avoid excessive use of depth positioning without understanding the associated viewing fatigue that was involved. Accurate image alignment in both camera capture and projection also contributed to further viewing discomfort, which resulted in the demise of further releases.

So we are now experiencing the 3rd wave of stereoscopic movies and what's different this time round?

Will it last and will it move into the mainstream of movie storytelling? There are still many sceptics who believe that the additional costs of creation and exhibition together with the burden of everyone having to use eyewear will defeat even the latest efforts. But these naysayers are firmly in the minority, with the hard facts fully supporting this phase of Stereoscopic activity.

So what's different this time around?

1) Digital Cinema technology is delivering the stable image presentation that is prerequisite to a comfortable viewing experience. The Stereo 3D effect arises from the lateral differences between the images shown to each eye. It is therefore essential that all the differences are intended and not accidental.

- 2) Stable image acquisition is now afforded by digital cameras and rigs with digitally controlled shooting platforms.
- 3) Digitally based post production tools allow images to be shifted, warped and corrected to ensure near perfect pixel level registration.
- 4) Digital projectors using single lens optics can deliver pin-sharp images to every viewer – every time.
- 5) Support from the major motion picture studios ensures a continuous flow of stereoscopic releases.
- 6) Support from leading directors with the most ambitious stories and budgets.
- 7) Enthusiastic investment by exhibitors who ensure that releases are available to an eager audience ensuring box office success for all involved.

The results are already self-evident, with growing success and box office records being broken almost every week.

Early commitments by major studios have demonstrated the unique experience offered in cinematic form and have even taken full marketing brand advantage of the eyewear required. (Disney's *Chicken Little*). The animation studios quickly realised that with their understanding of 3D objects and spaces they were able to produce stereoscopic versions with relatively little extra investment. Jeffrey Katzenburg's bold commitment by Dreamworks Animation to producing 3D versions of all product after 2009 certainly set a major marker for the world of animation.

Content creation

Of course shooting movies in Stereo 3D adds considerable expense and requires new skills on set. So far, live action releases have been limited for this reason.

But many are arguing that the creation of Stereo 3D from 2D original material offers exciting potential. It avoids the higher acquisition costs but still is a costly post production process.

This is a hot area of debate where new techniques, technologies and required resources are changing the rules for filmmakers. Although still quite labour intensive, the conversion companies offer highly comfortable 3D viewing where all registration and alignment issues can be properly managed. Creating content that is as realistic as that obtained with stereo cameras is the challenge. The debate between the rival approaches is now being fought out with near religious zeal and passion. Inevitably, the best movies of the future will likely use the best of both forms to deliver the most exciting shows, but the prospect of resurrecting the great movies of the past in 3D is itself quite mouth watering.

Alternative content

D Cinema owners and patrons have started to enjoy some new experiences with live broadcasts of concerts and events together with recorded shows. This genre has also started to use Stereo 3D to increase the sense of occasion and reality. This area has not enjoyed the benefit of format standardisation yet but first productions have already started successfully in several areas including sport, music, opera and dance. Lookout for a forthcoming EDCF publication in this area.

The business case

Media analysts Screen Digest have shown that Stereo 3D releases are generating more than half of their box office returns from a much smaller share of 3D equipped screens. And 20th Century Fox's release of James Cameron's 'Avatar' became the highest grossing movie of all time in 2010.

Just a short while ago, exhibitors were worrying about whether the flow of 3D movies would justify their investment. Now, there's a battle for screens as 3D releases are flowing faster and sustaining audiences for much longer.

In short, the tickets sell at a premium, to larger audiences for longer runs – no wonder the market for D Cinema projectors and the 3D projection technology is manufacturing capacity limited in some companies!

All this excitement has not just been experienced in the D Cinema world. Traditional film projectors now have new options for delivering a 3D experience with new innovations and some revised practices from earlier days. No-one is, I think, suggesting that the film versions are as impressive as Digital 3D, but these systems may help to satisfy a booming demand until the D Cinema deployment is complete.

While the D Cinema standardisation process (DCI) frustrated some users in the time taken to produce a common format, it did simplify the product selection process quite considerably. Things are not quite as orderly in the 3D world with the availability of several different systems and technologies. They each have their strengths and weaknesses and this guide is intended to provide prospective purchasers with a familiarity of the terms used and highlight some of the issues that need to be considered. Fortunately these various systems can all play the DCI specified content thanks to further definition by the SMPTE 21DC standards activity. There are still a number of 3D areas requiring further standardisation but the movie distributors are coping with these challenges while this work completes.

Competing technologies

David Pope's article in Chapter 5 provides a synopsis of the systems currently available. There are already at least five D-Cinema 3D projection systems and 3 for film projectors. The two D Cinema projection technologies (DLP Cinema® by Texas Instruments and SXRD™ by Sony Corporation) both support 3D projection at 2K resolution). There are currently many more system choices for the DLP Cinema® technology but the SXRD™ system delivers images to both eyes simultaneously.

Careful choice of the projection system is required to ensure that adequate brightness can be delivered to the screen being used. Projection running costs correlate closely to lamp consumables and electricity used so overall system efficiency should be a major procurement consideration.

There is a general consensus that the current generation of 3D systems do a great job but would be improved by greater brightness. It will be interesting to see how this unfolds as projection and 3D technology improves over time. (See Peter Wilson's article in Chapter 8).

So far the public response has been shown in the box office results and film makers are quickly learning how the new tools and techniques can be applied judiciously for maximum effect and viewer comfort. There are a number of cinema patrons who regrettably will not be able to enjoy stereo due to their own visual situation. There will be some others who find the experience uncomfortable but these are certainly in a minority. Further work is required to better understand what situations would be best avoided regarding extended stereo viewing.

And it's not just happening in the movie world. New Blu Ray recorders will be capable of playing 3D high definition disks into 3D equipped TV receivers. We even expect to see 3D screens on mobile phones. There are lots of challenges ahead and for this reason the early lead in cinema is keeping the movie going experience special.

With all this activity, energy and commitment there seems little doubt that 3D Cinema is here to stay this time. We hope you agree and find the guide informative and helpful – enjoy!

Peter Wilson

*Director of the EDCF Technical Support Group
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Stop Press

This latest EDCF Guide has taken a long time in the making and significant changes and during this time improvements have been made to the various Stereoscopic 3D systems in the market. The EDCF has made the text available to the various manufacturers of 3D systems for approval and feedback.

Several of the sections contain tables and references to brightness and system efficiency; there is some variability in the stated data due to variations in measuring methods for both brightness and efficiency combined with improvements over time.

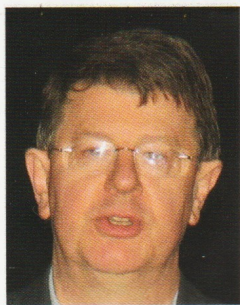
Matt Cowan and Kevin Wines have contributed sections on measurements so it is now possible for any EDCF Member to carry out their own measurements though the methods used are not in any way standardised by any official body. Rather than rework the whole document we decided the most neutral way to deal with the variability is to ask the vendors to state their efficiency figures for publication. The EDCF does not endorse any particular system nor does it discriminate against any particular system.

The manufacturers stated figures for efficiency in alphabetical order are:

Dolby	15%
MasterImage 3D	17%
MasterImage AR	18.7%
Panavision	17%
Real-D ZS	16%
Real-D XL	30%
Real-D XLS	30%
XpanD	17%

Peter Wilson 21/02/2011

2. Depth Perception and Binocular Vision



David Monk
CEO European Digital Cinema Forum

Introduction

The theatrical presentation of '3D' movies should strictly be called Stereoscopic 3D not just 3D. A true 3D system would be one whose viewpoint changed with the position of the viewer. The systems that are currently being deployed rely on the capability of the human visual system to obtain depth information from the difference between the images formed on the retina of each eye. For the sake of simplicity we'll use the term '3D' as a short-hand for the full term.

3D movies have been produced and presented for nearly 60 years but the technique has not been continuously available to exhibitors as the technology required to deliver the images has failed to provide a satisfactory entertainment experience in many cases. This is changing rapidly in the latest digital projector based deployment phase.

Depth Perception

Human beings are able to perceive the world around them with a vivid sense of spatial depth. As we know this process begins with our eyes collecting images at the photosensitive retina via a small lens. What is less obvious is that the process of vision or visual perception is the result of the processing of the brain not just the eye alone. After all if the eye produces an image where is the 'eye' in the brain to view the image – and so on. More than 50% of the brain is involved in interpreting the information from our eyes into a perception of the world. It's fortunate that we are gifted with huge computational capacity to analyse and interpret the images over a wide range of activities with massively varying conditions of lighting, colour, orientation, and position.

One of the many things we take for granted is the ability to produce a stationary perception of the world while our bodies, heads and eyes are in motion and traversing that world. We move our heads from side to side but the world we perceive remains steady. That is entirely a function of human visual perception. If you try moving a video camera in the same way that we move our heads, and then view the recordings on a TV screen you quickly realise how much work the brain has to do to keep the perception steady!

Our perceived world is one that has depth as well as height and width. The optical signals that we receive from the eyes do not immediately come coded with depth data in the same way that we see colour. Depth information has to be 'decoded' from the images. Visual scientists group the various methods of extracting depth information into categories. There are some 10 different categories or depth 'cues'. All but two of these cues are monocular. In other words we are able to obtain the depth information from a single eye. (This is just as well because approximately 5-10% of the population do not see with two eyes working in perfect balance). The monocular depth cues are obtained from things like Colour, Lighting and

Shadow, Perspective, Masking etc.

It's important to understand the monocular depth cues because they produce powerful depth information within the brain. Movie makers use many tricks and special effects in their creative work. Like conventional artists they use knowledge about depth processing to create an illusion of depth in backdrops to scenes and in artificial effects. When the camera is also capturing depth position information great care must be taken to ensure that these information sources do not conflict with each other. So the whole art of cinematography, set design and special effects needs to manage new considerations in the 3D world.

Let's take a quick look at the Monocular Depth Cues

a) Relative Size.



As objects get nearer to us their apparent size increases. Easily demonstrated by moving a hand from arm's length to the nose. As the hand moves closer it occupies more of the visual field and consequently appears larger. In the absence of any other information we normally deduce that larger objects are closer.

b) Familiar Size.



We know from experience that certain objects have an expected size within a range of variation. A person, the height of a table, a car, a truck, a bus, a house, a hedgerow, a tree are all items that we can size with a fairly good degree of accuracy (most of the time). These memorised objects act as benchmarks against which size other items which are perhaps unknown to us. We also use this information to deduce the relative depth of objects. If we know the actual sizes we can make inferences about how close objects are. (This is quite a complex process because we are often unconsciously changing the focal length of our eyes – which in turn changes the computation.) Graphic artists often place a known coin or pen by an object to allow us to scale the perceptual size.

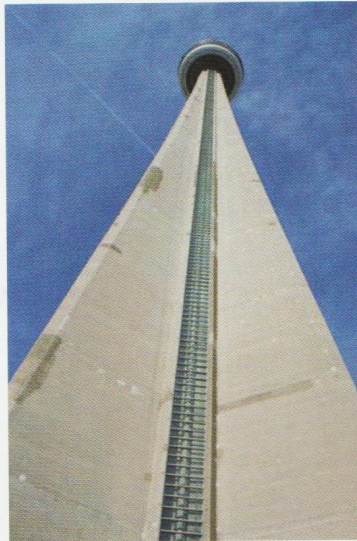
c) Perspective.



When we look at a road or a line of objects the extended edges converge as we look along the line. This is probably one of the first elements in a drawing class. By conforming to the rules of linear perspective we are able to place objects at the right depth in a scene. The greater the convergence of the perspective the farther the object is away. One of the many reasons why cinematographers don't use zoom lenses is that the linear convergence relationship changes as the focal length changes with the zoom. Telephoto lenses make the perspective more parallel and thus flatten objects – removing the depth cue. Wide angle lens increase the perspective and enhance the depth cue.

d) Texture or Detail.

When objects are close – they appear bigger (as discussed) and occupy a larger part of the visual field. We are therefore able to resolve more detail. As they move further away this detail becomes more indistinct or blurred until it finally appears as a uniform tone. This texture effect can be blade of grass in a near ground shot, tiles on roofs or windows on buildings. The extent to which we can resolve the detail provides another cue to the distance of objects.



e) Interposition



This cue arises from the masking of one object from another in a scene. It requires that we first of all can separate the

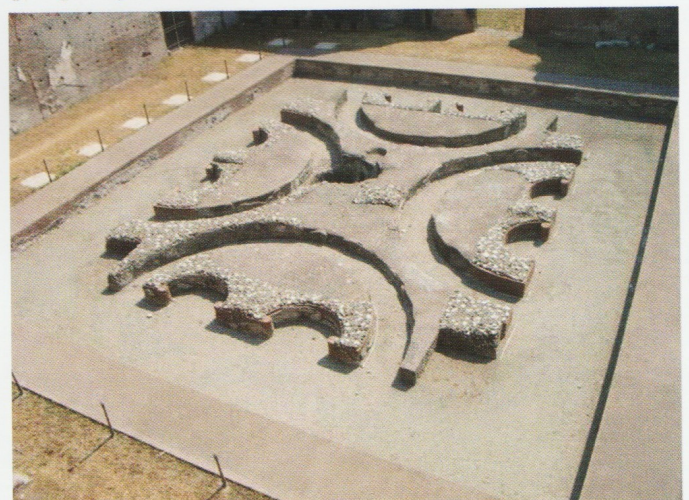
objects perceptually but then the masking of one object by a second one generates a cue that the second object is in front of the first. This is one of the more powerful depth cues and it's almost impossible to be convinced that a masking object is behind a masked object. This cue becomes critical when we consider that the theatrical screen is itself a mask or window which has a position in the depth field. See later discussion on 'Floating Windows'.

f) Clarity and Colour



Objects in the real world are generally clearer when they are nearer as a result not just of image size but because of the atmosphere in between the viewer and the object. Mist, fog, humidity etc all reduce the light that is reflected from distant objects. The farther the object the greater the diffusion and the lower the clarity. This also affects the richness or 'saturation' of colours. Watercolour artists routinely apply a weaker wash for more distant background elements to recreate this effect. It's a technique that set painters also use, but may be revealed by 3D cameras if great care is not taken.

g) Lighting and Shadow



In our world the sources of illumination are normally from above (the sun, the moon, household or street lights). We therefore expect a shadow to be formed below the object. Lighting also reveals the shape of objects as it forms a variation of brightness in relationship with the volume of the object. The difference between a plain disc and a sphere is only revealed by lighting. The distance of the shadow from the object reveals the distance of the object to the surface where the shadow is formed. Lighting thus plays a critical part in our perception of depth and spatial position.

h) Angle of Declination



In most of the scenes that we normally view objects at the top of our vision are usually farther away and objects most close are at the bottom of our field of view. So we learn that, as a general rule, we can deduce the distance of object by the place in our visual field from bottom to top. This is why optometrists normally put the 'reading' correction in the bottom of our spectacles. It's not a universally correct assumption as we find out when we try to read a label on a top shelf or look down a staircase— but it's normally a good rule.

i) Focus

Our eyes are constantly changing focus as we look at object at different distances. Muscles within the eye stretch the flexible lens to change its shape and optical power (focal length). This action is managed automatically by the brain so that we are never conscious of either the change or the objects which fall out of focus. (Distant objects when we focus close or close objects when we look in the distance). The process of focussing is called accommodation and the actuation knowledge is used by the brain to help with depth perception.

j) Motion Parallax.

This is depth information that we subconsciously decode from analysis of moving objects. Because distant objects appear smaller, they occupy a smaller angle of view. Larger objects occupy a larger angle. So when nearer objects move they appear to move faster. This effect helps us to deduce position from speed of moving objects but can also be used to judge distance from head or body movement. People with good sight in only one eye will often move their head more to utilise this information.

Many of the depth cues or 'clues' discussed above are derivatives or related to each other. The amazing thing is that the human brain synthesises all of these information sources and creates a perceptual depth map. Most of our depth perception is derived from these cues which are all 'monocular'. In other words we only require one good eye to get the perception of depth. This is why we have been largely satisfied looking at cinema, television, paintings and photographs for most of our lives – they are all 2D sources – until just recently.

The Stereoscopic Depth Cues

Convergence.

In order for us to use the images from two eyes, the individual images must be fused into one. This requires that the two eyes must be aligned at the point of interest. This process is called fixation and is essential to the fusion process. Simply stated, the two eyes must be converged so that they are both aligned with the object being viewed. When objects are at infinity such as a star in the sky, our eyes are aligned in parallel but when we look at nearer objects such as our hands we are required

to turn each eye inwards. This angular movement is called vergence or convergence when we look at near objects. The vergence process is controlled by the viewer's brain which sends signals to the 6 muscles around the globe of each eye to control the eye's motion relative to the head position. These ocular-motor muscles are able to converge the eyes but have very little divergence capability as this is normally not required.

In general, convergence causes the eyes to turn in towards the nose and slightly down to the feet. These linked movements occur because closer objects are usually lower in the visual field. The nearer the object to the observer the more the two eyes turn in and down. At conscious rest our eyes looking at a distant object will look straight and be parallel to each other. The amount of effort (vergence) that the muscles are required to turn in order to align an object is information which it is believed the brain can use to determine the depth position of an object. This is the Convergence Depth Cue.

Stereopsis

Stereopsis is the perception of depth that arises from binocular vision - two eyes working together that send images to the brain that are slightly different. The difference arises from the shifted horizontal position of each eye which creates a different viewpoint. With both eyes aligned on an object the relative position of other objects falls at different positions on each retina. This difference or 'retinal disparity' provides the brain with information that can be used to deduce depth information. This is a difficult concept to grasp as the left eye might see three objects as left, centre and right whereas the right eye may see them respectively as right, centre and left. Incredibly, the brain can then create a single perception of the three objects in spatial depth at near, mid and far.

Instead of moving the head to generate a motion parallax we can thus obtain information constantly from fixed images with neither image nor head motion. Stereopsis thus provides an opportunity to decode some depth information without the monocular analysis discussed above. It therefore provides a powerful adjunct to our visual system that can provide a level of precision not available monocularly. This precision manifests itself as greater spatial acuity as well as more accurate depth positioning.

Stereoacuity

Stereoacuity is the measure of stereopsis. Individual viewers have different abilities to make depth judgement using binocular vision. This term becomes important when we consider the impact of viewers with defective binocular vision.

3D Movies

The process of creating 3D movies relies on the delivery of slightly different images to each eye to replicate the images that are seen naturally in the real world. Hence the correct term is Stereoscopic 3D. The perception arises from the use of two eyes each seeing a slightly different image that arises because of the depth positions of the objects in the scene. Stereoscopic perception works with the analysis of the scene's monocular depth cues to produce a composite visual perception.

Because the monocular depth cues drive so much perception we have no difficulty in perceiving depth when we view two dimensional images as paintings, television pictures or photographs. It also explains why people with only one effective eye can do things like drive a car or pick up an object on a table. Although we can survive without stereopsis our world suddenly becomes more detailed when we can use our two eyes together.

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3. 3D Systems in cinemas

- an overview



Dr. Siegfried Foessel
Fraunhofer IIS

This article describes the principles of 3D movie reproduction in digital cinemas. After a basic overview of stereoscopic projection techniques the concept of anaglyph images as historical method will be explained. Later on digital cinema and its components will be discussed, which allows also new projection technologies. At the end some advantages and disadvantages of projection techniques will be listed.

Introduction

3D reproduction of movies in theatres allows people a new viewing experience, because it makes a great visual impact and it is not available so far in the digital home. The plasticity of 3D movies gives the impression to immerse into the scene. But 3D cinema is not new. The first 3D movie was already shown more than hundred years ago. Since this time there were many periods, in which 3D movies popped up on the market [Lipton]. But because of technical issues with projection systems, the assignment of too much man-power and insufficient image quality these technologies had not the right break-through. With the introduction of digital cinema and new presentation and projection technologies it was possible to improve the viewing experience significantly. Today all projection technologies in cinemas are using the stereoscopic method with two images for the scene, one for the left eye, the other one for the right eye. There is also some research on so called "ultra-realistic" methods based on holographic concepts, but experts calculate about 20 years more for their commercial use. The holodeck of star wars is a long time coming.

3D Perception in cinemas

The stereoscopic 3D perception of human beings is based on the fact, that both eyes can see a scene from different perspectives (see Figure 1). The human brain can calculate from the disparity depth information and together with hidden edges for only one eye this gives a 3D impression. This calculation is learned during the childhood. The closer the image disparity, the focus and rotation of the eyes is like in natural optical imagings, the more realistic is the 3D-impression.

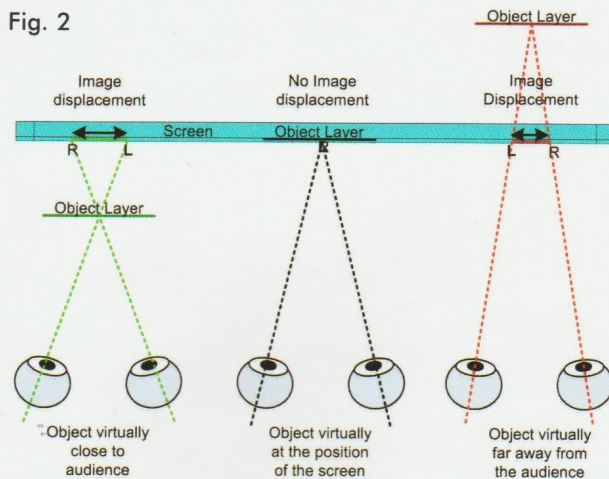
To achieve this in cinemas, the image pairs for left and right eyes will be projected at the same time or nearly at the same time. By using specific methods the image pairs will be separated for the left and right eye at the position of the human beings again. That's one of the reasons why today glasses are necessary in cinemas.

To produce a 3D impression with a screen, objects of a scene with different distances to the audience will be projected with a



Fig.1

Fig. 2



different disparity on the screen (see Figure 2.). If an object is virtually located at the position of the screen, no image displacement exists, the disparity is zero. Shall the object be virtually closer or farther to the audience a disparity can be achieved by projecting the object with an image displacement for left and right eye on the screen. Mismatches can cause head ache and symptoms of fatigue. Therefore it is very important to realise a natural reproduction of the disparity.

The Anaglyph Method

The first systems for reproduction of 3D perceptions worked with the anaglyph method (see Figure 3). Here the images for the left and right eye were coloured differently. The images were pro-

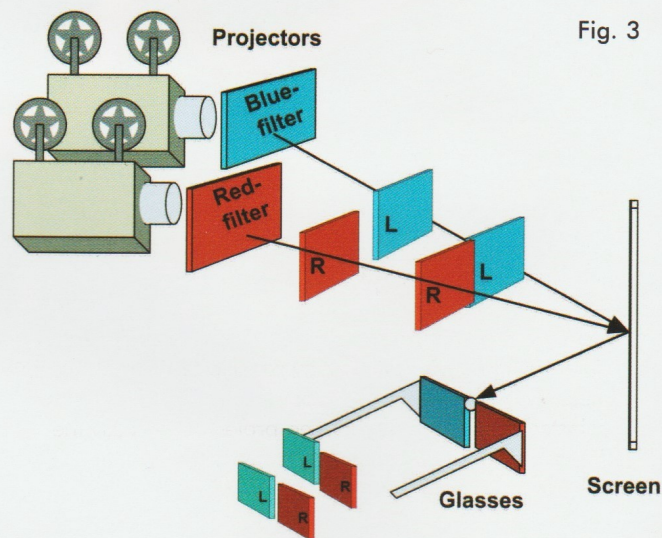


Fig. 3

jected with two projectors at the same time, one e.g. with a red filter for the right eye, the other one with a blue filter for the left eye. The viewer got glasses with corresponding red and blue filters to separate the images for the eyes. With this method a first 3D perception was possible. The method is also available with other colour combinations. But because of the broadband colour filters a realistic colour reproduction was not possible. The main issues of this method had been: the mechanical synchronisation of both projectors, a good match of the optical projection on the screen, mechanical judder and low-quality image separation by using the colour filters. An example can be seen in Figure 4.

Digital Cinema

The use of digital technology in cinemas, especially the use of digital projectors solved many problems of the old 3D-Cinema. Today digital projectors are able to display images with a frame rate high enough, so that left and right eye image can be pro-



Fig. 4

jected with one projector in a time-multiplex manner. Many of the above mentioned issues are no longer existent with this method.

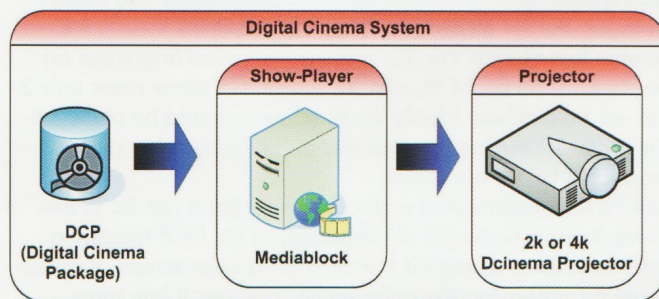


Fig. 5 Components of Digital Cinema

The fundament of modern 3D-Cinema is the use of digital technology (see Figure 5). For upgrading a 2D Digital Cinema to a 3D Cinema only few additional components are necessary. More to this can be found in the chapter Projection technologies. The image data for digital cinema will be delivered in form of a digital data packet, the so called Digital Cinema Package DCP, either via Hard disk drive or by satellite or internet distribution. These data will be played back in a digital cinema player and projected by a digital D-Cinema projector. Typically the playback speed of the movie is 24 frames per second. For 3D the images in the DCP are interleaved pack, one for left eye, one for right eye, which gives a total speed of 48 images or frames per second [Foessel]

Projection Techniques

In Table 1 (below) the main different 3D projection techniques and their characteristics are listed. Each of them has its specific advantages. In practice most 3D systems are one projector systems. This reduces the alignment efforts to calibrate two projections from two different projectors. However as each method absorbs a lot of light, in some cases dual projector systems are necessary with the advantage of brighter screens and the disadvantage of higher costs. Some technologies will be explained more in detail.

	Anaglyph	RealD	Xpand	MasterImage	Dolby	Sony	Dual projector
Separation Method	Broadband colour filter (Fixed filters)	Circular polarisation (Z-Screen)	Polarisation (Shutter glasses)	Circular polarisation (Filter Wheel)	Small band RGB filter (Fixed filters)	Circular polarisation (Beam splitter and fixed filters)	Circular polarisation (Two fixed filters)
Glasses	Passive Colour	Passive Polarisation	Active Shutter	Passive Polarisation	Passive Colour	Passive Polarisation	Passive Polarisation
Temporal	Simultaneous Projection	Time-Multiplexed	Time-Multiplexed	Time-Multiplexed	Time-Multiplexed	Simultaneous Projection	Simultaneous Projection
Screen	Normal Matt-white	Silver Screen	Normal Matt-white	Silver Screen	Normal Matt-white	Silver Screen	Silver Screen

Real-D, MasterImage3D (Figure 6)

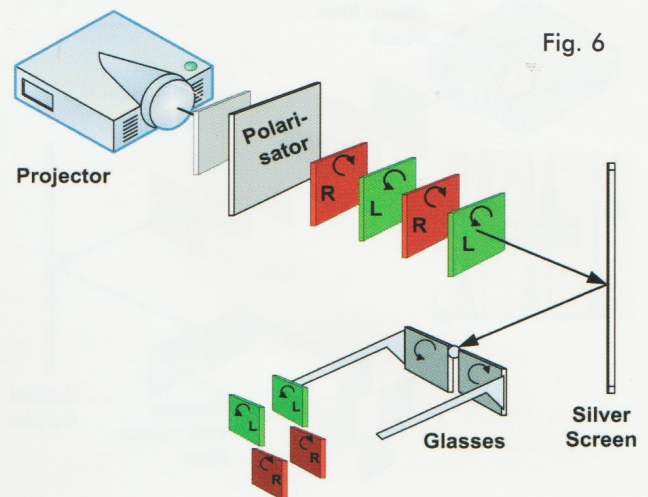


Fig. 6

The movie will be delivered as digital package (DCP) with 48 frames per second. The images for left and right eye are stored interleaved in the package, means the movie is 2 eyes by 24 frames per second (fps). To reduce flicker artefacts, one image pair will be repeated in the projector two or three times (double flash with 96 fps or triple flash with 144 fps).

For later image separation at the viewer position the projected images will be polarised. For example the images for the left eye will be left circular polarised, the images for the right eye will be right circular polarised. This polarisation can be done either by an electro-optical modulator (Z-Screen, RealD) or by a rotating filter wheel (MasterImage 3D), where filter segments have different polarisation filter characteristics. It is important that the filters are synchronised with the projector to guarantee the right polarisation direction. On normal screens the polarisation is destroyed, so for these methods a specific silver screen is necessary. This type of screen preserves the polarisation. At the viewer position the separation of the images for right and left eye is done by passive polarised glasses. Light, where the glasses have the same polarisation direction, can pass, light with different polarisation direction is blocked. Today 3D DCPs with these methods have to be pre-processed in the mastering process to compensate ghosts (so called ghost busting). In the future however the pre-processing or ghost busting shall be done inside the player systems. Today 3D systems with passive polarising are the most common ones.

Xpand, Nuvision (Figure 7)

The image pairs will be repeated during projection several times like in the RealD or MasterImage 3D systems. However the

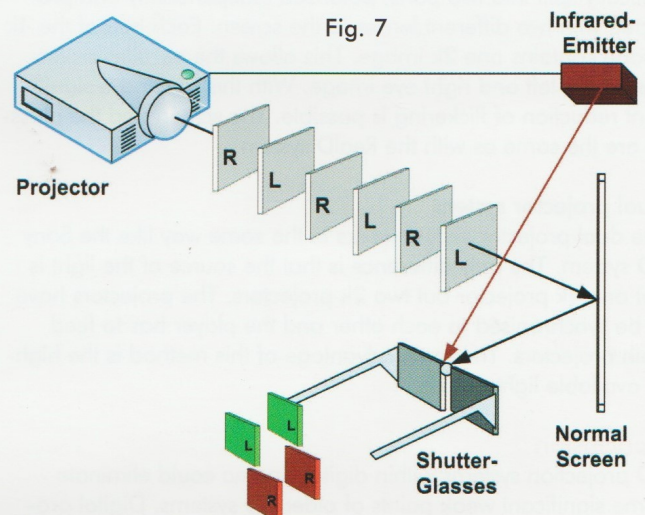


Fig. 7

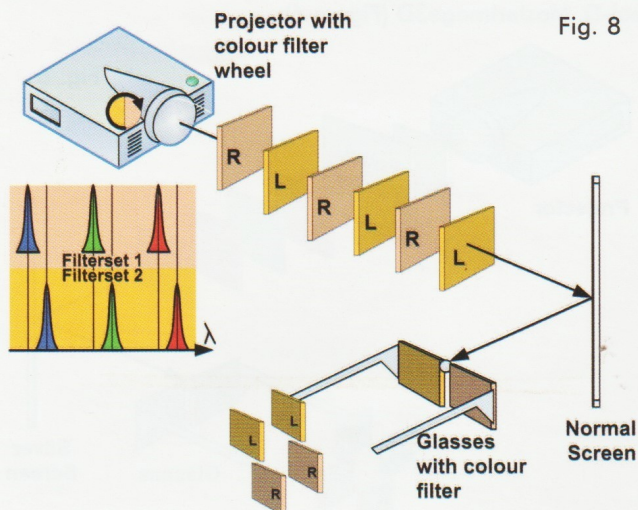


Fig. 8

images will not be polarised after leaving the projector. That allows keeping the normal screen. The viewer has an active shutter glass, in which the image for one eye can pass and will be simultaneously blocked for the other eye and vice versa. The physical principle is the same as with RealD, the only difference is that the polarisator and the passive glasses are combined in one device, the active shutter glasses. To synchronise the shutter glasses with the projector an infrared emitter is necessary. Because of the active nature of the glasses they are more costly than the passive glasses and need internal battery and electronics.

Dolby (Figure 8)

The Dolby system uses a rotating colour filter wheel inside the projector. The colour filter wheel has two sets of small band RGB colour filters, which have slightly different transmission characteristics. That means, each set can pass a RGB image with slightly different spectral curves. The glasses have also the same filters. Set1 is used for the left eye, Set2 is used for the right eye. So the glasses are tuned to the different sets of the filter wheel. Because of the small band filters one eye can only see the corresponding filtered image. The idea was developed by Infitec and adopted for the cinema by Dolby. One advantage is the usability of normal screens. The glasses are costly because of the small band filters, but passive. With higher production volumes the costs are expected to decrease.

Sony (Figure 9)

The previous methods are using the high projection frame rates of 2k DLP projectors. Sony with its 4k projectors benefits from the high resolution. Within the Sony 3D system the 4k image is optically split into two parts, polarized independently and projected with two different lenses to the screen. Each half of the 4k image contains one 2k image. This allows the parallel projection of the left and right eye image. With this method a significant reduction of flickering is possible. The screen and the glasses are the same as with the RealD system.

Dual projector system

The dual projector system works in the same way like the Sony 3D system. The only difference is that the source of the light is not one 4k projector but two 2k projectors. The projectors have to be synchronised to each other and the player has to feed both projectors. The main advantage of this method is the higher available light output.

Conclusion

3D projection systems within digital cinema could eliminate some significant weak points of older 3D systems. Digital pro-

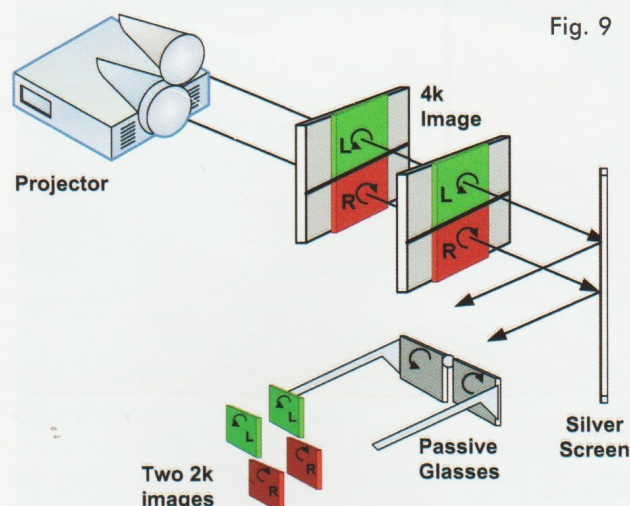


Fig. 9

jectors have no judder, with the use of only one projector an alignment of left and right eye image position is not necessary and the digital technology allows the seamless integration of other electronic components like active glasses, player systems or electro-optical modulators.

Each system has its own characteristic advantages and disadvantages. But for all of them, the main still open issue is the extreme loss of light. For 2D systems the typical brightness on the screen shall be 14 fti, with 3D systems in many cases only 3-5 fti will be reached. Ideally the brightness should be at least 6-7 fti. With 3D the lamp power has to be increased to get acceptable brightness values.

Systems with polarisation methods deliver good results. In the moment ghost busting is still necessary in the DCP mastering process. A disadvantage is the need for a silver screen. It is necessary for preserving the polarisation; however it has some direction dependencies for the reflectance, which is not optimal for 2D projections. Here either two screens are necessary, one for 2D and one for 3D, or the theatre can only show one kind of movies in one room. The big advantage of polarising systems is the cheap glasses. The glasses from the Dolby system are also passive, but because of its price not suitable as one-way glasses. Similar like Xpand glasses the glasses have to be collected and cleaned after each show. With Xpand glasses in addition the operational capabilities have to be tested, as they are active glasses.

All manufacturers work hard to eliminate or reduce the remaining weak points, either by integrating compensation algorithms in the player or by cost reduction of necessary equipment and components. Which method will be successful has to be decided on the market-place. In any case with all new systems the viewer has an interesting 3D experience.

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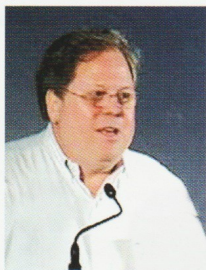
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4. Mastering Stereoscopic Movies



Jim Whittlesey
Deluxe Laboratories

Introduction

In the original "EDCF Guide to Digital Cinema Mastering" we defined Digital Cinema Mastering as the process of converting the Digital Intermediate film out (images) files into compressed, encrypted track files – this being the digital cinema equivalent of film reels. Combining (in sync) these image track files with the uncompressed audio files track files and subtitle track files to form a DCI/SMPTE complaint Digital Cinema Package (DCP).

3D Digital Cinema Mastering is much the same process, with a few additional steps in the workflow. The majority of the extra workflow is processing the 3-D image files.

It is worth noting that at the present time (June 2010) 3D Digital Cinema supports 2K images only - 4K images are not supported in 3D Digital Cinema.

Incoming QC and Verification

As before, it is important to do a thorough QC and verification of the incoming files. In the case of 3D, the image Digital Cinema Distribution Master (DCDM) files should be delivered in directories grouped as a separate left eye/right eye and reels. For example: left_eye_directory with sub directories for reel_1, reel_2reel_n; right_eye_directory with sub directories for reel_1, reel_2reel-n. In addition to the typical QC of incoming image files, it is critical that you verify that there are exactly same number of frames for each left eye right eye reel pairs. If there is a difference, it indicates you have been delivered more left eye frames than right eye or visa-versa. In either case, it is a disaster waiting to happen and must be corrected without going forward.

Image Encoding/Compression

The next step in the 3D Digital Cinema Master workflow is to compress the image files.

DCI selected JPEG 2000 for Digital Cinema. DCI also specified the maximum compression bit rate. The maximum compressed bit rate is the same for 2D 2K images, 2D 4K images and 3D 2K images. From the DCI Specification v1.2, page 42, Section 4.4:

- For a frame rate of 24FPS, a 2K distribution shall have a maximum of 1,302,083 per frame.
- For a frame rate of 48FPS, a 2K distribution shall have a maximum of 651,041 per frame.
- For a frame rate of 24FPS, a 4K distribution shall have a maximum of 1,302,083 per frame.

It is important to note that the maximum bit-rate for the above three cases is the same; 250 Mbits per second. Since 3D is running at 48FPS (twice the frame rate – therefore twice the number of frames per second) the maximum size of each frame is cut in half in order to maintain a max of 250 Mbits per second.

Compress the DCDMs (*.tiff) files as separate left-right eye reels. When compressing a reel (either left or right eye), the maximum bit rate must be set to 125 Mbits per second. The combined bit for a left eye reel and a right eye reel will be 250 Mbits per second – meeting the DCI specification. Should you forget to lower the bit rate and compress both reels at 250 Mbits per second (the combine bit rate will be 500 Mbits per second), you will have server interoperability issues – most playback servers will not be able to playback the 3D DCP. This is a headache you don't need.

Making the Image MXF Track File(s)

In digital cinema the 3D image track file is the equivalent of a reel of 3D film (2 perf over-under). Unlike film, where a reel of 3D film will contain two images per frame, the 3D MXF track files stores the separate left eye frame and right eye frame sequentially.

How do make this image MXF track with sequential left eye right eye frames?

We have a directory structure something like:

```
movie_title/left_eye/reel_1/*.jpeg
movie_title/left_eye/reel_2/*.jpeg
movie_title/left_eye/reel_n/*.jpeg
movie_title/right_eye/reel_1/*.jpeg
movie_title/right_eye/reel_2/*.jpeg
movie_title/right_eye/reel_n/*.jpeg
```

Each directory has a *.jpeg for each frame of the reel (left or right eye - typically 20,000 to 30,000 frames per reel per eye). The next step is to create a combined folder per reel that has the left eye *.jpeg and right eye *.jpeg frames sequentially number. The first numbered *.jpeg frame in this directory must be a left eye frame and the last numbered *.jpeg file must be a right eye.

For reference from the DCI Stereoscopic DC Addendum, page 2, section 2.2:

- The first frame of each reel shall be a left eye, and the last frame of each reel shall be a right eye.

From this folder, you will make the MXF track file. Most mastering system will provide tools to do this file manipulation. For example: Doremi DMS 2000 provides a tool called "File in Motion" to perform the above operation. It uses the UNIX symbolic links so files are not actually copied. There are a number of utilities that can help in performing the file interleaving into a new directory.

One could ask, Why wait until the compressed file state to do the file interleave (one could do this step at the DCDM level)? This is true and it may make the compress step a little easy. In the event there are scene changes for say international versioning, I believe it is easier to "drop in" the new compressed frames, re-create the interleave folder and make the image MXF track file.

"Dropping in" the new files at the DCDM level, you must recompress the entire reel as opposed to just the "drop in" frames.

It now should be entirely obvious as to why there must be the same number of left eye frames and right eye frames per reel at the DCDM delivery.

Build Composition Playlist(s) CPLs

From the original "EDCF Guide to Digital Cinema Mastering": The Composition Playlist (CPL) defines how a movie is played. It defines the order in which each track file is played. The CPL also defines the starting frame and the duration of frames to be played within a track file.

For a 3D CPL, the entry point and duration of a image MXF track must be even numbers and typically will 2x the number for a 2D CPL. For example, a typically 2D image MXF track will have a 192 frame leader at the beginning. Since we do not want to play the leader, the entry point will be set to 192, thereby skipping over the leader and starting with the First Frame of Action for that reel. For a 3D CPL, in which both the left eye and right reels have 192 frames of leader, the entry point will be 394.

It was previously stated that the "entry point and duration ... must be even numbers". **What would happen if the duration is an odd number?** I would normally leave this as an exercise to the student but result is unwatchable so ...

If you have an odd number frames for the duration of reel 1, the CPL will play the last frame (a left eye) of reel 1 and go to the next image MXF track expecting to play a right eye. Remember the images are played as sequential left eye right eye pairs. The DCI specification requires the first frame of an image MXF track to be a left eye. You are now displaying a left eye instead of a right eye image. The left eye images and right eye images are out of sync. This will continue for the entire reel or movie. The audience will remove their 3D glasses quickly

One last point on the CPL; the edit rate must be set to 48FPS to indicate 48FPS playback.

Summary

3D Digital Cinema Mastering is essentially the same workflow as 2D Digital Cinema Mastering with a few additional steps.

- Verify the DCDM (*.tiff) have exactly the same number of left eye images and right eye images.
- When creating the image MXF track, make sure the left eye image is the first displayable frame of the left eye – right eye pair.
- When JPEG 2000 compressing the DCDM (*.tiff) files make sure the combined bit rate for the left eye frames and right eye frames (48 frames per second) is less than 250 Mbits per second.
- When making the CPL, make the edit rate is set 48fps and the image MXF track file entry points and durations must be even numbers. (remember 0 (zero) is an even number)

Adding these simple steps to your 2D Digital Cinema workflow will make for a smooth transition into 3D Digital Cinema mastering.

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SMPTE 426-5 Subtitle Track File
SMPTE 426-6 MXF Track File Essence Encryption
SMPTE 429-7 Composition Playlist.
SMPTE 429-8. Packing List
SMPTE 429-9 Asset Map

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5. There is more to 3D than meets the eye!



David Pope, Director of Operations for UK and Ireland for leading European digital cinema service company XDC.

A note from the author:

Since the original publication of this article in Cinema Technology magazine (March/June 2010 issues), there have been some further developments which I am pleased to take the opportunity to update here. In addition, I have had some very useful feedback from readers seeking clarification on specific points.

The light efficiency table indicates the systems which require 'ghost busting'. As mentioned in the article, the industry was already moving away from providing ghost busted DCPs towards integrating the process into the screen server. To the best of my knowledge this has now been completed and all the relevant screen servers have been updated. As a result the studios are no longer distributing pre-ghost busted packages.

In hindsight, the figure of 70% light efficiency for dual projector operation is rather misleading compared with the other figures in the table, which quote an absolute figure from measuring just one channel (left or right eye). Since only one channel is being measured in the single projector systems, these measurements are already subject to a 50% reduction due to the sequential left eye/right eye switching. Comparing like for like, the figure in the dual projection column should therefore be 35%.

Whilst this would seem to indicate that it is no more efficient to have two projectors, it should be noted that systems which are able to display the left and right eye images simultaneously will benefit from a higher degree of combinative light. Using yet another audio analogy, imagine the light channels are like stereo sound channels going to a pair of earphones. Take one earpiece away and it's theoretically half as loud, but in fact it sounds quieter than that. The effect with light is the same; if both images are visible simultaneously it gives the effect of being brighter than if they are sequential. This is the reason for the 30% efficiency figure for Sony with RealD, which is a single projector system but delivers simultaneous left and right eye images.

Finally, a clarification of my reference to triple flash getting more light on screen. By using a larger pixel area, the latest implementation of triple flash has definitely been an improvement over previous versions, but what it still does not do is get more light on screen than a conventional 2D non-triple flash arrangement. In fact, the main purpose of triple flash is not really related to light output, it is designed to reduce the flicker effect created by the left eye/right eye image switching.



3D audience at CineMec, The Netherlands.

Photo Guy Ackermans

The hot topic at every trade show for the past year has been 3D and CES 2010 in Las Vegas was no exception. 3D will be hitting consumer markets and Home Cinema in a big way much sooner than anyone expected, and this will in turn create a demand for more 3D content than Hollywood can produce over the next two to three years.

A product I have therefore found very interesting is JVC's IF-2D3D1. It converts 2D video into 3D in real-time, although it only produces the positive 'Z plane' – nothing comes out of the screen at you, which is arguably not such a bad thing. It is obviously no substitute for the expertise of companies such as InThree but perhaps this type of software tool can help with the 'leg work', leaving the expert human eye to pick up and correct any errors, and adding negative plane imaging if required by the director. Whilst it is uncertain as to whether this box will be used for real-time broadcast, it will certainly be used in post production and will contribute to a higher throughput of 3D material, making the process more cost effective.

But what has the IF-2D3D1 got to do with our cinema business? One overriding message I gained from the demonstration of this product is that home 3D has the potential to be a very high quality entertainment experience indeed. Should we be worried? Did we worry much about the proliferation of large HD flat screens? The answer to both of these questions is probably 'a little', but I would argue that in the case of 3D we should be a little more worried given the current state of presentation.

I am sure I am not the only one who has come away from numerous 3D screenings thinking it was good but the colours were a little dull, there really needed to be more light on the screen. In fact, I don't need to speculate on this, there are measured facts and even 'standards' which verify clearly that a 3D screening does deliver significantly less light to the eyes. Why is 14 fL the industry accepted standard for 2D and 4.5 fL the figure currently being proposed for 3D? To understand this we need to explore how the various systems work. In this article we will take an in depth look at the various single projector cinema based systems on the market. But first, a little more about JVC's 2D-3D converter.

At the JVC Pro demo the 2D screen was right alongside the 3D and in ambient light conditions. The 3D display was very bright and very clear. Compare this with a cinema 3D experience and

3D CINEMA TECHNOLOGY REVIEW

	DOLBY	MASTER IMAGE MI-2100	REALD Z-SCREEN	REALD XL	SONY	XPAND
3D System Hardware Description	180 degree color wheel	Rotational time division polarizer	Time division multiplexing polarizer	Dual opposing time division multiplexing polarizer (aka Light Doubler)	Dual 2k image planes in an over / under fashion on a 4k chip	IR sync emitter / controller (active)
Efficiency (approx)	11%	16%	15%	28%	30%	17%
Lamp power delta 2D vs 3D	55%	48%	50%	10%	10%	45%
Ghost Busted Package			•	•	•	
Requires Licensing (Annual Cost)*			•	•	•	
3D System Installation Time	3 hours	2 hours	2 hours	3 hours	2 hours	1 hour

* 3D systems provider business plans may vary from client to client and region to region

there may come a time when the public will ask, "Why is 3D at the cinema so dull?" Currently, they are still bowled over by the experience, it's all new and they have nothing to compare it with. Give it a couple of years when Sky's 3D channel is established and then ask if our current cinema 3D is good enough. The bottom line is, I think we need to do better and can do better. Let's keep ahead of the game. Cinema has always tried to deliver a superior experience over home cinema; that's where we are going with 4K. Let's make sure we don't leave 3D behind. If we plan for a bright 3D future today, exhibitors won't have to reinvest in upgrading their systems in the future.

It's not all about light intensity on the screen, is it?

No, far from it. As the title of this article describes, there is more to 3D than meets the eye! A lot goes on within our brains to fool us into thinking we really are looking at a 3D image. And here lies the challenge for engineers in quantifying and measuring the 'performance' of a 3D system. I believe there are parameters we just can't quantify at the moment and very often the only way to judge whether one 3D system is better than another is by subjective measurement through audience survey.

There are proper scientific methods and procedures for this that should involve a/b switching and blind testing of identical content in the same auditorium with the same audience. Technicolor acknowledged the importance of audience surveys in its demonstration at ShowEast in October 2009. For Technicolor this was essential as they would inevitably be questioned over the ability of a 35mm analogue system to produce the same 'quality' as the inherently stable and precision accuracy of a digital system. Pity then that they didn't follow scientific principles for their subjective testing.



Technicolor conducted a two week test with Warner Bros. and AMC at the Burbank 16 with the feature The Final Destination. The Technicolor 3D system ran in one auditorium while the same feature was shown concurrently in digital 3D in the same complex. Movie research firm OTX conducted exit polls for The Final Destination at both the Technicolor 3D screen and the digital 3D screen, and reported that the vast majority of both groups rated their viewing experience as "satisfied" or "extremely satisfied". Indeed, Technicolor 3D even generated a higher "extremely satisfied" response than digital 3D: 28% v. 21%.

But this comes back to my earlier point, what were they comparing it with? How can anyone make a proper analysis without a reference point? Satisfied, yes, I'm sure it was a great film and this was the overriding 'feeling' of the exit audience. The real test would have been to have had each group swap over half way through, or indeed just watch the movie again. Speaking as a former sound dubbing consultant, a test of a good movie for me was how many times I could watch it without getting bored! I found on watching a movie for the second time I would pick up all the detail I missed during the first screening. I was able to make a much more valued analysis and appreciation of the film's production qualities.

For the benefit of our audiences, we need to be much more critical of 3D than we are at the moment. I have a feeling this is a bit like the emperor's new clothes, no one feels comfortable speaking out. Competitors don't criticise the performance of each other's systems. Hollywood seems content to be, let's say, 'more flexible' on 3D specifications after doing an absolutely sterling job with the Digital Cinema Initiative (DCI) for 2D. I suspect no one wants to delay the onset of the 'cash cow' that 3D is turning into. Make hay while the sun shines, especially in these times of financial crisis. But, if we give a little more attention to getting 3D 'right' now, the 3D sun will shine a lot longer.

So let's have more competitor 'shoot outs', more a/b comparisons - and not just between 3D systems. Let's compare 3D with 2D. Healthy competition is what our industry is all about.

How does 3D cinema work?

I am sure that most readers will understand the basic principles of how 3D systems work, but here is a little trick you can play on your kids, or your financial director when challenged with, "You want to spend how much on this 3D system?"

- Place your index finger about one foot in front of your face (not any other finger, otherwise your financial director might get the wrong idea!).
- Now cover up one eye with your free hand and take a mental note of what you can see of your finger.
- Move the hand to the other eye and note the difference in the image.

You will notice that with one eye you can see further around one side of the finger, and with the other, further around the other side. Now we normally see these images simultaneously and our brain 'mixes' them into a composite image, which allows us to see in 3D (or stereoscopic) all the time. Another thing to note; while you had that finger up in front of your eyes in perfect focus, did you notice the background? By definition, it was out of focus. This is another piece of information our brain processes to form the stereoscopic view, along with parallax and other visual cues such as knowledge of the size of specific objects and estimating their distance away from us. Suffice to say, then, that there is a high degree of brain processing going on to form that final stereoscopic image. All 3D cinema systems work on the same principle of separating the left and right eye images, and hence all 3D cinematographers work on the same principle of creating separate images for the left and right eyes.

A 3D system does the same job as your hand in the trick described above, but it does it so rapidly that the two images appear to be simultaneous - just like 2D, where film action appears smooth and realistic even though the images are flashing at us 24 times a second.

In a standard 3D projection system the left image flashes at only the left eye in one instant, and then the next instant the right eye receives its image while the left eye should see nothing, or more specifically 'black', just as if your hand was covering the left eye. Digital 3D systems use a rate of 48 frames per second to achieve this, so effectively are delivering the left eye/right eye frames in the same time span as an original 2D 24fps presentation. In addition to this, digital projectors also apply a technique called 'triple flash' which takes each frame and flashes the image three times within that same time span. This has the effect of making a smoother image motion, reducing flicker and also increases the perceived light on the screen. All 3D systems need to get more light on the screen since they all suffer from being rather inefficient. Even the best only lets 30% of the original source light through. So, triple flash is good news for the systems that use a digital projector.

So, why aren't 3D systems perfect?

In theory, 3D systems have the potential to be perfect and as good as our own built-in human '3D system'. In practice, though, there are some enormous challenges and problems for a 3D system to overcome. Let's go back to our little finger trick from the previous section. For this second part of the trick you will need a pair of the darkest sun glasses you can find, preferably with removable lenses. Now, if a 3D system could block out the light as your hand did in the first trick, then the 3D system would be on the route to being perfect. However, these systems do not stop all the light reaching the right eye from the left eye image (and vice versa), which leads to an imperfection termed 'ghosting'.



To demonstrate to yourself an extreme form of ghosting, take the two lenses from your dark sunglasses and put one over the other to make a very dark lens. Now, instead of putting your hand over one eye, put this dark lens combination in front of the left eye. What your left eye now sees is a ghostly image of what the right eye is seeing. That's ghosting, and with 3D systems it becomes more noticeable with high contrast images - a black cloak against white snow, for example.

Ghosting is also more noticeable the more the image extends into the negative Z plane, when the image appears to come right out of the screen into the auditorium. The three dimensions of 3D are termed, X, Y and Z. X and Y are the usual two dimensions, Z being the third dimension, depth. Positive Z is going back into the screen, negative Z is coming out of the screen. Some 3D systems suffer more from ghosting than others and some are so extreme that they have to employ image processing known as 'ghost busting'. The more efficient the system is at preventing 'crosstalk' between the left and right eye images, the less noticeable the ghosting. Some systems have sufficiently low crosstalk for the ghosting to be virtually imperceptible even at the most extreme contrast.

What would make a perfect system?

If you come away from a 3D screening suffering from eye fatigue or eye strain it could be for a variety of reasons. It is possible that you have reached a certain age where your eyes are simply not up to performing 3D gymnastics (me for example), or it could be that the film director has just placed too many demands on your eyes. Let's go back to the old finger demo again and take it to extremes.

- Move your finger so close that your eyes begin to cross over (we Brits call it 'going boss eyed').

It's not particularly pleasant and can even be slightly painful. To a lesser degree this is what is happening when the director decides to use a lot of negative Z plane. In other words, the more and further out into the auditorium the focal plane, the more work your eyes have to do. It is this constant adjustment to different focal planes that can strain the eyes. In cutting from one scene to another, the director also has to take into consideration that the focal planes are consistent. So, the bottom line is, we could have a perfect delivery of the content but with an inconsiderate film director - the result is eye strain even for those with the most gymnastic eyes!

Another factor that can cause eye fatigue, even with a perfect

delivery system, is the stability and alignment of the captured image. With CGI animated features this is rarely an issue but with live action capture, it can be. Companies such as 3ality have developed high precision camera rigs and the expertise to use them. Zoom operation and tracking the image with stereoscopic capture is quite a challenge, but it can be done very effectively and with sufficient precision to produce a very high quality presentation. However, if there is any vertical misalignment between the left and right image it will show up in the presentation unless corrected in post production. There are numerous software packages that allow a skilled operator to correct vertical misalignment, but it's always much more cost effective to capture it correctly in the first place. This type of misalignment will generally exhibit itself as an image with slightly fuzzy edges; you may interpret it as being slightly out of focus. When it gets to extremes, our brain suspends the 3D belief and gives up trying to construct it. But all the time it keeps on trying to construct it and this can also lead to eye fatigue. There are three basic requirements for achieving perfection in a 3D delivery system:

- **Perfect image stability**
- **100% left/right eye separation**
- **100% light efficiency**

So, assuming that we have perfectly structured 3D content to start with, let's explore the possible deficiencies in the delivery systems which can lead to a less than perfect presentation.

Perfect image stability

This is the benefit of digital projection, absolute integrity and stability of the image is inherent which ensures perfect alignment between the left and right images. The whole system runs on an internal clock with precision many millions of times finer than could ever be achieved with the most lovingly cared for analogue 35mm projector. All those sprockets and wheels, transport guides, etc, have inevitable mechanical tolerance and the 35mm film media itself is subject to damage and wear as it passes through the rollers. At a recent BKSTS projectionist training course, I heard from an acknowledged expert in the field of projector maintenance (Nigel Shore) that the tiniest build up of emulsion on a sprocket wheel can result in quite an alarming shift of the image on screen. To quote Nigel, a 0.25mm shift at the sprocket wheel translates into 110mm on the screen. So, whilst analogue 3D projection could claim to achieve stability within one frame (since left and right eye images are contained within a single frame), it certainly doesn't get anywhere close to digital across a number of frames. It is sometimes appropriate to hang on to old tradition and old technology, but we rightly need to be sceptical when claims are made that its performance in the context of 3D is equal to digital.

D-Cinema is expensive and it does seem unfair that the small exhibitors who can't yet afford to upgrade lose out on all this amazing 3D content. Under ideal conditions, perhaps the performance can get close. But we all know that 'ideal conditions' rarely prevail. I believe once we get the measure of measuring the performance and quality of 3D, it will be obvious for all to see the difference.

100% left/right eye separation

As described in the opening paragraphs, all 3D systems have some level of 'crosstalk' when delivering left and right eye images to our respective eyes. The left eye will always see something of what was intended for the right eye and vice versa. If this can be kept to a minimum, then it seems our brains filter

the artefact out and we appear not to be aware of it. If the crosstalk becomes more severe, then of course we become aware of it and the artefact is termed ghosting. It occurs to me that this 'crosstalk' parameter is something which could be measured and quantified. Since it clearly has an effect on the quality of the viewing experience, I would hope that the various organisations tasked with defining specifications for the cinema industry will include this parameter in any final system specifications.

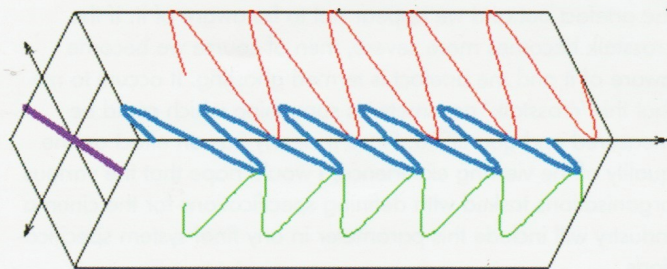
It is important to note that when talking about a 'system', this includes the screen. The quality of the silver screen that is needed to achieve the separation in a polarised 3D system will have an effect on the measured crosstalk, that is, if the industry ever gets around to measuring it! I will explain the purpose of the silver screen later, when we take a closer look at the individual 3D technologies, but suffice to say at the moment that none of the systems achieve anything like 100% left/right eye separation. Some are certainly better than others, but again, without a proper industry approved system of measurement, we have no way to define 'better'. It's also important to note that the intensity and contrast of the image are very relevant to this crosstalk parameter. Take the analogy of a sound-proofed room, or better still a multiplex cinema auditorium. The sound proofing has to be good, but how often have you heard the soundtrack from the film playing in the auditorium next door? You hear it when it gets loud, right? The same applies to left/right eye imaging; it breaks through when it reaches a certain level of intensity, no matter how good the system may be.

100% light efficiency

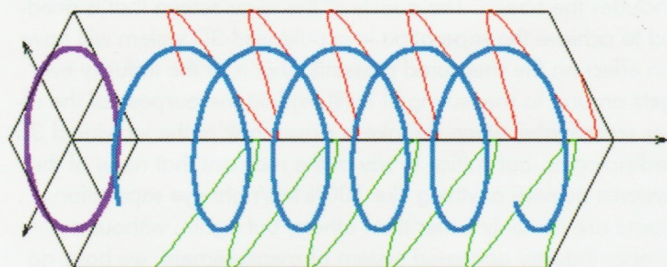
Finally, something that is measured and published! Looking at our comparison table, the Digital 3D Matrix, you can see that even the most efficient single projector 3D system achieves only 30%. That means that just 30% of the original light source is getting to the viewers eyes. The other interesting figure in the comparison table is the Lamp Power Delta 2D v 3D. This rates the extra percentage lamp power needed to achieve 4.5 ftL. You can see that, logically, the less efficient the system, the more lamp power it needs. If only it were as simple as increasing the lamp power! If that were so, we could just turn up the lamp, overcome the inefficiency of the system and get a much brighter image than 4.5ftL. Unfortunately this is not the case.

Let's take another audio analogy to explain this. In cinema audio we have a reference level that is maintained from post production through to play-out in the cinema auditorium. All projectionists will be familiar with number 7 on the sound processor level control. Play it at that level and we replicate exactly the sound mix the director intended. Turn it down and certain low level ambient sounds begin to disappear, turn it up and the dynamics and balance of the mix change. It's the same with the picture. Turn up the light intensity and not only will the colours change but also the colour balance. The audience are then no longer seeing what the director intended.

At the recent launch of the film Avatar in London's Leicester Square, the director decided he wanted 6.5 ftL on screen (very bright by 3D presentation standards). This not only required double the number of projectors (four in all - but it is a big screen), it also required a specially produced Digital Cinema Package (DCP). This was necessary to faithfully reproduce the original colour and balance. Having one version of a DCP that can play anywhere on any approved D-Cinema server has been



Linear Polarisation



Circular Polarisation

one of the overriding objectives of the DCI's standards for 2D. I am sure the DCI aspires to the same objectives for 3D, but at the moment most distributors accept that multiple versions have to be produced. These include: ghost busted and non-ghost busted, subtitled and non-subtitled, plus different packages to suit the various types of presentation venue.

Competition is the key

The great thing about the 3D cinema market at the moment is the healthy range of competition. The compatibility and interoperability of content files will hopefully continue to ensure this competition continues. Competition keeps all the manufacturers on their toes and drives them to further innovation. It also keeps prices down! None of the systems are perfect but all of the systems have the capability to deliver a high quality entertainment experience when each is given optimum operating conditions. The not so good thing about the market is the apparent dumbing down of so-called 'recommended standards' to the worst performing common denominator. The industry sets a high standard for 2D with 14 fL. We all know that cinemas fall short of this from time to time; lamps are turned down to make them last a little longer, something that is often overlooked because 12 fL still looks pretty good, but set an only just acceptable 4.5 fL standard for 3D and you can be sure that failure to meet this will be much more commonplace. I have seen enough lacklustre 3D screenings to know that 4.5 fL is certainly not always achieved.

So why is 4.5 fL even considered acceptable? Surely the industry needs to set the bar higher so that a marginal fall in the lamp output does not result in such a poor performance? I have heard that the ghosting artefacts in one particular system become unacceptable above 4.5 fL and this is the reason for the current recommended 'standard'. It is a great shame if this is indeed the case since this is not a VHS/Betamax format war we are in, or even a Dolby/DTS. Exhibitors are free to choose whatever system they prefer and will be assured of content. The studios have the option of raising the bar and setting a reasonable time frame for all manufacturers to comply. They should not settle on a specification based on the dominant system.

The various 3D Presentation Technologies

All cinema 3D systems work on the same principle of separating the left and right eye images. There are three basic ways to achieve this: circular polarisation, active lens shutters, and colour filtering. All are capable of delivering a very high quality 3D experience when operating under optimum conditions. Let's have a look at how each of these technologies work...

Circular Polarising Systems

Polarising 3D systems have come a long way in recent years. Did you ever try the polarising sunglasses lens trick, where you turn one lens 90 degrees to the other and the combination goes black? Virtually no light gets through. Interesting, but not really practical for cinema unless you keep your head perfectly vertically aligned... for two hours or more! Fortunately the current systems use circular polarisation filters, which means you can move your head, relax and enjoy the film.

At the time of writing (September 2010) there are three 3D systems on the market that use circular polarisation. Two of them, RealD and MasterImage 3D, are D-Cinema based and the third, from Technicolor, is designed for 35mm film. All three systems are very easy to install and can be moved from one projection booth to another, some more easily than others.

The two D-Cinema systems comprise:

- Projector Polarising Switch Unit
- Silver Screen
- Passive Polarising Glasses

Both systems can be installed on site in front of the lens of a standard D-Cinema projector. They each have a serial connector which receives the frame timing data from the projector and allows the system to synchronise the polarising filters. When the projector is showing the left eye image the system arranges for an anti-clockwise polarisation filter to be in front of the lens. When the right eye image is shown, a clockwise polarisation filter is presented to the lens.

In the auditorium, the audience puts on their passive disposable polarised glasses. The left eye lens is an anti-clockwise polariser, the right eye lens a clockwise polariser. The luminance inefficiency of both systems originates here. Since the light passes through two sets of filters, it is attenuated twice. Take the glasses off when you are watching a 3D film through a polarising system and you will see an immediate doubling of the light intensity. Notice also that when you do this the colours change quite dramatically. (Remember my earlier comments about colour balance and light intensity.) If it were possible to remove the polarising filters at the projector end you would see a further doubling of light intensity. There is not much to be done about making polarising lenses more efficient; they are what they are and by their nature they reduce the light passing through them. However, RealD has developed a clever box called a light doubler (see Fig.1) which catches the light bouncing off the first filter and sends it back through the system, thereby improving the efficiency from around 15% to 30%. This doesn't necessarily mean you will get a brighter image from an existing DCP – a specially prepared DCP is needed to compensate for the additional brightness – what it actually means is that the system will use less lamp power for a given fL on screen. The important point here is not the efficiency of the systems, but the need for an absolute luminance standard in 3D. Why was 6.5 fL used for the premiere of Avatar at the Empire, Leicester Square rather

Fig. 1 RealD XL

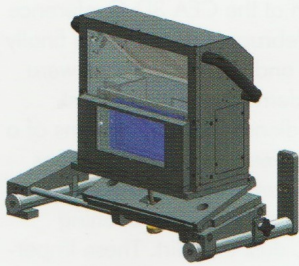


Fig. 2 RealD Z Screen



Fig. 3 MasterImage 3D



than the more regular 4.5 fL? Why can't we all have 6.5fL? To answer that question we need to examine the issue of ghosting and the role of the silver screen in these polarising systems.

Why do polarising systems need a silver screen?

The polarising systems currently on the market have to use a silver screen. Without it, the ghosting effect would be unacceptable. A regular screen has the effect of scattering the light so that the polarised light incident on the screen becomes depolarised. This would result in severe crosstalk between the left and right eye images.

A silver screen has a surface constructed from millions of tiny flakes of silver reflectors which reflect the incident light in a much more defined fashion, thereby maintaining the polarity in the reflected light. A poor quality silver screen will scatter light more than a good quality one, making artefacts such as ghosting more noticeable. A good quality screen is an essential part of a 3D polarisation system and therefore not an area to skimp on cost. A further point on silver screens is that they may have variable directional properties and variable light intensity, so you may experience a variance in 3D image quality depending on where you are seated in the auditorium.

The main advantage of systems that need a polarising screen is the savings made by having very low cost disposable glasses. Polarising glasses usually cost less than a euro, and can be reused if the exhibitor is willing to invest in a glass cleaning system and the labour to operate it. The downside is the cost of the screen, which is not insignificant, ranging from 5,000 to 10,000 Euros, depending on the size. In addition, a silver screen's performance with regular 2D content is compromised by the appearance of a 'hot spot'. Its 'virtue' of not scattering polarised light leads to an intensifying of light at the point directly in line with the projector, the centre of the screen. At the low light levels of 3D (4.5 fL) this is not noticeable, but with regular 2D content at 14 fL it can be. A cinema consultant friend of mine recently reported a huge variance in fL measurement across the silver screen at one site he was testing. With regular 2D, a measurement of 18fL was found in the centre and 3fL at the sides! However, it is probably fair to say that the majority of cinemagoers would not notice a 'hot spot'. It is also an undeniable fact that the most successful 3D system in the world (by virtue of the number of installations) uses a silver screen.

Why does one polarising system need ghost busting and the other not?

You will notice from the performance chart that some systems have a tick in the 'Ghost Busted Package' row, while others do not. The main difference between the RealD and MasterImage 3D polarising systems is the way in which they implement the polarising switch at the projector lens. See figs 2 and 3.

RealD uses a liquid crystal electronic switch which configures the appropriate polarising filter to appear at the correct time. MasterImage 3D achieves this using a mechanical disc of some 380mm in diameter divided into alternate sections for left eye/right eye polarisation. MasterImage 3D's disc spins at 4,320 rpm and in consequence requires a very stable platform, provided by the sheer weight of the housing, 180lbs (81Kg)! Fortunately (and rather essentially, I would say) the unit is on lockable wheels. The spinning disc is synchronised to place the appropriate filter in the lens path at the appropriate time. The simplicity of this system results in very few performance limitations, especially in the production of the polarising filters which can be optimised to a high level of precision.

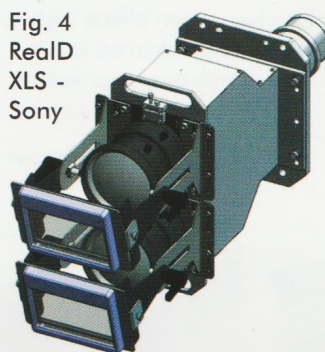
RealD's system, on the other hand, is limited by the performance of liquid crystal technology. Liquid crystal has latency in the switching response and a limitation in the precision of the polarising filter. It is in the nature of liquid crystal as it transitions from one polarisation mode to another that it does not entirely switch off and go absolute 'black'. A combination of all these factors results in the system suffering from crosstalk severe enough to require 'ghost busting'. The effects of ghosting can be counteracted either by the film distributor sending DCPs with pre-ghost busted content, or by applying ghost busting software to a regular 3D DCP as it plays out in the projection booth. The advantage of the latter solution is that only one version of the DCP is required and no account has to be taken of which servers have ghost busting software and which don't. However, at least one Hollywood studio is sending out pre-ghost busted files to all locations regardless of whether their systems require it or not. Hopefully other studios will not follow this example. It would be a shame if systems that perform well enough not to require ghost busting are then compromised by having to play ghost busted files, especially since the manufacturer of the system that requires ghost busting has made its ghost busting software readily available to D-Cinema server manufacturers.

Sony's application of RealD

Whilst discussing 3D polarising systems, it is worth noting Sony's application of RealD's technology. It differs quite significantly and leads to an improved performance in a number of respects. Sony is well known in the cinema industry for a number of reasons, but over the past five years its campaign to raise the awareness of 4K cinema has been the most prominent. The

importance of healthy competition in the industry is highlighted by TI's recent launch of its 4K chip. Some day all D-Cinema projectors will be equipped with 4K capability, although it will be a long time before 4K distribution is the norm. Vast file sizes and longer duplication times will prohibit this for a while yet. In the meantime,

Fig. 4
RealD
XLS -
Sony



though, Sony has chosen to apply its 4K technology to 3D. Not by giving us a 3D 4K image, but by using the additional pixels to create simultaneous left eye/right eye 2K images. This of course leads to improved light efficiency, as shown in the comparison table.

Having seen Sony's 3D system demonstrated on numerous occasions, my subjective opinion is that the image transition looks smoother. This could be because the system is not switching between left eye/right eye like the other systems. Fig.4 shows how Sony's projector integrates with the RealD system to deliver 3D into the auditorium. The projector is equipped with a special double lens for the left and right eye images, and RealD fixed polarising filters are installed in front of each lens. Standard RealD glasses are used in the auditorium.

Technicolor's 35mm analogue solution

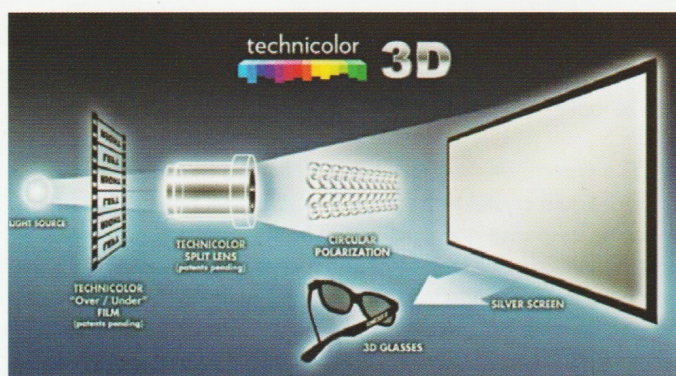


Fig. 5 Technicolor 3D

3D from a single analogue print is not new, of course. Many of us will remember a similar system a decade or so ago, well before we had the benefits of D-Cinema. At first examination, Technicolor's system appears to differ in only one respect; instead of the left and right images being squeezed side-by-side into one 35mm frame, they are placed above/below each other in the frame. Like the Sony/RealD system, it uses a special dual lens with circular polarisers over each and, like all polarising systems, it needs a silver screen. The polarising glasses are much the same as those used by RealD and MasterImage 3D, very lightweight and disposable. Looking further into the Technicolor system, it has certainly come a long way since those of a decade ago. Here, analogue 35mm 3D is being refined to a much higher degree, but will still suffer from the obvious limitations of a mechanical projector. See Fig.5, Technicolor schematic. Technicolor says it has developed a 3D split lens based on modern 'ultra' lens technology (as opposed to the older cement based lenses) with improvements to eliminate polariser burnouts, increase the quality of polarisation, and maximise light transmittance, colour rendering, resolution and contrast. In addition to the actual lens refinement, Technicolor also claims to employ algorithms matched to the 3D lens and prints in order to improve luminance balance between left-eye and right-eye images, and minimise silver screen effects such as flattening of the luminance field. The system is claimed to achieve a 17% light efficiency contingent with proper projection set-up.

Fig. 6 XpanD emitter

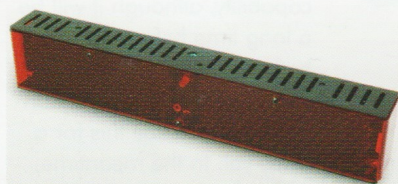


Fig. 7 XpanD glasses



I have now seen three demonstrations of Technicolor 3D: at ShowEast in October last year, again at the CEA 3D Conference at the Apollo Cinema, Piccadilly in February this year, and finally at ShoWest in March. The ShowEast and ShoWest demos were quite convincing, but I'm afraid the demo at the Apollo just served to remind everyone in the audience of the limitations of a 35mm print. The main difference between the demonstrations was that at ShowEast the print was in pristine condition, whilst the one at the Apollo was obviously well used. The opening footage had clearly visible scratches, dust and dirt. These imperfections are greatly magnified over regular 2D because the left and right images are in a single frame and to fill the screen the lens is magnifying effectively twice as much. Any imperfections, including grain, become much more visible and progressively deteriorate with use. It is, of course, one of D-Cinema's greatest benefits that the first play looks exactly the same as the 1,000th play. I also noticed some extreme ghosting at the Apollo demo that I did not see at ShowEast or ShoWest.

I think the jury is out on film-based 3D. It really depends on whether enough of the major Hollywood studios support it as to whether it can gain a sufficient installed base to survive. From a technical standpoint, I am not convinced that a film-based system can be in the same performance category as digital, but then again it is considerably cheaper!

The phenomenal success of 3D over the last year has been because of D-Cinema. If analogue 35mm 3D really can equal the performance of digital, then let's see more proof. I for one would love Technicolor 3D – and any other film-based solution – to be the subject of proper scientific subjective testing analysis. This is why we need properly formulated testing procedures and standards for 3D. The sooner we get them the better.

The Shutter Glasses System

At the time of writing there is only one active shutter glasses system on the market for D-Cinema, from XpanD (formerly known as NuVision). This system is about the closest you can get to the finger demo I mentioned early in this article. Just as your hand shut off the image to the eye you covered, so the XpanD glasses shut off the image to one eye and then the other in rapid succession. Like the polarising systems, the switching is synchronised to the frame rate from the projector. The XpanD glasses simply switch in synchronisation with the corresponding image on the screen. The big difference is that XpanD does not use polarised images and consequently the system does not require a silver screen. Nothing is placed in front of the lens of the projector so the light efficiency of the system is determined solely by the glasses. XpanD uses an infrared transmitter installed in the auditorium to relay the synchronisation signal from the projector. The glasses are equipped with infrared receivers and a built in battery which powers the liquid crystal lenses. In their powered off state the lenses are clear. A signal from the transmitter triggers the glasses to switch on, a voltage is applied to one lens, then the other, causing them to turn opaque and block the light accordingly.

Fig. 6 shows the XpanD infra-red transmitter and Fig. 7 the active shutter glasses.

The system comprises:

- Projector Synchronisation Unit
- Infrared Transmitter
- Active Shutter Glasses

The main benefits of the XpanD system are that it doesn't need a silver screen and it doesn't require any ghost busting. By not using a silver screen, consistency in quality of the 3D image is retained regardless of where you are seated in the auditorium. It is also very simple to install and can be moved easily from one

Fig. 8 Dolby filter wheel

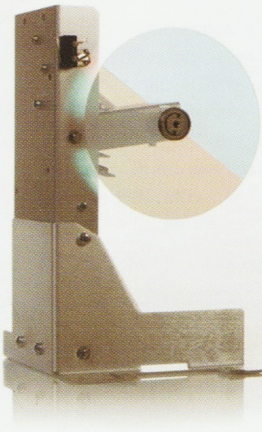


Fig. 10 Dolby 3D System



Fig. 9 Dolby filter controller DFC 100



Fig. 11 Dolby glasses



auditorium to another. The downsides are that the glasses are relatively heavy compared with the disposable polarised type and the fact that they are not disposable means they need cleaning between each screening. In addition, the batteries must be replaced after every 300 hours of use, that's roughly 150 screenings or 100 *Avatars*! Cleaning and maintenance are not the only additional overheads that the exhibitor has to contend with. Of all the 3D systems, the XpanD glasses are without doubt the most expensive so, aside from the issues of loss or damage through rough handling, security needs to be taken into account when assessing the overall cost of ownership. Some people think they have the right to own the glasses since they paid a premium on the ticket, or maybe they just want to have a souvenir! Some exhibitors have lost as much as 25% of their inventory over a three month period and so a tagging system with detectors at the exits to the auditorium is probably a worthwhile investment.

Colour Filter Systems

Until very recently, Dolby was alone in offering a 3D system for D-Cinema based on colour filters. However, Panavision, famous for high quality 35mm production cameras, and Deluxe, famous for film processing, have joined forces with Omega Optical to develop a new system. The Panavision-Deluxe 3D system will be launched during 2010. If you have a reasonable understanding of how a colour image is composed for video transmission, and RGB means something to you, then you should have no problem getting to grips with how the Dolby and Panavision systems work. If not, check out this Wikipedia link <http://en.wikipedia.org/wiki/RGB> for a more detailed explanation first. Suffice to say, our eyes have three primary colour receptors: red, green and blue. Colour video projection is achieved by combining or overlaying three frames - one for red, one for green, and one for blue - to make one full colour frame. If you imagine that a black and white image uses a grey scale to achieve the different tones and contrasts in the image, then you will appreciate that you can have a red image version of the grey scale, and the same for green and blue. When these are overlaid, all the range of colours that the eye can see can be reproduced on the screen. It has been estimated that humans can distinguish between roughly 10 million different colours ref: http://en.wikipedia.org/wiki/Color#Color_perception). Current D-Cinema projection systems are capable of reproducing more than 16 million colours. It is not a great leap of faith then to imagine that you could have two 'reds' on screen that

are virtually indistinguishable, or two greens or two blues. Take this a step further and you can see that it would be possible, by the use of high precision colour filter lenses, to separate these two almost imperceptible colour differences into two separate images. This is effectively what the Dolby and Panavision-Deluxe systems do.

The light coming directly from the projector lamp house is fed through a precision colour filter wheel fitted inside the projector. This happens prior to the image being formed in the light engine. Exactly half the colour wheel has one composite set of filters to cover RGB and the other half has another, spectrum shifted, set of composite RGB filters. The wheel spins in synchronisation with the formation of the left and right eye images in the projector's light engine. The glasses worn in the auditorium have precision matched colour filter lenses which then allow the left and right eyes to see the corresponding filter-matched images. The crosstalk in the system is very low and therefore requires no ghost busting.

Figs 8, 9 and 10 show the component parts of the Dolby system and Fig.11 shows Dolby's passive filter glasses.

The systems comprise:

- Filter Wheel Assembly
- Filter Control Unit
- Passive precision filter glasses

Panavision-Deluxe is also offering the option of providing the filtering by dual lens application - similar to Sony/RealD and Technicolor - except that this is not a polarising lens but a colour filter dual lens. This in turn gives Panavision the ability to provide their system for 35mm film as well as D-Cinema (assuming they, like Technicolor, can secure the film stock supply). There is one further distinct difference between Dolby's and Panavision-Deluxe's applications of the colour filtering method. The latter applies a technique founded by French physicists Fabry and Perot back in the 1920s. The technique uses parallel reflective surfaces tuned to the wavelength of the incident light in order to block parts of the spectrum and create a comb filter. The practical outcome is apparently a much simpler and cost effective lens coating process which is likely to lead to a significantly lower price than current reusable non-polarised glasses.

The main benefits of the Dolby and Panavision-Deluxe systems are that they do not need a silver screen and no ghost busting is required. As with XpanD, by not needing a silver screen, consistency in quality of the 3D image is retained regardless of where you are seated in the auditorium. Another advantage with Dolby and Panavision is that the glasses are passive, very light in weight and do not require batteries. On the downside, although the glasses are not as expensive as XpanD's, the same overheads of cleaning and security need to be taken into account. Over the past year Dolby's glasses have almost halved in price, and Panavision-Deluxe's are expected to be much less again, but this is still not at a price point where they could be considered disposable or recyclable. Also, the systems are probably the least easy to move from one projector to another since the component colour filter wheel is built in to the projector. Panavision has the dual lens option, but moving lenses is not easy, being a two man job. In addition, on the comparison chart you will notice that Dolby is rated as the least efficient of all the systems. Clearly, the higher lamp power needed to achieve 4.5 fL means that it will need replacing sooner. Whether this becomes a significant cost factor will of course depend on how many 3D screenings are scheduled. Efficiency will certainly become more of an issue if a higher illumination standard is agreed. I have not seen any efficiency figures from Panavision but they claim it will be one of the most efficient due to the lens requiring far fewer layers to achieve the desired filter-

ing. Dolby claims that colour filtering achieves sharper images and retains better colour accuracy than the other systems because the colour filter is inserted before the light engine. This could well be the case, and it is certainly my impression from the numerous demonstrations of Dolby's system that I have enjoyed, but this is another area which could benefit from some scientific subjective testing. It is difficult to put a measurement on such performance, so it would be great if we could find a way to quantify it.

As for the Panavision-Deluxe system, I saw this demonstrated in their screening room in California just before ShoWest and was extremely impressed.

Conclusions

If you look at the market now, it appears as though the systems which don't have disposable glasses (XpanD and Dolby) are struggling to keep up; the polarised systems are way ahead. This is not a reflection of cost or performance. All manufacturers are putting forward perfectly viable business models given the quantity of 3D films coming through, and they each perform very well. It just seems that the overhead of managing retainable glasses is a prospect that many exhibitors would simply rather not get into. Many cinemas are already running with the bare minimum of staff and the idea of adding more duties to their rota, or indeed adding more staff, is simply not practical. However, the pressure on the industry to be more 'green' will soon mean that disposing of, or even recycling, the polarised glasses will be simply unacceptable. Even now, with the small percentage of 3D screens in the world (less than 10%), the number of disposable glasses being produced each month is around 10 million! The writing is on the wall, as they say, and the manufacturers are already responding by producing re-usable washable glasses. They are slightly more expensive than the disposable type but still much cheaper than Dolby's or XpanD's. Whilst the overhead of managing the re-use of polarised glasses is more or less the same as for the other systems, the security factor need not be as rigorous. Losing one or two pairs every screening won't break the bank. That said, the overall cost of ownership between the systems will narrow significantly once everyone has to re-use glasses. This is an opportunity for the non-polarised system vendors to catch up. I for one wish they would; competition is good.

In closing, as one who has experienced industry screenings that show all the systems at their very best, I do detect a difference in the quality of performance. It's a subjective reasoning and I wish the industry could find a method of quantifying it. There is definitely room for improvement in the way we are able to measure the performance of 3D systems. I appreciate that it takes a long time for the organisations tasked with creating standards to arrive at a final publication but, in the meantime, maybe the industry could benefit from something akin to 'THX for 3D'.

David Pope

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With many thanks to Bill Foster for his editorial assistance and to the manufacturers who have provided valuable information.

Thanks to Guy Ackermans for the pictures of a 3D audience at CineMec in the Netherlands.

3D Keeps Moving On

3D Cinema projection is currently a fast-moving and rapidly developing art. Those who wrote the detailed technical articles in this guide are experts in the field and fully conscious that some of the technologies have improved since the pieces were originally written some months ago. It is in everyone's interests that a Guide like this should carry the very latest information possible about how 3D is developing, and EDCF Manufacturers have made the following comments, which should be taken into account whilst reading this guide.

- **MasterImage 3D's** standard polarizing filter disk in the MI-2100 cinema system now achieves a light efficiency of 17% as a more efficient disk material is used in its construction. Recent advances by MasterImage 3D have also made available to the MI-2100 the option to use an "anti reflection" coated filter disk which raises this light transmission efficiency to 18.5% as well as further improving polarization efficiency, providing for an excellent presentation on larger sized screens. The quality and simplicity of the MasterImage 3D polarizing optical chain provides a clear 3D image with very natural colours.

- For the largest cinema screens MasterImage 3D recommends the dual static glass circular polarizers, called MI-1000, which have a typical light efficiency of 36%.
- Installation of the system can be achieved with the MI-2100 up and running on screen in under an hour.

- **XpanD** point out that the Nuvision brand name is no longer used - the system is XpanD.

- Although the system is often used in order to avoid the disadvantages of the silver screen which is used with polarized systems, the XpanD system can be used on both silver and matt screens.

- Although XpanD glasses do contain a polarizer, this is not used to separate left eye from right eye, and "active shutter glasses" is the most appropriate description for their technology. Image pairs are repeated during projection several times, generating 144FPS, but the images are not polarized after leaving the projector, which allows a normal matt screen to be used, avoiding the negative side effects of the silver screens needed by other systems. The active shutter glasses pass the image to one eye whilst simultaneously blocking the image for the other eye and vice versa. The LCD shutter completely (near 100%) blocks the image of the inactive eye.

- Active glasses are more costly than passive glasses, but the lifetime of the glasses is extremely long - up to 5000 shows.

- The installation time for XpanD is now 15 - 30 minutes maximum.

- **RealD** systems no longer need ghostbusted masters - ghostbusting is now being done in the server during content playback, as with other 3D systems.

- RealD point out that in all forms of 3D presentation the highest 3D:2D brightness ratio that can be achieved is 50% because all of the light from the projector, or projectors, is effectively split between two movies being shown at the same time: the left eye movie and the right eye movie. The viewer sees only one movie with each eye, therefore in the best case the luminance is half of what it would be when a single 2D movie is presented. Even a 100% efficient 3D system would offer 50% of the 2D luminance when running in 3D mode. Absorption in polarizing or color filters causes the brightness to be lower than that 50% maximum.

- Triple flashing, necessary in all time sequential 3D systems, requires the projector to insert a dark period between flashes to allow the viewing system to change from left eye state to right eye state. In the case of rotating systems, the dark time must be sufficient to allow the spoke between wheel segments to pass completely through the light path. RealD has the shortest dark time at 430 microseconds, other systems can be over 1000 microseconds.

- The RealD Cinema System uses a polarizing film to polarize the light, just as the MasterImage, XpanD and static polarizer systems do. Systems using liquid crystal polarisers cause the linear polarized light to become circular and produce just as much dark time as any other system. All 3D projection systems create some ghosting and all could benefit from ghostbusting technology.

Appendix - Understanding 3D Projection Efficiency *Matt Cowan RealD*

Brightness is an important factor in 3D projection systems, as discussed elsewhere in this document. As a result, "system efficiency" is an important parameter to consider in choosing a 3D projection system. The practical factors affecting system efficiency are different in the different implementations of 3D projection systems. When considering efficiency, it is important to understand that the 3D projection system is playing 2 movies at the same time, so the projector's output is split between the left eye movie and the right eye movie, providing in the best theoretical case half the light to each eye.

I will consider each system in turn. Note that the numbers represented below are "typical" numbers. Individual manufacturers will vary slightly one way or the other.

1) DLP Based single projector systems. These systems use a sequential method of 3D which switches the light between the left and right eyes. This gives full brightness to each eye for about half the time, which the eye integrates as half brightness. In practice it takes time to switch between the eyes. The projector will go black (where it doesn't project to either eye) for the designated switching time, further reducing the light to each eye. In the DLP projectors, this is programmed in as "dark time". This switching time varies from about 0.42 milliseconds to 1.5 milliseconds, depending on the specific system type. This impacts the overall "duty cycle" of the system. Consider that at 144 frames per second, the total time for a left and a right frame is $1/72$ seconds = 13.88 msec. Each eye can potentially be on for a maximum of 50% of the time, or an "on" time of 6.94 msec. A dark time of 1 millisecond will result in an "on" time of $6.94 - 1 = 5.94$ msec. The duty cycle is calculated by:

on time/total L-R cycle time.

With 1000 microseconds dark time, the resulting duty cycle is $5.94/13.88 = 42.7\%$.

a. Shutter glasses. Shutter glasses work as an optical switch at the eye. They have an input polarizer and an output polarizer, and a liquid crystal switch in between, which will align or cross the polarization inside the glasses, resulting in light transmission or blocking. Typical polarizer efficiency at the input is 42% transmission, and the output polarizer will transmit 84% of light polarized in the same direction. The liquid crystal portion is essentially transparent. There can be transmission losses of up to 8% if the optical surfaces are not coated with anti reflection coatings.

b. Z Screen. The Z screen is a polarization switch that resides on the projector lens. It is made up of a single polarizer and a liquid crystal switching retarder. The polarizer transmission is essentially 41%, and the liquid crystal cells are essentially transparent. Z screens are anti reflection coated to eliminate any surface losses. The polarized light is further transmitted through polarized glasses, which are typically 84% transparent.

c. XL Light Doubler. This device "captures" the unwanted polarization that is normally absorbed in the Z screen or other polarizing systems, and converts it into the desired polarization. The system consists of two beam paths, each having the same efficiency as the Z screen, resulting in a doubling of the light throughput. The result is a polarization switching filter that is approximately 82% efficient. This is coupled with eyewear that is 84% transmissive.

d. Rotating Polarizer Wheel. This system uses a rotating polarizer wheel at the projector lens. The polarizer is typically 42% transparent. The polarized light is further transmitted through polarized glasses, which are typically 84% transmissive.

e. Spectral Division. This system divides the spectrum of the projection beam into separate left and right spectra. The system requires that narrow band filters are in place, and that the left and right filters do not overlap significantly. It is difficult to put "typical" numbers on the transmission of this system, but suffice it

to say that the efficiency can be less than 50% because of the light that is blocked to make sure that the filters do not overlap, but with many bands and careful design this system can become more efficient

2) Sony System. The Sony single projector system has a unique approach to presenting 3D. The system dedicates approximately $1/4$ of its modulator to each eye, on a continuous basis.

This means that about $1/4$ of the light from the projector is available to each eye. The system uses polarization. Because the light is already polarized, the polarization conversion for left and right eyes is very efficient – between 80 and 90%.

Efficiency calculation

The efficiency can be calculated, if the basic numbers are known. The calculation is achieved by simply multiplying the duty cycle by the transmission of each element in the system. Note that for simplicity, this has not considered the effect of screen gain.

Efficiency calculation examples:

Shutter glasses:

Duty cycle with 1.0 msec = 42.7% Transmission first polarizer 42%
Transmission second polarizer 84% Assume anti reflection coated surfaces
Multiply together – **Total transmission = 15.6%**

Z screen:

Duty cycle with 0.420 msec = 47% Transmission Z screen 41%
Transmission polarized glasses 84% **Total transmission = 16.2%**

XL Light Doubler

Duty Cycle with 0.420 msec dark time = 47%
Light Doubler Transmission = 82% Transmission of polarized glasses = 84%
Total transmission = 32.4%

Measured numbers will likely be lower based on practical optical efficiency of anti reflection coatings and basic glass transmission.

Besides calculating theoretical efficiency, it is also possible to measure efficiency directly in an operating theatre. Several methods are used.

1. The first method requires a peak white patch to be projected onto the screen. With the light meter firmly on a tripod, measure the screen brightness with the 3D apparatus in place, and again with the 3D apparatus removed. The resulting efficiency number does not take into account dark times, which will change the resulting efficiency by several percent. (Note that the 3D apparatus includes glasses and any other part of the system that is required for 3D projection. Typically the glasses are placed over the lens of the light meter to ensure that the light meter is emulating what the eye would actually see.) Calculate the efficiency by dividing the 3D brightness by the 2D brightness.

2. The second method involves having separate 2D and 3D peak white test patterns. The lamp current in the projector must be kept constant for this test. With the projector in 3D mode, measure the brightness of the 3D test pattern. Switch to the 2D test pattern and put the projector in 2D mode. Measure the brightness of the test pattern. Calculate the efficiency by dividing the 3D brightness by the 2D brightness.

3. The third approach involves comparing the lamp power in 3D and 2D modes. Set the 3D brightness for 4.5 fL using a 3D test pattern and measuring through the 3D system including glasses. Note the lamp power. Reset the projector for 14 fL in 2D mode (with all 3D apparatus removed from the path). Note the lamp power. This will give the relative transmissions for each system, but not absolute transmission numbers, without normalizing for the difference in light level and considering the efficiency of the Xenon lamp at different lamp powers. This method will give exhibitors an idea of the increased power necessary for good 3D.

Method two is preferred for real efficiency numbers.

Note about Screen Gain: Some of the inefficiencies introduced by the 3D selection methods can be mitigated by introducing higher gain screens. Higher gain screens reflect more light to the audience (and less to the walls and ceiling). Using a moderate gain screen will be beneficial in increasing the image brightness to the audience. Note that screen gain has not been considered in the comparison of system efficiencies. The Silver screens mandatory for the polarized systems have not only the brightness advantage mentioned above as a consequence of the higher reflectance but due to narrower ideal viewing angles than regular screens can be sensitive to both seat position and projection port positioning. See Andrew Robinson's summary in Chapter 6.

6. Screens for Digital 3D Cinema



Andrew Robinson
Managing Director
Harkness Screens



Introduction

Digital projection has made single projector 3D solutions much cheaper and of a much higher quality than traditional film projector systems. A single projector can be used. All 3D systems rely on creating separate images for the right eye and left eye. Different technologies are used to create the separate right eye and left eye image streams. Depending on the technology used, there are significant implications for the choice of cinema screen.

3D Technologies

There are 3 principal technologies used for 3D systems in cinemas:

- Polarised light systems. These rely on light being polarised in different forms to create the right eye and left eye image. This can either be done by circular polarisation or linear polarisation or a combination. This technology is well established and has been used for a long time with film projection. It is used by RealD, which is the most popular system used with digital projection in cinemas. Master Image also use a variation of this technology.
- Dolby use a system based on different wavelength triplets of visible light to create separate right eye/left eye images. This, like the polarised light system, is a passive system.
- So called "active" 3D systems use special eyewear with shutters to control the provision of separate images to the eyes. The eyewear is battery operated and controlled by an IR signal. Xpand use this technology.

One feature of all 3D systems is that they absorb a very large amount of the light that is normally available from the projector in 2D mode. The light loss is a result of having to create separate images for each eye, which immediately loses 50%, and there are further losses from the filters in the system. Because of the huge light losses, high power lamps normally need to be used in the projectors; typically 6kw Xenon lamps, although for smaller screens 4kw may be sufficient. RealD's XL system recovers some of this lost light and has a higher overall efficiency making it very suitable for larger screens.

Screen implications for 3D systems

Polarised light systems require a screen that will maintain the polarisation of the light when it is reflected. So-called silver screens are used for this purpose. In fact, these screens are coated with a special paint containing fine aluminium flakes. The usual white cinema screens are not suitable, as they diffuse the light and change the polarisation. The signal-to-noise (or extinction) ratio measures the amount of interference between the right eye and left eye images. Typically at least 120:1 extinction ratio on axis is required to maintain a good 3D image. The 3D image has a "ghost image" if the left eye

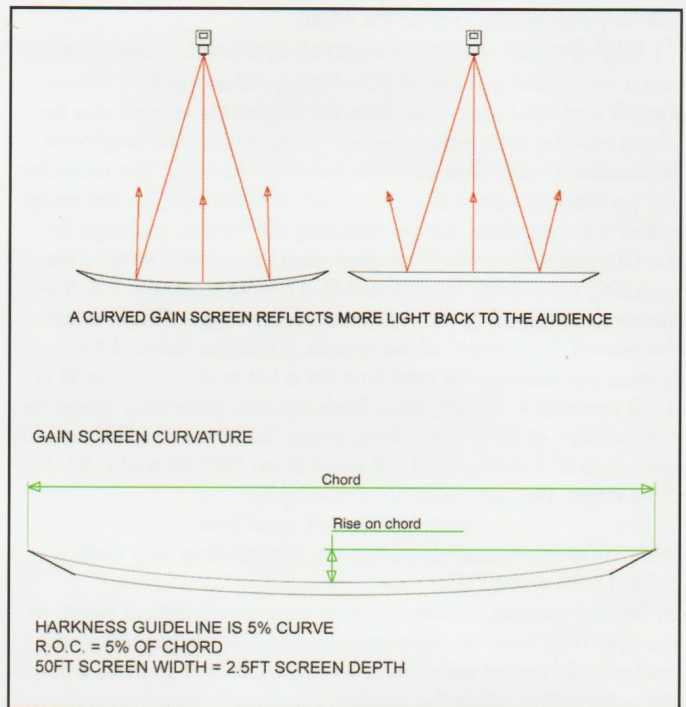
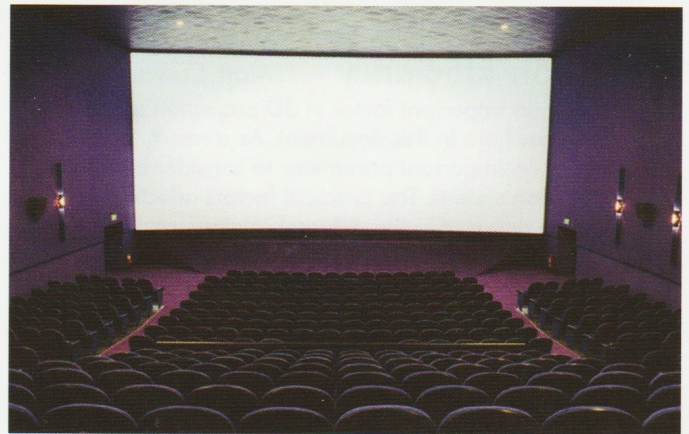


image is partially received by the right eye.

The other 3D technologies use white screens but because of the huge light loss, screens with a high degree of "gain" are required for all screens except small sizes. Silver screens inherently have a high gain level (typically 2.4) so polarised light systems benefit from the intrinsic gain of the silver screen. The implication of this is that, in most theatres, it will be necessary to change the screen when installing any 3D system using a single projector. This will always have to be done with the polarised light system, but often it will need to be done with other systems to achieve adequate brightness levels.

Harkness Screens has introduced a 2.2 gain screen specifically for 3D systems that do not use polarised light but which will benefit from a higher gain level.

Implications for 2D viewing

As theatres are not usually dedicated to run 3D movies all the time, 2D movies will be run in the same theatre and on the same screen. Regardless of the system being used, the main implication is that the screen will have a higher brightness level than is needed for 2D. This means that the projector light output has to be reduced by decreasing the current or by changing the lamp. RealD's XL system, because of its higher efficiency, does not usually require this adjustment.

Provider	Technology	Light efficiency (1)	Screen type	Eyewear	Max screen size (2)
REAL D	Polarised light and Z screen	15% XL 27%	Silver 2.4 gain	Passive	45ft, >60ft with XL
DOLBY	Wave triplets and filter wheel	12%	White 1.8/2.2 gain, except for small screens	Passive	40ft with high gain screens; <30ft with matt white screens
XPAND	Synchronised projector and eyewear shutters	18%	White; gain on bigger screens	Active	50ft with high gain screens
MASTER IMAGE	Polarised light, rotating polarising wheel	15%	Silver 2.4 gain	Passive	45ft

(1) Light measured through eyewear compared with projection in 2D mode on same screen gain.

(2) To achieve a minimum of 4.5 ft. lamberts in 3D mode.

Implications for theatre selection

Because of the high gain level, the viewing angle on the screen is narrower and, as a result, the seats in the more extreme regions at the front of the theatre may see some variation in brightness. It is therefore recommended, when deciding in which theatre to install a 3D system, to choose auditoria that have a relatively long "throw" in relation to the screen width because this minimises the consequences of the viewing angle effect of high gain screens. Theatres that have relatively short focal length lenses for 2D will contain more poor seats than longer throw theatres. Seats that are outside a viewing cone of 25-30° off screen axis are likely to suffer a poorer viewing experience.

Screen size and shape

Screens for 3D viewing should be curved as this improves the

light distribution. The recommended curve is 1:20 (depth / width). The diagram illustrates how a curved screen reflects more light back to the audience.

Light levels

With a 6kw lamp in a digital projector and a screen gain of 1.8 or more, it is possible to operate 3D on screens up to 45-50 ft with acceptable light levels. Whereas for 2D viewing 14ft lamberts is recognised as the norm for digital projection, for 3D it is expected only to achieve 4.5ft-lamberts, and films are colour graded accordingly. RealD's XL version can be used for screens over 60ft.

Andrew Robinson

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7. 3D - The Exhibitor's Perspective



Frank de Neeve
Technical Manager
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The Netherlands and Editor of
Cineserver.nl a Dutch website on
digital cinema.

New opportunities, new choices
3D movies introduced the exhibitor to new equipment, with new choices to be made. On which grounds does he make his decisions and

which areas leave room for improvement?

'The ideal 3D projection system would not require any 3D glasses, but I don't think that can ever be satisfactorily realised. More realistically, the ideal system would not require a silver screen and would feature active glasses, but with the weight of disposable glasses. Customers would bring along their own 3D glasses, that would also be sold in the cinema and that could be used for 3D TVs at home as well.'

It's always nice to dream, as this exhibitor does, but unfortunately the ideal 3D system doesn't exist. The systems presently on the market, be it polarisation, spectral division or active glasses, all have their advantages and drawbacks. Some require a silver screen to be installed, others have low light efficiency, while others still require expensive 3D glasses, that need to be collected and sanitized after each screening.

Digital 3D projection systems have been on the market for a couple of years now, but it is generally agreed that Avatar served as a watershed moment in the current revival, or rebirth, of 3D. Most exhibitors that were not convinced about the (financial) merits of digital 3D before are convinced now, although they don't think that the current hype will last. Upon re-evaluating their initial point of view some are now considering (further) investments in 3D. But on what grounds do they base their decisions? Are there things that can be improved in the current 3D systems? And what importance do exhibitors attach to the different issues surrounding 3D?

There are a couple of issues that generally pop up when 3D projection systems are being discussed: quality, cost and flexibility - although most of the time it boils down to the choice between cheap or expensive glasses and whether a system requires a silver screen or not. Some would even argue that quality is the first issue that is disregarded and that cost is the prevailing, if not only, argument for the exhibitor. There are however many different types of cinemas, that operate in different ways. For instance the issue of glasses that need to be collected after a show, will be judged differently in small cinemas than in big multiplexes.

Another issue that is at the heart of the 3D discussion, although more or less indifferent to which projection system is used, is that of the 3D surcharge that cinema audiences pay to see a 3D show. Part of it was intended to cover the investment of the exhibitor, but distributors also demand their share of the specific glasses fee.

Putting the fun back into cinema

To find out what is important to exhibitors in the 3D discussion and which issues they feel should be improved, we spoke to four European exhibitors, running cinemas ranging from large multiplexes to smaller complexes. All of them had recently reconsidered their initial investment and were therefore well informed about the current 3D systems and the choices that need to be made.

Nico Simon is the chairman of the Utopia Group, with cinemas in Belgium, France, Luxembourg and The Netherlands. The Utopia Group started showing 3D films three years ago, but to Nico Simon's amazement audiences are only just starting to notice. "At the release of Avatar, people congratulated us for now also showing 3D films. It made me realize that marketing finally got home to people," Simon says.

Nico Vertommen is senior manager Operations with Pathé, the market leader in The Netherlands and part of the large European Europolaces group. According to him the 'extra dimension' of 3D is of commercial interest to exhibitors. "I expect it'll take another five years before the same quality of 3D as we have in the cinema now is reached for home cinema," he says.

In 2008 **Cynthia Marras** bought Cinemajestic, a 4-plex in Deventer, in the east of The Netherlands. After a careful start in February 2009 Marras gained confidence in 3D. "We initially leased a 3D projection system, but after the recent success of 3D films we bought the system at the beginning of 2010."

The young entrepreneur **Philip Cleynens** runs a family owned 2 screen cinema in a small town in Flanders, that went digital just before the release of Avatar. "The arrival of 3D has put the fun back into cinema going," he says. "The success of Alice in Wonderland proved to us that Avatar was not a one off hit and that 3D increased our market share."

A fair share

Although there has been much talk about the different 3D projection systems, the main 3D discussion in the past year focused on the surcharge that exhibitors charge the audience to pay for their equipment. Distributors demand their share, as they argue that they make extra costs as well, because 3D films are more expensive to make than regular movies. Although some exhibitors argue that a fair share for the distributors is reasonable, in 2009 the issue became so large that some cinemas decided not to screen certain films in 3D, as they made more money showing the film in regular 2D. In France, exhibitors and distributors seem to have reached an agreement via the official 'ombudsman' (médiateur du cinéma), but in most countries issues surrounding the surcharge are an ongoing concern.

Naturally, large exhibitors can negotiate good conditions; smaller exhibitors can only take it as it comes. Cinema Albert, located in the poorest municipality of Flanders charges €1.50 extra for a 3D screening. "People never complain about having to pay extra for 3D screenings," says Philip Cleynens, "but maybe that's also because they know that our main competitor charges considerably more." Distributors also take the

agreed film rental percentage over the surcharge, leaving Cinema Albert about € 0.30 extra for each ticket.

According to Cynthia Marras of Cinemajestic, distributors should take note of the different deals that exhibitors have. When Marras leased her equipment, she even had to pay film rental over the rental charge of the 3D projection system, which she considers to be unfair. As a result of all this, some exhibitors started selling the glasses instead of charging a surcharge, arguing that if they sell a physical product the distributors cannot take a share. "We should agree that a fair share is reasonable," says Nico Simon. "Now some are choosing polarized systems purely for economic reasons, because then they can sell the glasses." However, selling the glasses also has its up points. Some chains, like Pathé are talking to manufacturers that specialize in novelty 3D glasses, that can be sold to movie fans at the box office.

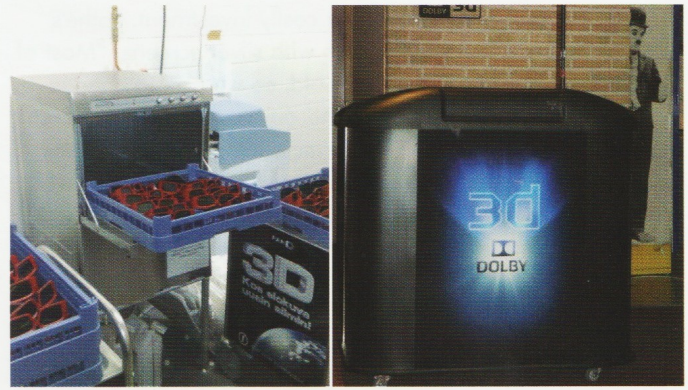


Glasses Galore

With the emergence of digital 3D, many exhibitors started off using XpanD, the system with active glasses. It has the advantage of combining low initial costs, no need for a special screen and flexibility, as the system can be moved easily between digital screens. Come the success of Avatar, many are now re-evaluating their initial decision. "Although the visual quality of XpanD is the best, the handling of the glasses is a concern, as they need to be collected and sanitized," says Nico Simon of the Utopia Group. The group is now testing a system that uses disposable glasses.

Pathé in The Netherlands took a similar approach. The company initially tried several systems in different cinemas and found that they lost many active glasses because of theft. "XpanD glasses are attractive to our customers," Nico Vertommen says with a sense of understatement. Pathé finally decided for the RealD system. "From an operational point of view, we favour disposable glasses," Vertommen says.

Smaller cinemas have different needs. Cynthia Marras of Cinemajestic says that they can handle collecting the glasses in her 4-plex, so they decided to buy the system that they initially leased. "We started off with 20 minutes between each screening, but that was a bit too tight for sanitation. We now



Cinemas using re-usable glasses need to make arrangements for collecting, washing and for battery replacement

know the routine, but on a busy day it takes about 4 hours to clean the glasses." A little known fact is that all this sanitizing can damage the glasses. Most exhibitors mention scratches on the glass and rubber finishing coming off because of frequent cleaning. Philip Cleynens of Cinema Albert in Belgium was fine with collecting and sanitizing glasses, but had another problem. "Almost every show someone would walk out of the screening, as the glasses didn't work because of empty batteries," he says. "However, sometimes we would only find out about this after the show, as people are too timid to complain." Cleynens, who has now recently opted for the Dolby system, is really satisfied with the new passive glasses system. "Although we get less light on the screen, the glasses are lighter and the image is easier on the eyes."

Vulnerable Silver Screens

It is well known that low light levels are the number one concern for 3D projection. Some exhibitors can install a higher performance lamp in their projector, but most can't. Therefore even with systems that claim to be able to use the standard projection screen, the exhibitor sometimes has to install a special 'high gain' screen, that reflects more light. 3D projection systems that work with polarised light, need a silver screen to maintain polarization. Over the last few years progress has been made to reduce the negative side effects



'Please do not touch - this movie screen is fragile', says the on-screen caption in this Dutch cinema. There is a small barrier in front of the screen to prevent people touching it.

of these screens, but it remains a costly investment. Pathé's Nico Vertommen has no problem with silver screens. "Most of our cinemas are about ten years old, so we had to change the screens anyway," he says. "And our customers never complain about silver screens." However, silver screens are very vulnerable and one Pathé screen already had to be renewed after 6 months, due to marks left by people touching the screen – a down point of modern wall to wall and ceiling to floor projection. Some cinemas have now taken precautions and had physical means installed to prevent people from touching the screen.

But not all exhibitors are indifferent to silver screens. "Silver screen systems were never an option for us," says Philip Cleynens. "We gained so much quality when going digital; to now take a step back with a silver screen is unacceptable for me."

Dummy guide

As said before, the ideal 3D system does not yet exist, but which improvements could be made by the manufacturers? Naturally they should produce more light, but according to Nico Simon the current systems are also too expensive. "Most digital 3D systems are improvements of older 3D systems. The manufacturers didn't invent anything new, only made improvements," he says.

Simon also mentions that 3D glasses should be made more comfortable to wear for people already wearing regular glasses, to which Cynthia Marras adds that special children's

glasses are needed. She also thinks that manufacturers should not only sell the equipment, but should take more care in providing marketing materials, and give guidance as to where exhibitors can obtain specialized washing machines. "And why do they only include a technical guide of the system," she says. "That thing is so large that I never even opened it. Manufacturers should include a Dummy Guide as well," she says with a smile.

But it's all about the movies

But in the end it's all about the films. The most frequently heard complaint from exhibitors is that all 3D films should feature excellent 3D effects. They feel that the studios should not convert movies to 3D until they are indistinguishable from films that are 'native 3D'. And while the studios are planning to convert more films to 3D, some exhibitors are already considering not to book these films.

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Thanks to Benny IJntema of Luxor Theater Hoogeveen for the XpanD system photos and to Sander Verdonk of CineCity Vlissingen for the movie screen picture.



The advertisement features a pair of white Polaroid 3D glasses in the foreground. The left lens shows a city skyline, and the right lens shows a person in a dark hoodie and jeans falling through the air, with a small airplane flying above them. The background is a dark, stylized cityscape. In the top right corner, there is a blue banner with the text "real D CERTIFIED". At the bottom, the text "PERFECT 3D VISION." is displayed in large, bold letters, with the Polaroid logo and "Premium 3D Glasses" to the right. Below the main text, the website "polaroidewear.com/3D" is visible. A small circular logo with "3D" is also present.

PERFECT 3D VISION.
polaroidewear.com/3D

Polaroid
Premium 3D Glasses

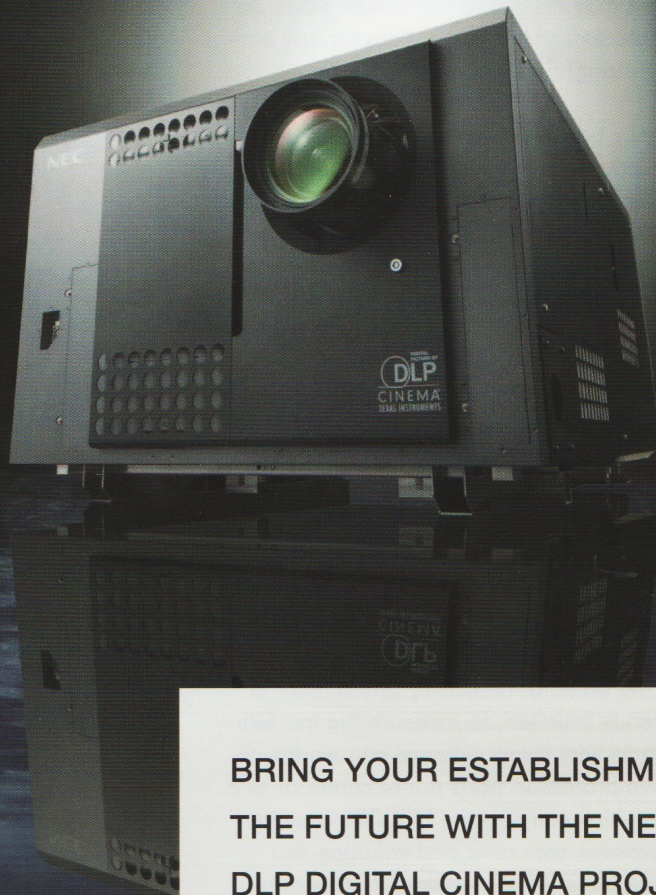
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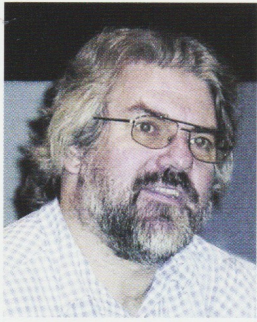
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8. 3D Brightness Measurements



Peter Wilson
HDDC

There are several 3D projection technologies on the market using a range of techniques; the different techniques have differing efficiencies and may need different screen types. As you might expect the selection of the best system for any particular cinema is not as straightforward as it might seem.

Existing cinemas normally have white screens with a reasonable reflectivity. White screens can be used with several of the technologies but the low reflectivity means that it can be difficult to get useful screen brightness but on the plus side they are colour neutral and due to the low reflectivity it is easy to get a well rounded and uniform screen illumination. The polarised systems must use a silver screen to preserve the polarisation of the left and right eye channels, an added bonus of the silver screens is that the screens have a better reflectivity than a regular screen and can support higher brightness or lower running costs. There is of course a snag, the silver screens add a different 'feel' to the picture and the higher reflectivity is more directional. This directionality makes them unsuited to all venues and can give less than optimal results in some seats.

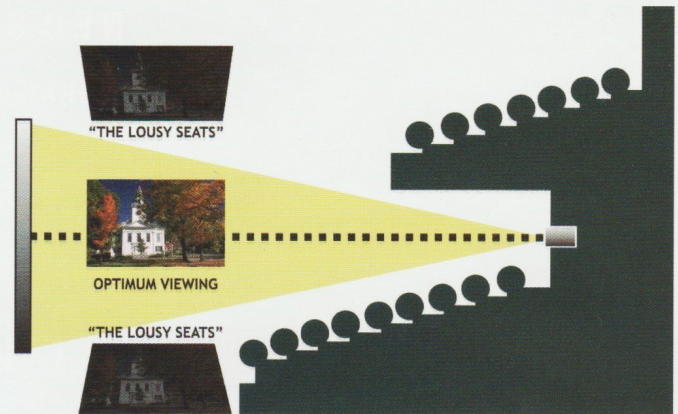
When surveying any cinema and choosing a system it is important to measure the angle of reflectivity and if there is a projector already installed, to measure the incident angle to the screen. While very many cinemas can work with silver screens some have projection ports out of centre or at a steep downward angle which can cause a big difference in perceived brightness between seat rows and columns. For measurements to be meaningful it's important that there is consistency between measurers. This means that there needs to be a standardised process or at least a recommended practise which system integrators or exhibitors can follow.

Below is an extract from a submission to the ISDCF by Kevin Wines who has carried out many tests in many cinemas. It is by no means accepted by all but is an example of a realistic method. The Inter Society Digital Cinema Forum has a small group looking at this process.

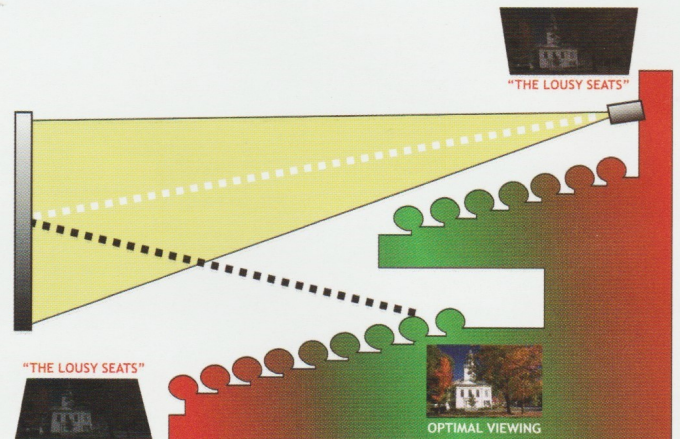
Wines Method

"You have to know the incident angle of the light hitting the centre of the illuminated spot, and the angle at which you are measuring to know if your reading is accurate. And you need the 1/2-gain angle of the screen - either from the manufacturer, or determine it by measurement.

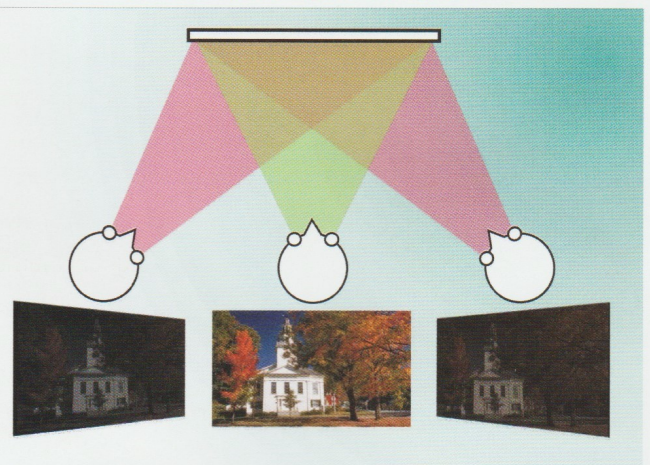
Gain, by definition is the tendency of the object to reflect light back to the source, not reflect like a mirror.



The best seat in the house is in the projection box...



Changing the projector to screen angle can favour different parts of the auditorium



Curving the screen may help to widen the useful seating area (see section 6)

All your work has to be "centred" on the centre projection line, so if the projector is not on centre line of the theatre, you have to work from the centre of projection, not centre of the theatre. Even with lens shift, if the projector is not centred, the hot spot is not actually on the centre of the screen, but on centre to the angular line from the lens to the screen.

From this centre point, you lay out lines at 10 degree increments.

It is actually easier than it sounds. Typically you don't need to go out more than 30 degrees. I will usually go to 20, 25, 30, & 35 degrees to help me hone in on the point I am looking for.

Measure the centre dot from each point. When the light falls to 1/2 the original measurement, you are now in the "lousy" seats.

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If the projector is actually on centre, you only need to do this in one direction, if it is off-centre, you have to go both left & right to find the edge of the 1/2-gain angle. It will surprise you how many seats are outside this area in a modern theatre.

This works on any gain screen (silver or white), whether or not you are looking through polarizing filters, and is remarkably accurate. It makes theatre seating layouts fairly straightforward to design.

As for the inconsistency of the 3D glasses and filters, they are irrelevant to this part of the testing because all measurements are relative, not absolute.

What to do about the filters? Well, mathematically we already know what to expect (in polarized systems anyway). The reason we are all stuck at 3.5 FtL is because of the known behaviour of polarizing filters. By the time the light hits one of our eyes, we have about 1/2 of 1/2 of the original light exiting the projector (the RealD XL panel excepted, of course). So I generally start at 14 FtL unfiltered and measured on the centre line described above. Put the filters in place and measure again. If I am at or near 3.5 FtL, I am good. Sometimes I have to go through a few pairs of glasses to find one "centred" at the right passivity. I then use this set to calibrate for light level and chromaticity.

Since you have no control over the variances of all the pairs of glasses, you need to find a sort of "reference" set that you consistently use for the measurements. All of the polarized filters skew a little purple, so you really do need to use them to set the colours/white point.

This has worked for me in theatres as small as the Clarity room and as large as the Nokia Theatre in LA. Often compared against the CAD drawings to confirm the angles used for measurement.

Now, if you are unsure of the screen gain, there is a consistent way to determine that as well (this is fun). Believe it or not, the little "brightness" rating on a ream of Xerox paper is actually a gain rating. 92 means 0.92 gain. And they are quite consistent. So I will tape a few sheets to a poster board and carefully place it at the screen.

Sample (simple) math:

For ease, I will work to 10 FtL. If I measure 9.2 FtL on the paper, $9.2 / 0.92 = 10$. That is what I would get on a matte screen. Now, I will measure the screen. If I measure 14 FtL, the gain is 1.4."

Gobbledygook or good sense?

The vertical aspect is also very important especially in older theatres which may still have balconies. You don't want the best place to sit to be under the seat in the 3rd row!

So, as mentioned above, a small group in the ISDCF is looking at this issue and will draft a method which is acceptable to most parties.

Formal standardisation of a method is a big task but agreement between organisations such as the EDCF and the ISDCF should bring us an acceptable method. Apart from pre-checking cinemas to decide which system works best a good understanding of the light levels in different parts of the auditorium may also enable the exhibitor to charge a premium for the measurably best seats.

Peter Wilson
HDDC

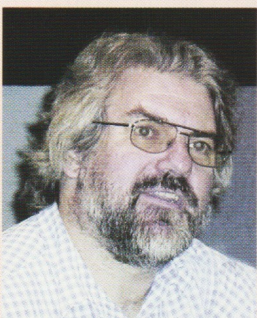
email: Peter.Wilson@hddc.co.uk

Many thanks to Kevin Wines, Director, Image Technology at THX, for his assistance with this article.

A useful article for further information is *The Effective Gain of a Projection Screen in an Auditorium* by Martin Richards and Dave Schnuelle, which appeared in the SMPTE Journal October 2010. Details from

http://store.smpete.org/product-p/journal_10-2010.htm

9. EDCF Guide to 3D Digital Exhibition - Where we are - Summary



Peter Wilson

3D Movies have now become commonplace and in fact have driven the change to digital in the last year. (2009/2010) Many screens all over the world were installed for Avatar. There are now several 3D technologies for exhibition, even for film in the interim, and each has its place and I hope this guide has made the readers understanding clearer and enabled the reader to know what to expect from the various systems when he or she makes their choice.

Brightness and silver screens are also important issues. On brightness I have seen specially mastered Disney Cars clips mastered and projected at 2D brightness; all I can say is its breathtakingly good and I can foresee competition in the future as there is no official 3D brightness setting for projection. The

Avatar premiere in London used four projectors to get the director's brightness on the big screen.

Silver screens will be a discussion topic for many years to come. Offering higher efficiency and thus lower operating costs, but not fitting in with the wishes of some directors or some auditoriums due to projector positioning.

Live 3D will be an interesting challenge for a while to come due to issues such as interlace or progressive scan, resolution, frame rate, physical connections, and transmission formats. I hope this guide is useful to all who read it.

Thanks to all the companies and authors who have contributed to this guide, which provides both 'state of the art' information and fascinating glimpses into the future.

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10. EDCF Glossary of Digital Cinema Terms



Angelo D'Alessio,
Cine Design Group



The Beautiful Chaos of Digital Cinema terminology. The use of digital technology and digital processes through the "film" chain is modifying the workflow and changing the terminology used by professionals. After a century of celluloid, the whole business model and the Art of "film" features is now changing.

Digital projection has already shown the benefits of digital techniques and the whole digital film business is moving forward. To understand the potential of digital cinema, this glossary includes terminology about the Mastering, Distribution and Exhibition of D-Cinema supply chain.

Digital cinema can offer viable benefits if everyone involved in the supply chain understands and has a basic knowledge of both sections.

The key purpose of this EDCF Glossary is to facilitate and help new professionals entering into the "Beautiful Chaos" of digital Cinema!

EDCF DIGITAL CINEMA GLOSSARY

2D+Delta

A single image along with data that represents the difference between that image view and a second eye image view along with other additional metadata. The delta data could be spatial temporal 2D. (Two dimensional. An image or object with only two dimensions, such as width and height, but no depth, stereo disparity, temporal predictive or bidirectional motion compensation).

2D signal processing

A signal processing chain where 2D and 3D signals receive the same processing steps and the processor does not need to know what type of signal is being processed.

3D

Having or appearing to have width, height, and depth (three-dimensional).

3D (stereo)

In television, film or cinema, 3D may refer to material that is shot using a set of 'stereo' cameras and shown on the screen as a pair of superimposed stereo images (usually 'decoded' by the viewer with polarized spectacles). Also known as stereo 3D and stereoscopic 3D.

Accommodation

The focusing of the eyes -- or more properly the ability of the eyes' lenses to change shape in order to focus.

Accommodation/Vergence Relationship

The learned relationship established through early experience between the focusing of the eyes and verging of the eyes when looking at a particular object point in the visual world. Usually called the accommodation/convergence relationship (or the convergence/accommodation relationship.)

Active glasses

Powered shutter glasses that function by alternately allowing each eye to see the left-eye/right-eye images in an eye sequential 3D system. Most commonly based on liquid crystal devices.

Active picture

The area of video frame which carries image information.

Active stereo

See eye sequential 3D.

Adaptive white

A color that an observer, adapted to a set of viewing conditions, would judge to be white.

Alternative Content

Content available through a digital cinema system that would typically occur on a "one-off" basis or "off-peak hours" run basis. Sometimes referred as "non-traditional content".

Alternative Content Fee (ACF)

This is a fee that is paid when alternative content is played.

Amblyopia

"Lazy eye". A visual defect that affects approximately 2 or 3 out of every 100 children in the United States. Amblyopia involves lowered visual acuity (clarity) and/or poor muscle control in one eye. The result is often a loss of stereoscopic vision and binocular depth perception.

Anaglyph (Stereoscopic)

A type of stereoscopy in which the left eye and right eye images are separated by color filtering and then superimposed as a single image rather than two separate images. Each eye sees only the required image through the use of complementary colored filters (e.g. red and green or red and cyan). Anaglyph glasses have been popular over the years for viewing 3D comics and some 3D films (particularly on VHS and DVD).

Asset

Audio and video material complete with rights of ownership or for publication. Material without rights has no commercial value. The following figure represents the Media Asset and its components.

Artefact

Particular visible effects which are a direct result of some technical limitation.

Binocular

Two eyes. The term binocular stereopsis (two-eyed solid seeing) is used in some psychology books for the depth sense more simply described as stereopsis.

Bit Depth

The total number of bits available to represent each pixel or color sample in a digital imaging system, or the bits available to represent each sample in a digital audio system. Using linear binary coding, the total number of resolution steps available is equal to 2 raised to the power of the bit depth.

Breaking the frame (Stereoscopic)

Stereo objects in front of the screen plane (negative parallax) are problematic if they intersect the edge of frame, as contradictory depth cues are sent to the viewer. Essentially one cue is saying that the object is in front of the screen and another is saying that the object is behind it. This problem can be reduced in post production by a technique known as a 'floating window'. This involves applying a partially transparent mask, reducing the strength of the cues on whichever side the object is breaking frame (and simultaneously if there are objects breaking frame both left and right).

Another kind of issue is caused by objects moving backwards and forwards over the edge of frame. As an object moves off the edge of a screen one stereo camera signal is lost before the other. The result is that the stereo signal temporarily 'switches off'. This can sometimes be solved by sizing up both images in post, causing the object to move off screen altogether.

Brightness

The property of a surface emitting or reflecting light. In lighting, it is our impression of the amount of light received from a surface. It is measured in candelas per square metre and is called luminosity in the USA.

Cataloguing

Adding meaningful metadata to a stored asset to ensure that it will be easy to find in future with any relevant searches. This involves adding cross-references as the asset may be important to a number of separate subjects and generally creating the metadata needed to allow maximum use of the asset.

Calibration

The process by which a device or system is brought into the condition whereby a defined input produces a defined output.

Cardboarding (Stereoscopic)

Lack of true 3D feel to a shot making it look like it is made from cardboard cutouts. This is also referred to as Cutout Planar Effect. Caused by inadequate depth resolution due to an incorrect matching between the focal length of the recording lens (or CGI camera) and the interocular distance between the cameras.

See also: Interocular

Central Storage

A central location where the packaged Digital Cinema content is stored for a multiple screen installation.

Checkerboard contrast

The intra-frame contrast in which the black and white patches in an image are arranged in alternating pattern. In this case, the white luminance is measured as the sum of the white luminance of each white patch and the black luminance is measured as the sum of the black luminance of each black patch as long as the number of white and black patches is the same.

Chromaticity

The color aspect of light which includes hue and saturation, but not brightness.

Chromaticity diagram

A plot of the x and y chromaticity coordinates in which the x coordinate is plotted on the abscissa and the y coordinate is plotted on the ordinate. There is a similar u', v' chromaticity diagram, but it is not used in this guideline.

Chrominance

The part of the video signal which conveys color hue and saturation information as distinct from luminance. Also called chroma.

CIE

Commission Internationale de l'Eclairage, an international organization responsible for photometry and colorimetry.

CIE Standard Colorimetric Observer

An observer with spectral sensitivities that exactly match the CIE 1931 color matching functions.

CIE tristimulus values

The X, Y, and Z values determined by the data and equations defined in 1931 by the CIE for the Standard Colorimetric Observer.

CineLink™2

The technology that encrypts the link between the media player and the projector. This technology supports the DCI specifications for strong link encryption.

Circular Polarization

A form of polarized light in which the tip of the electric vector of the light ray moves through a corkscrew in space.

Colour appearance

What a colour looks like to an observer. Colour appearance depends in many factors including absolute luminance, surround luminance, adaptation of the observer, etc. Colour appearance differs from colour measurements in that the same measured colour will change its appearance as the environment in which the colour is observed changes.

Colour decoding

The definition of a relationship between colour information and numbers. Decoding is the conversion of the numbers, also called code values, into colour information.

Colour encoding

The definition of a relationship between color information and numbers. Encoding is the conversion of the colour information into the numbers, also called the code values.

Colour gamut

The range of colors allowed in a specific system, as defined within a triangular area located on the CIE color locus diagram whose corners are the three primaries of the system. The limits of the colours that can be displayed by a system. Also the limits of the colours that belong to a set of colours that are mathematically defined.

Composition

A motion picture, trailer, advertisement, etc. Composition consist of Metadata Composition Play List along with the Essence and other Metadata track files that define the work.

Convergence

The inward rotation of the eyes, in the horizontal direction, producing **fusion**. The more general term is vergence which includes inward and outward rotation. The term has also been used, confusingly, to describe the movement of left and right image fields or the rotation (toe-in) of camera heads.

Corresponding Points

The image points of the left and right fields referring to the same point on the object. The distance between the corresponding points on the projection screen is defined as parallax. Also known as **conjugate** or **homologous points**.

CPL – Composition Playlist

A Composition Playlist consists of all of the essence and metadata required for a single presentation of a feature, trailer, advertisement, or logo. A single CPL contains all of the information on how the files are to be played, at the time of a presentation. There is a separate CPL for each version of a motion picture/feature (composition).

Crosstalk. Incomplete isolation of the left and right image channels so that one leaks (leakage) or bleeds into the other. Looks like a double exposure. Crosstalk is a physical entity and can be objectively measured, whereas **ghosting** is a subjective term.

Cryptosystem

The entirety of methods and equipment used to protect content by cryptographic means, including scrambling and encryption, conditional access, key management, physical security of equipment (but not premises), and watermarking. It may also refer to all associated plaintexts and ciphertexts.

D-Cinema

A contraction of digital cinema. In the classic model the entire production chain from scene to screen is a digital process, with images first captured and processed digitally before then being compressed, encrypted and transmitted via satellite, broadband or disc to cinema theater for digital projection.

DCDM - Digital Cinema Distribution Master

A master set of files that have not been compressed, encrypted, or packaged for Digital Cinema distribution. The DCDM contains all of the elements required to provide a Digital Cinema presentation.

DCP - Digital Cinema Package. The set of files that are the result of the encoding, encryption and packaging process.

Definition

A description of sharpness or clarity of a picture. High definition pictures portray a lot of detail, while low definition pictures look soft and less clear. See also resolution.

Depth grading (Stereoscopic)

A post production process where negative and positive parallax convergence are adjusted.

This is not only a creative tool used to place objects on the Z axis but also a way to ensure that stereoscopic content can be comfortably watched on the screen size it is intended for. For example, in a post suite the director may be viewing a film on a small projection screen but the final delivery format may be a large theatre or IMAX.

In practice the eyes have little ability to diverge (up to one degree is considered the rule of thumb) and this is especially a consideration in depth grading for very large screens with positive parallax images, where the distance between the left and right representations of an image may be very widely spaced.

Sometimes the term Depth Budget is used to refer to the combined value of positive and negative parallax and expressed as a percentage of screen width.

Depth Range

A term that applies to stereoscopic images created with cameras. The limits are defined as the range of distances in camera space from the background point producing maximum acceptable positive parallax to the foreground point producing maximum acceptable negative parallax.

Digital image

An image defined by code values.

Digital Cinema Projector

A Digital Cinema Projector is one that conforms to the DCI specifications and SMPTE standards. The available options in the marketplace today are those equipped with Texas Instrument's DLP Cinema® chip or Sony's SXRD® technology.

Diplopia

'Double vision'. In stereo viewing, a condition where the left and right homologues in a stereogram remain separate instead of being fused into a single image.

Disparity

The distance between conjugate points on overlaid retinæ, sometimes called **retinal disparity**. The corresponding term for the display screen is **parallax**.

Distribution Package

The collection of files delivered by the distributor to the exhibitor. A distribution package may contain pieces of a composition, a complete composition, replacement/update files, etc.

DSM – Digital Source Master

The Digital Source Master is created in Post-Production and can be used to convert into a DCDM (Digital Cinema Distribution Master). The DSM can also be used to convert to a film duplication master, a home video master, and/or a master for archival purposes.

DPX

SMPTE file format for digital film images (extension .dpx) – ANSI/SMPTE 268M-1994. This uses the same raster formats as Cineon and only differs in its file header.

Encode (Compression)

In order for the digital cinema file to be a manageable size, it is compressed. A typical uncompressed feature can be approximately 2 Terabytes (TB) in size. After the compression process, those files may range between 150-250 Gigabytes (GB). This size file, while still large, is more easily delivered.

Encryption

Encryption can be considered as putting a lock on the content. The content is transformed by applying the encryption algorithm in conjunction with the encryption key. During the encoding process files must be encrypted to allow for secure transport of feature content. DCI adopted the AES (Advanced Encryption Standard) 128 bit encryption. AES 128 is the standard approved for U.S. government information classified to the SECRET level. Encryption is thus Hollywood's primary concern (fear) when it comes to digital cinema.

End-to-end Security

The consistent application of security measures across an entire process or system (the cryptosystem) such that the most vulnerable elements are sufficiently strong to maintain the desired level of security overall.

Essence

That part of the program data representing the image, audio or text that is directly presented to the audience.

Event Play List

A play list of compositions, describing an assembly of compositions in sequence. An event play list is typically created by content distributor and transferred to exhibition.

Expert viewing test

An assessment session based on the opinions of expert assessors, in which judgements are provided on visual quality and/or impairment visibility.

File

A structured collection of data characterized by a metadata header and a single body of data payload.

Frame rate

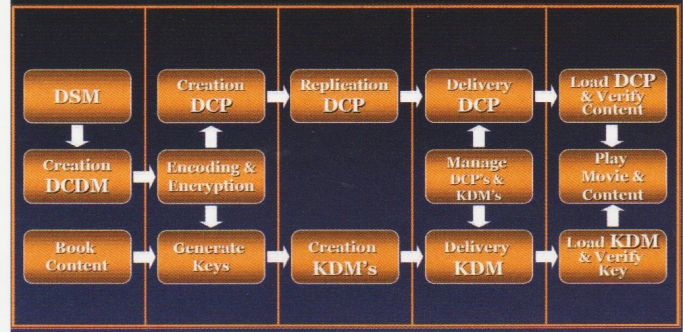
The number of pictures presented or recorded each second. It is measured in frames per second.

Fusion

The combination, by the mind, of the left and right images -- seen by the left and right eyes - into a single image.

Gamut mapping

A process by which one color, which a device cannot produce, is replaced by another color, which the device can produce.

Digital Cinema Workflow**Ghosting**

The perception of crosstalk is called ghosting.

Gigantism (Stereoscopic)

Confusing visual cues in a stereoscopic scene that can make an object appear to be the 'wrong' size, i.e. the impression of strangely enlarged size of objects. This is due to the choice of interocular distance relative to the focal length of the camera lenses, e.g. shooting with an interocular distance much less than that of adult human eyes can make a figure appear to be a giant.

Gray scale

The series of achromatic colors from the lowest luminance to the highest luminance.

HVDT

Human Vision Delta Luminance Threshold. This is the minimum change in luminance that a group of people can correctly identify 50% of the time. See also HVMT from which this is derived.

HVMT

Human Visual Modulation Threshold. This is the minimum modulation that a group of people can correctly identify 50% of the time.

Hyperstereo (Stereoscopic)

Using widely spaced cameras (e.g. beyond 70mm interocular) which record more stereo effect than the eyes can see. Such a large interocular distance can produce the effect of miniaturization. Also used in order to achieve the effect of more stereo depth and less scale in a scene.

For stereo effects on very long shots (e.g. landscapes) interocular camera set ups of several meters have been used (hyperstereo). One extreme example of hyperstereo is from cameras on each side of the earth to record the sun in 3D.

Hypostereo (Stereoscopic)

Using closely spaced cameras (e.g. less than 50 mm interocular) which record less stereo effect than the eyes can see. Such a small interocular distance can produce the effect of gigantism. If standard cameras are used, the minimum interocular distance is typically limited by the thickness of the cameras so a mirror or beam splitter system is often used, enabling interoculars down to millimeters.

Image State Diagram

A diagram showing the various states in which an encoded image can exist. There are three states, the Scene Referred State, the Output Referred State, and the Input Referred State. An image can be transformed between any two states.

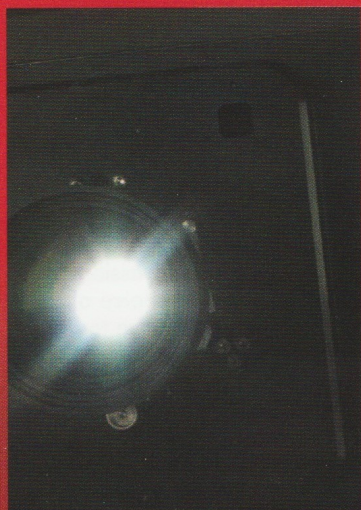
Integration

Making one system, application or set of data work very closely with others. Ideally, the distinctions and boundaries and barriers between the separate parts should disappear as the integrated system or information works seamlessly - as one. This is a very 'deep' form of interfacing and goes a great deal further than simply interchanging information with a third party. The use of industry-wide standards is essential if extensive integration is to be achieved.

Interface

A means of passing on information from one application to another. Interfaces can either be proprietary, in which case only one or a chosen few applications can use it, or open

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with the interface details publicly available and, best of all, complying with the appropriate international standards.

Interocular distance (Stereoscopic)

The distance between the centers of the lenses of two recording cameras. A typical distance would be 63.5 mm (approximating average adult eye spacing).

The term 'interaxial' is sometimes also used interchangeably with 'interocular' (when referring to eyesight, 'interpupillary' is often used).

Interoperability

The ability of systems to interoperate – to understand and work with information passed from one to another. Applied to television this means video, audio and metadata from one system can be used directly by another. Digital signals may be originated in various formats and subjected to different types of compression so care is needed to maintain interoperability.

Intra-frame contrast

The ratio of the luminance of the white divided by the luminance of the black, normalized to a denominator of 1, when the white and black that are measured are projected onto the screen in the same image. This is usually expressed as number:1, for example 2000:1. See also checkerboard contrast.

ISDCF Voluntary Naming Convention

The most significant information about the DCP is contained in the first 40 characters of the CPL text fields due to limited display space of certain DC servers. Additional information is included for servers that can display more than 40 characters.

JPEG 2000

A wavelet-based image compression standard. It was created by the Joint Photographic Expert Group (JPEG) committee with the intention of superseding their original discrete cosine transform-based JPEG standard. It is the compression method specified by DCI for digital cinema picturetracks.

KDM – Key Delivery Message

The KDM provides the method for securely delivering content and key elements. A KDM contains the 'keys' to unlock the elements of a CPL for a specific device. If a DCP contains multiple CPLs, a unique KDM is required for each different CPL, and can only be generated for devices on the Trusted Device List (TDL).

Legacy

Something that is influenced by or a part of the past. As much as new applications and technologies spring up, most times even these bright new ideas are steeped in legacy - they are not a clean break from the past.

Library Management Server® (LMS)

A group of servers and networking components that are integrated and tested to create a powerful central hub for all communication needs in the multiplex. It allows central storage of all movies, alternative content, trailers, advertising and more. This component networks the theatre, increasing the value of the individual components on each screen.

Linear Polarization

A form of polarized light in which the tip of the electric vector of the light ray remains confined to a plane.

Local Storage

A storage device that is associated with the individual playout device.

LSDI

Large Screen Digital Imagery. Is a family of digital imagery systems applicable to programs such as dramas, plays, sporting events, concerts, cultural events, etc, from capture to large screen presentation in high resolution quality in appropriately equipped theaters, halls and other venues.

Luminance

A measure of the energy being reflected or emitted by a surface and in which the energy is weighted by the CIE V_λ, also called the CIE y-bar color matching function. Luminance is an approximate correlate of brightness. The Y value in the set of CIE XYZ tristimulus values is the luminance.

Luminance factor

The ratio of the luminance of a sample divided by the luminance of a perfectly reflecting or transmitting object when both are illuminated identically.

Mastering

Mastering indicates the set of those technical activities that lead to the finished edited master of a program, which normally materializes the creative intent of its authors.

Media Server

Each digital cinema projector requires a media player to decompress and decrypt Digital Cinema Packages (DCP), allowing the content to be played on the associated projector. There is one media server for every projector in a multiplex.

Metadata

Data about data. For programme material this might include the title, duration, time and date, copyright details, location or type of programme. Metadata has become a vital part of storing digital content, image and audio, in large archives to enable it to be found again easily. Information that is considered ancillary to or otherwise directly complementary to Essence. Any information that a content provider considers useful or of value when associated with the Essence being provided.

Miniaturization (Stereoscopic)

Confusing visual cues in a stereoscopic scene that can make an object appear to be the 'wrong' size i.e. the impression of being strangely reduced in size. This is due to the choice of an interaxial distance of greater than 63.5 mm relative to the focal length of the camera lenses e.g. shooting with very widely spaced cameras. Subjectively this makes the audience feel like a giant looking at tiny objects, which is why miniaturization is sometimes referred to as Lilliputianism.

MXF

The Material Exchange Format is aimed at the exchange of program material between file servers and is a format for tape streamers and digital archives. It usually contains one complete sequence but this may comprise a sequence of clips and program segments. MXF bridges file and streaming transfers, helping to move material between AAF file-based post production and streaming program reply using standard networks. The MXF body carries the content that can include MPEG, DV and uncompressed video and contains an interleaved sequence of picture frames, each with audio and data essence plus frame-based metadata.

Near point stress

The term used when close work is causing the individual unacceptable stress. This is often seen when the relationship between accommodation and convergence is maintained only by excessive effort. The response to this is either a tendency to avoid close work (known as evasion) or alternatively, to use progressively more and more effort. This is typified by a tendency to get closer and closer to the work and then to suffer slower work rates, head aches and eye discomfort. Writing often becomes laboured and difficult, showing a tight pencil grip and excessive pressure. They may complain of blurred vision, print getting smaller, colored fringes around text that sometimes moves on the page and possibly double vision. There is often a generalized ocular discomfort and there can be complaints of feeling 'washed out' after prolonged concentration. Symptoms can vary from day to day.

Ortho stereo

The ideal position and distance for viewing a stereo image.

Orthostereoscopic (Stereoscopic)

A one-to-one condition where what is being displayed is the same as the 'real world'. For example IMAX 3D is often shot with parallel cameras spaced at the average human adult interpupillary distance (approx 63.5 mm) and with wide angle lenses that closely match an audience member's view of the screen.

Parallax

The distance between conjugate points. It may be measured with a ruler or, given the distance of an observer from the screen, in terms of angular measure. In the latter case the parallax angle directly provides information about disparity.

Parallax Budget

The range of parallax values, from maximum negative to maximum positive, that is within an acceptable range for comfortable viewing.

Passive polarized 3D glasses

3D glasses made with polarizing filters. Used in conjunction with a view screen that preserves polarized light.

Passive stereo

A technique whereby 3D stereoscopic imagery is achieved by polarizing the left and right images differently at source, viewed using low-cost polarizing glasses.

Primary

A color from which other colors are made by addition or subtraction. The Reference Projector primaries are red, green, and blue and all other colors are made by addition of light from each of these primaries. The DCDM encoding primaries are X, Y, and Z, which are imaginary primaries, and by which all other colors are defined.

Pseudoscopic (Stereoscopic)

If a stereoscopic signal is reversed (e.g. each eye is being fed the opposite eye signal) a strange 'punched in' effect appears. This is also referred to as inverted stereo or reversed stereo.

Pulfrich effect (Stereoscopic)

Horizontal motion that can be interpreted as binocular depth. A stereo effect which is produced when 2D images moving laterally on a single plane are viewed at slightly different times by each eye.

Realtime 3D graphics

Realtime graphics are produced on-the-fly, by a 3D graphics card. Realtime is essential if the user needs to interact with the images as in virtual reality, as opposed to watching a movie sequence.

Review room

A theatre in which decisions are made about images projected onto a screen.

Rig

Dual camera heads in a properly engineered mounting used to shoot stereo movies.

Rights

Material can only become a valuable asset if it has rights to its use. Such information which defines the allowable circumstances of its use needs to be associated with the material as a part of its linked metadata. For example, rights may be granted for broadcast on a certain channel at a particular time. At the same Rights Protection prevents the use of the asset where it is not licensed.

RPGb

Reference Projector Gamut Boundary, the limits of the colors that can be displayed by the Reference Projector.

Saturation

The colorfulness of an area judged in proportion to its brightness. On a chromaticity diagram, the saturation of a color increases as its distance from the white point on the diagram increases. Also, on a chromaticity diagram, the points that plot at the same xy coordinates, but have different Y values, form a series in colors that have the same saturation, but different brightness.

Screen Space

The region appearing to be within a screen or behind the surface of the screen. Images with positive parallax will appear to be in screen space. The boundary between screen and theater space is the plane of the screen and has zero parallax.

Sequential contrast

The ratio of the luminance of the white divided by the luminance of the black, normalized to a denominator of 1, when the white and black that are measured are projected onto the screen as full frame images. This is usually expressed as number:1, for example 2000:1.

Show Play List - SPL

A Play List of Compositions, Play lists and Event Play lists, describing a sequence that occurs at a particular screen. A Show Play List is typically created by exhibition using theatre management software to transfer screen ads, trailers, features to the equipment controlling a particular screen..

Silvered screen

A type of screen surface used for passive stereoscopic front projection. These screens maintain the polarization of the light introduced by polarizing filters in front of the two projector lenses.

Stereopsis

The binocular depth sense, literally "solid seeing."

Stereoscopy

The art and science of creating images with the depth sense stereopsis.

Stereoscopic Window (Stereoscopic)

The amount of stereo image available to the viewer is dictated by the frame surrounding a stereoscopic image, e.g. the size of TV or projection screen. This boundary is called the Stereo Window. Depending on their parallax objects will appear either in front, at or behind this window. IMAX has the largest window.

Stereo acuity

The ability to distinguish different planes of depth, measured by the smallest angular differences of parallax that can be resolved binocularly.

Stereo blind

A term describing people who cannot fuse two images into one with depth (stereopsis).

Stereographer

A person who makes stereo pictures.

Surround

The vertical and horizontal edges immediately adjacent to the screen.

†

In stereoscopy, † is used to denote the distance between the eyes, called the **interpupillary** or **interocular distance**. **tc** is used to denote the distance between stereoscopic camera heads' lens axes and is called the **interaxial**.

Transfer function

The equation that shows luminance as a function of the DCDM Y' code value, $Y = f(Y')$, Equation 6-5.

TDL – Trusted Device List

The TDL is list comprised of digital equipment installed in theatres for which studios or other rights owners have given their approval to these 'trusted' devices to play their content. KDMs are only created for devices on the list. This adds another level of security to the DC process.

Theater Space

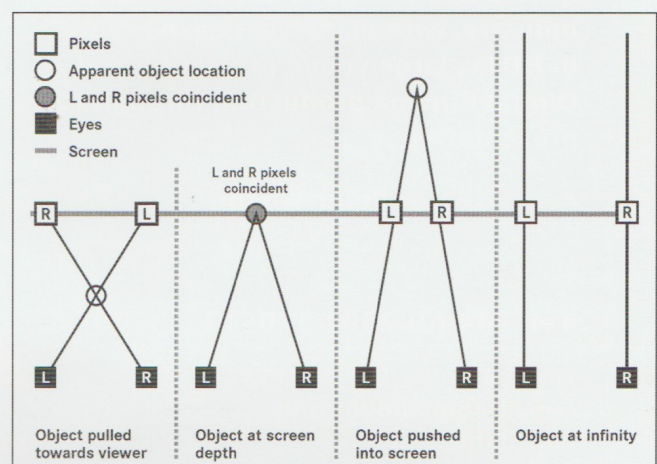
The region appearing to be in front of the screen or out into the audience. Can also be called audience space. Images with negative parallax will appear to be in theater space. The boundary between screen and theater space is the plane of the screen and has zero parallax. See **Screen Space**.

Therapeutic 3D viewing

3D viewing for the sake of improving important visual skills such eye teaming, binocular coordination and depth perception.

Transport and Delivery

Digital Cinema Packages (DCPs) and Key Delivery Messages (KDMs) are transported either physically on media (such as



hard drives) or electronically via satellite. When the DCP arrives at the theater and is loaded, it is unpackaged, decrypted and decompressed for play out by the projection equipment.

Watermark

Watermarking refers to the type of technology used to embed information, including content usage rules, securely into a video or audio signal. Watermarks are designed to be imperceptible by the audience, and they travel with the content even over analog interfaces. Watermarks are directly embedded into the actual content itself and therefore are difficult to remove. Furthermore, watermarks survive and "travel with" content as it is converted from digital to analog form or is re-digitized from analog back into digital. While watermark technology permits content protection rules to "stay with" content, watermarks do not, in and of themselves, protect the content. Watermarking is simply a technology for signaling information and usage rights to devices that may receive the content.

Window

The stereo window corresponds to the screen surround unless floating windows are used.

Wrapper

A digital container that contains program Content and also defines and describes the structure of the Content.

Visually Lossless

An image is considered visually lossless when the processed image is indistinguishable from the unprocessed image under normal theatrical viewing conditions.

XYZ

A shorthand notation for the CIE tristimulus values.

X'Y'Z'

A shorthand notation for the DCDM encoded code values. Notably, the DCDM encoded code values are normalized to a maximum code value of 4095 and have a non-linear transfer function of $1/2.6$.

ZPS

Zero parallax setting, or the means used to control screen parallax to place an object in the plane of the screen. ZPS may be controlled by HIT, or toe-in. We can refer to the plane of zero parallax, or the point of zero parallax (PZP) so achieved. Prior terminology says that left and right images are converged when in the plane of the screen. That term should be avoided because it may be confused with the convergence of the eyes and because the word implies rotation of camera heads. Such rotation produces geometric distortion and may be expedient in camera rigs but is unforgivable in a CG virtual camera rig.

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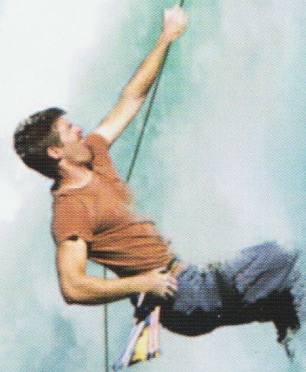
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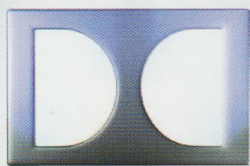
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