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D-Cinema Equipment Frequently Asked Questions

These FAQs have been kindly provided by the author as a companion to the forthcoming publication **Digital Archival Projection – an extension to "The Advanced Projection Manual"** (Oslo/Brussels 2006) by **Torkell Sætervadet**

Background

In 2006, FIAF and The Norwegian Film Institute jointly published "The Advanced Projection Manual" (APM), written by the Norwegian cinema technology specialist, Mr. Torkell Sætervadet. Since its publication, the manual has become a popular guide in the craft of projecting film classics with modern equipment among film archives and cinematheques.

Even though the book was film centric, it also included an extensive chapter on electronic and digital projection. The field of D-cinema has seen a rapid development since the book was published, however, and the long awaited paradigm change from film to digital has finally taken place.

To address the new challenges that the archival cinemas are experiencing, FIAF's Programming and Access to Collections Commission (PAC) contacted the author in 2011 with the aim to encourage an extension to the APM. The author agreed to move forward given that sufficient funding was put in place to ensure publication on paper as well as in digital form.

Funding and publishing

The author applied for funding from The Norwegian Film Institute's funding programme "Funding for activities supporting film culture", and approximately 45 percent of the total budget was initially granted in July 2011. The FIAF PAC has signalled a positive interest in a pre-purchase of the booklet, securing another 33 percent of the budget, and the author hopes for further funding from the NFI once the first draft of the text is complete.

The current project plan assumes that the author will also be the publisher of the book. The first draft of the text is expected to be ready for an initial review by August 1st 2012. The release target for the finished booklet is October 2012.

The author has provided this Frequently Asked Questions section, which includes some extracts from the booklet, to satisfy archival cinemas' immediate need for information. The questions have been collected by the FIAF Technical Commission (TC).

Content

The booklet is expected to contain around 80 pages in printed format, including illustrations. Digital e-book distribution is also planned, though the technical details are not yet finalized. The booklet will cover the following topics:

* Pixels and projection – the basics behind digital projection technology
* Digital projection formats and frame rates
* Digital signal transmission
* Sound for D-cinema
* 3D systems
* Connectivity and interfaces
* Choosing the right equipment
* Digital showmanship
* Maintenance and troubleshooting

About the author

Mr. Torkell Sætervadet is the executive editor of Norway's leading aviation magazine, but he is also a part time senior consultant to Unique Cinema Systems (UCS), a company specialising in digital cinema.

Until 2010, the author held the post as director of technology at UCS and was pivotal in the technical research and analysis leading up to the roll-out of D-cinema in Norway.

Prior to his engagement with UCS, the author co-founded Norsk kinokonsult, a company specialising in cinema design and technology. Other past positions include technical manager at The Norwegian Film Institute in Oslo and principal engineer for cinema systems at Sony Cinema Products Europe in London.

In addition to "The Advanced Projection Manual", the author has previously written "Lydfilmens historie" ("The history of motion picture sound") in the book "Drømmen om de levende bilder", published in Oslo, 1999. Furthermore, he was co-author and section editor of "Storia Tecnica del Cinema" in "The Triccani Film and Cinema Encyclopedia" (Rome, 2003).

Mr. Torkell Sætervadet is a member of SMPTE and supported the archival frame rate efforts of the SMPTE DC.28 committee. He is currently also an associate member of the FIAF Technical Commission.

D-Cinema Equipment FAQs

by Torkell Sætervadet

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1. What is meant by D-Cinema? Is this the same as 'DCI Compliant'?

D-Cinema is an abbreviation for digital cinema. As such, the term could be used to describe any cinema system, which is digital in contrast to a cinema system based on analogue film (or electronic video tape, for that matter). In "The Advanced Projection Manual" (Oslo/Brussels, 2006), the definition was a bit more concise: "D-Cinema is the term used to describe a complete digital distribution and projection system able to produce a picture quality similar to 35mm film."

In this publication, however, we have chosen a more narrow definition of D-cinema: The term describes a cinema playback and projection system, which complies with the current SMPTE standards for digital cinema as well as being DCI compliant.

The standards compliance is important for two reasons: First, it provides a certain level of insurance that the picture and sound quality is predictable and in line with the film makers' intentions. Audience present at a D-cinema screening can be reasonably sure that the image and sound experience is very close to the experience on the premiere night.

Secondly, by being DCI compliant, the D-cinema system will be accepted by the major copyright holders, and the cinema will be regarded as a legitimate venue for their films. Without DCI compliancy, the cinema will simply not be allowed to play the majority of feature films on the market. This goes for films in current cinema distribution as well as restored film classics owned and/or managed by the Hollywood majors.

While the D-cinema standards are still being refined and developed further, some common characteristics apply to current D-cinema systems:

* The film is referred to as a DCP (Digital Cinema Package) and it is played from a playback server
* The image is compressed using JPEG2000 intra-frame compression, and the frame rate was originally limited to 24 (2D) or 48 fps (3D).
* The sound is uncompressed at 24 bits and sampled either at 48 kHz or 96 kHz.
* The image and sound may be encrypted in its stored form to avoid content theft, but the encryption is optional
* The playback server can be stand-alone (where the media block is integrated in the projector) or have a media block built in. If the latter, the media block outputs video signals to the projector (in the form of dual HD-SDI link-encrypted video signals).
* The signal path is partially encrypted to avoid content theft
* The projector resolution is either 2k (2048 x 1080) or 4k (4096 x 2160). The actual image resolution will depend on the content.
* In the projector, there is one light modulator for each primary color (RGB)
* The light modulator is currently either a DMD (Digital Micro-mirror Device) being a part of Texas Instruments' DLP (Digital Light Processing) system or an SXRD chip (Silicon X-tal Reflective Display) from Sony. Other light modulators are under development.
* The projected image contrast is natively high and standardised to certain minimum values. No dynamic iris or other unpredictable contrast enhancing devices are allowed.
* The light source is normally a xenon bulb to ensure a full and compliant colour spectrum. Experimental systems may utilise lasers as a light source, however all DCI compliant projectors commercially available today use xenon lamps.
* The projector can fairly easily be calibrated with a colour meter (spectroradiometer), ensuring correct colours and light levels.
* A D-cinema audio system has a minimum channel configuration of 5.1, but the DCP can contain as many as 16 channels of audio. The number of channels for a particular film may be less than 5.1 (for instance single channel mono).

To distinguish between D-cinema and other forms of digital film projection, the terms Electronic Cinema (E-cinema) and Home Cinema will also be used in this publication. E-cinema refers to any commercial grade non-DCI-compliant projection and playback platform. It will typically consist of a computer, tape based players and BluRay or DVD player, in combination with a digital projector intended for professional use.

E-cinema may be accompanied by two-channel stereo or 5.1 channel sound.

E-cinema will normally be of a lower quality than D-cinema, but there are E-cinema systems out there with better performance than most D-cinema systems, for example some ultra-high resolution systems. The main problem with E-cinema systems is that they are not standardised and normally not accepted for D-cinema screenings. It is of little help to have a projection system which is either cheaper or better than a D-cinema system, if you can't get access to most motion picture content.

Home Cinema describes a projection system for domestic use, which mimics the performance of a D-cinema system. In some cases, high-end home cinema will outperform D-cinema. However, home cinema systems are generally not standardised, and often unpredictable technologies are used to "enhance" the image experience. Such technologies include the dynamic iris, a system that uses a variable lens aperture to increase or reduce the light output depending on the image content of a scene. While this technology will increase the perceived image contrast from one scene to the other, the more important intra-frame contrast (contrast within a frame) stays the same. Also, there are few ways to ensure that the viewing experience is consistent across auditoria. Another drawback is that these systems are fairly hard to calibrate to industry standards. (They are on the contrary frighteningly easy to calibrate to the viewer's taste.)

2. What is meant by an integrated media block?

A media block is the part of the D-cinema playback system, which prepares the film content as output from the storage system during playback to a video and audio signal. The term "integrated media block" describes a layout of the D-cinema system, where the media block is built in to the projector casing and the video signal is sent to the projector directly over PCI Express interface.

In most early 2k D-cinema systems, the media block was a part of the server instead of being integrated in the projector. By encrypting the video signal going from the media block to the projector (using the proprietary CineLink link encryption system), the video signals could not be copied for the purposes of content theft, even though the media block was located outside the "secure" projector shell.

Since there was no readily available link encryption system for 4k video signals when 4k was first introduced for D-cinema by Sony, 4k systems were instead furnished with a built-in media block. Here, the physical projector casing rather than link encryption provides a certain security level. In these systems, also the playback server was built into the projector/pedestal casing. With this layout, the 4k video data is transferred from the media block to the projector electronics using unencrypted LVDS (Low Voltage Digital Signalling).

As the 2k projector manufacturers were expanding the DMD/DLP technology to 4k with the Texas Instruments Series-2 projectors, the concept with a built-in media block became more widespread, as these projectors can either have an integrated or a separate media block.

3. What can I do with an integrated media block projector that I couldn't do before?

The integrated media block is not primarily developed to provide the end user with a range of new features or functions. However, with an integrated media block, it is easier to implement 4k playback, since the video signals don't have to be link encrypted.

Some manufacturers of built-in media blocks (such as Doremi) have chosen to include various scaler, source selector and imaging processor functions in their media blocks, thereby rendering external imaging processors / video scalers superfluous. They may also be equipped with HDMI inputs for external video sources.

Apart from that, the concept of a built-in media block has very few advantages, and a number of teething problems have been experienced with the early generation units.

4. Can I upgrade my old projector to incorporate an integrated media block?

Under certain circumstances, it is possible to upgrade from an external to an integrated media block. The Series-2 DLP projectors are designed with this functionality in mind. Series-1 projectors, on the contrary, cannot be upgraded.

The upgrade is primarily relevant if the projector can and will be upgraded from 2k to 4k.

5. Why doesn't my D-Cinema system support Archive Frame Rates?

The SMPTE Archival Frame Rate standard – demanding as it was to get it through SMPTE at all – is a voluntary standard. (SMPTE ST 428-21:2011 Archive Frame Rates for D-Cinema.) As such, the manufacturers of projectors and servers will only implement the standard if the market demand for this functionality is sufficient.

Consequently, it is important that all film archives and cinematheques put archival frame rate support as a requirement whenever they prepare a tender for a D-cinema system. While the purchasing power of film archives is limited compared to commercial cinemas, one may find that a particular manufacturer (typically one without market dominance) would consider this functionality if it could secure some extra sales. Once one manufacturer supports the standard, it will be more difficult for others to ignore it.

From a hardware and software standpoint, implementing archive frame rates in a server is a fairly minor item. On the projector side, however, it could be more of a technical challenge. This is especially the case for DLP projectors, since the DMD system is using variable mirror movement as a way to modulate the light.The DMD is a binary device, which is either on or off, and to create grayscales, it is necessary to toggle the mirror between these to extreme states in fast sequence. Changing the frame rate means re-calculating the mirror movements while ensuring that no image artefacts occur. Even though the re-calculation process is primarily a matter of "leg work", it has a cost involved, which the manufacturers have to feel confident will be paid back through increased projector sales.

SXRD projectors, on the contrary, are using light valves with a fixed modulator position for each light level (per frame). The implementation of other-than-standard frame rates was done already when the projectors were first launched, and archival frame rates should theoretically be fairly easy to implement, pending good will on the manufacturer's side.

6. Can I use a software application such as EasyDCP Player for my D-Cinema instead of a D-Cinema server system?

You can connect a PC/mac to a D-cinema projector, typically using DVI-D, HDMI or HD-SDI as a video interface. By installing EasyDCP on this computer, you can play back DCPs which don't require a secure playback environment. In practice, this means that most films from major studios cannot be played back, while DCPs from some independent sources (such as some film archives) under certain circumstances can.

7. EasyDCP Player offers me the option of playing a DCP at various frame rates. Are these all compatible with D-Cinema projectors?

This has to be tested for each combination of hardware, software, firmware and frame rate. Tests have been performed in the past, proving that non-standard frame rates may work in certain cases. However, there may be image artefacts or movement artefacts present. In many cases, no image will be shown at all.

The success will for instance depend on how the computer outputs the selected frame rate. In many cases, the computer will transfer from the actual file frame rate to a standardised frame rate associated with the video output interface (for instance 60, 50, 25, 24 or 23.97 Hz when running DVI-D). As long as the projector accepts this standardised frame rate, the projection will work, though movement anomalies may be detected, depending on how the frame rate conversion is done in the computer.

If the computer outputs the native file frame rate over the selected video output, the success will primarily depend on the functionality of the projector. Again, modulation anomalies (in the case of DLP) or movement anomalies may occur.

8. Can I connect a BluRay player to a D-Cinema projector?

As long as the D-cinema projector is furnished with an HDCP compatible DVI-D input, and given that the input can handle the video format in question (image size, frame rate), a D-cinema projector can project video from a BluRay player. If the video format is incompatible with the projector input, it is possible to install a video scaler/processor between the BluRay player and D-cinema projector. Note that both the scaler/processor and the projector must be HDCP compliant to ensure that the projection works.

HDCP stands for High Definition Content Protection and is an encryption technology, which is aimed at stopping content theft. The signal provider (in this case a BluRay player) will only output valid video data if the receiver is a legitimate device.

9. Can I connect other equipment (video players, DVD players, computers) to a D-Cinema projector?

Also other video equipment such as DVD players, video player and computers can be connected to a D-cinema projector. Depending on the type of projector and which kind of video signal the external device provides, it may be necessary to install a video scaler/processor, which converts incompatible video signals (for instance analogue component video) to a signal that the projector accepts (typically DVI-D).

10. What is the difference between a D-Cinema projector and other (cheaper) projectors?

The D-cinema projector has a number of properties which other/cheaper projectors lack:

* A D-cinema projector is capable of reproducing a large range of colours with great accuracy thanks to advanced image processing as well as the use of a light source with

a wide and continuous colour spectrum (xenon lamp). Other projectors typically have a metal halide light source or another lamp with limited colour spectrum. The limitations are particularly noticeable in the deep-red colour area.

* A D-cinema projector will have a native image resolution of 2k (2048 x 1080) or 4k (4096 x 2160). Other projectors exist in a number of varying resolutions (such as 1920 x 1080).
* A D-cinema projector will always have one light modulator for each primary colour (RGB). Other projectors, particularly the ones intended for small screens, may have a single imaging device, which modulates the red, green and blue light in sequence with the help of a colour wheel. This technique may create artefacts visible to a certain percentage of the population. (Anecdotal evidence suggests that more than the quoted "two percent" of the population is disturbed by the rainbow artefact caused by single-chip projectors.)
* A D-cinema projector is able to receive encrypted video data from a D-cinema server, allowing D-cinema films to be played back. Also, the projector will communicate with the server over IP to validate the projector as a legitimate receiver of D-cinema video data. This function is unique to D-cinema projectors.
* A D-cinema projector is designed and should be installed/maintained according to a number of standards (SMPTE ST 431-1 etc), ensuring predictable image quality. Other projectors can be better, equal or of a lower quality, but the important matter is that the end result on screen is inherently unpredictable.

11. Can I set up a relatively cheap system for archive film material using, for instance, a lower specification projector linked to a computer or HDCAM player? Is this called E-Cinema?

There are low cost ways to do high quality digital projection, particularly if the screen size is fairly small (3-4 meters screen width or less in the CinemaScope format). The two most important questions one should ask oneself before choosing against D-cinema are:

1) Will my content providers accept the projection/playback system?
2) What do I want to accomplish with my cinema?

With regard to question 1, one may be fine with an E-cinema or home cinema system as long as there are no plans to screen films from content providers who are only willing to accept DCP projection of their films. (DCP: Digital Cinema Package = D-cinema films.) While many content providers would happily lend out a DigiBeta or HDCAM tape in the past, an increasing number of content providers will only accept DCP distribution. As cinemas are digitised across the globe, this trend is getting more and more prevalent by the day. Content protection and cost are the two main driving forces. Even some film archives will only distribute certain content as DCPs these days. Going for anything but D-cinema carries the risk that your cinema will lose access to content in the near future – to the extent it can access a wide range of digital content outside the DCP platform at all as it is.

If, however, you are only going to show your own archive content, you may obviously choose any other projection platform and stay with it as long as you like. Also, if your content provider allows you to use domestic BluRay disks for projection to a larger audience – and if you are confident that they will stick to this policy – you may be fine with an approach other than D-cinema.

The second question is of a more philosophic nature and taps into the core of the idea of cinematheques and archival cinemas as such. Today, people are surrounded by high quality moving images everywhere. As moving images of high quality are becoming the norm, the eyes of the audience are getting more and more critical. While one could easily project a hammered and faded 16 mm film print of a rare title some 20 years ago, today's audience will complain – or worse: Never return to the cinema.

Thanks to low cost BluRay, the cinephiles have access to extremely high quality versions of their favourite film classics. They can watch these films in the comfort of their own homes thanks to high-performance home cinema equipment.

Those less concerned about quality but more focused on selection and choice, can download or stream an incredible number of films online.

With this backdrop, why should the audience accept a sub-standard experience at national museums celebrating the film heritage (as most film archives are supposed to be)? If the cinematheques can't provide a reasonable guarantee that the audience is seeing something as close as possible to the original film experience, why should the cinematheques even exist? Hardly because they are generally better at putting films into context than a large number of online services, one would imagine.

It is this author's opinion that a cinematheque should provide a guarantee for the best possible film experience, just as a Michelin star restaurant gives a reasonable hope for an unforgettable meal.

Having said the above, there are circumstances where a projection system outside the D-cinema family makes sense, for instance in smaller theatres with limited screen sizes (up to 3 or 4 meters in screen width).

The reason why size matters, is that the smaller screens can be successfully equipped with high-end home cinema projectors, which are the closest to match the image quality of a D-cinema system at a substantially lower cost.

With regard to larger screens, one would either have to accept a lower image quality (most notably linked to colour reproduction, resolution and screen illumination) or choose equipment which is actually more expensive than a D-cinema system. Since D-cinema equipment is being rolled out in large quantities, the price for a large-screen D-cinema projector is often lower than a similarly bright conference room projector. The commercial conference market is typically associated with higher profits/margins than the D-cinema market, where the profit has shrunk to an incredibly low level during the past couple of years. Many cinemas will therefore be surprised to learn that going outside the D-cinema range is not a strategy guaranteed to cut costs.

Regardless of screen size, the following criteria should be absolute for a high-quality E-cinema/home cinema system:

* One light modulator per colour channel (three-chip projector)
* Minimum native resolution: 1920 x 1080 pixels
* Minimum contrast ratio: 2.000:1 (inter frame contrast)
* HDCP compatible DVI-D/HDMI input
* Other inputs should include: Secondary DVI-D/HDMI, RGBHV analogue video, YPbPr component analogue video, composite video. (Without these inputs, an external scaler/processor may be required.)
* Colour and illumination calibration features
* Projected colour range complying to ITU rec 709.
* Ideally, the projector should be equipped with a xenon light source to ensure wide-range colour projection.
* It should be possible to switch off on-screen-display messages, also when input sources are changed
* It is an advantage if the projector has lens presets (zoom, focus, lens shift), particularly if the cinema has a fixed image height.

12. Are there any problems in connecting up the projector and inputs such a system?

As long the output of the commercial or domestic playback gear utilised can be received by the projector, the connection of such a system is rather straight forward. However, one will often find that either the interface or the video signal is incompatible with the projection device. Most challenges are experienced when going across platforms, for instance from a professional grade E-cinema device such as an HDCAM player to a home cinema device such as a high-end home cinema projector. For instance: HD-SDI, which is a commonly used video signal platform in the professional sphere, is rarely included in projection equipment intended for domestic use. However, video scalers/processors can be installed, and these units convert the output signal to an acceptable projector input signal. A good video scaler/processor can be costly, and if it is not, it can be the culprit of image artefacts or cause operational issues.

13. What is the approximate cost (in 2012) of a D-Cinema system?

In fact, D-cinema equipment has become fairly inexpensive. Used complete systems with a projector and server that are DCI compliant are available for as little as 25.000 euros, and it is possible to purchase new systems for less than 50.000 euros.

The challenge is rather to find a skilled integrator, which understands the particular needs of an archive cinema.

14. What kind of lifetime do D-Cinema manufacturers promise for their systems?

D-cinema equipment should be amortised within 10 years. This is not to say that good D-cinema equipment can't last substantially longer. However, this is the maximum manufacturer guarantee one can reasonably hope to acquire. While D-cinema equipment normally has a one year warranty included in the basic price, good vendors are able to supply an additional warranty package covering up to ten years in total. After a period of ten years, the problem of obsolescence for electronic circuits is likely to make the projector and server difficult (though not necessarily impossible) to maintain.

For cinemas and archives used to analogue film projectors and their lifetime of more than 50 years, this represents a huge shift in culture. Some may claim that renewal of their cinema equipment every ten years is going to be financially impossible. However, the same institutions are probably used to replacing their more expensive IT systems more often than that.

The best way of ensuring that the D-cinema manufacturers favour a product design where longevity is key is indeed to keep purchasing those eight or ten year warranty plans.

15. What is the difference between Sony projectors and others brands? Can the same DCPs be played back on all projectors?

Currently, Sony is the only manufacturer of D-cinema projectors who does not utilise Texas Instruments' DMD (Digital Micro-Mirror Device) and their DLP (Digital Light Processing) system to modulate the light in the projector. Instead, Sony has developed its own imaging device referred to as SXRD (Silicon X-tal Reflective Display).

SXRD belongs to the LCOS family (Liquid Crystals on Silicone) of light modulators, which in turn is loosely related to LCD (Liquid Crystal Displays).

LCD panels consist of liquid crystals between a mesh of switching transistors, and the panels are transmissive in that light passes through them, unlike DMDs, which are reflective. The liquid crystals act like light valves since the crystals will enable or disable polarisation, meaning that pre-polarised light from the light source is either stopped in the panel or let through. LCD panels have some shortcomings making them less-than-ideal for D-cinema projection, hence they are not used for D-cinema. For instance, the pixel density will be limited by the switching transistors between the pixels. Also, the transmissive nature of the panels means that some light will be absorbed in the panel while it is being used, heating it up and causing damages in the medium to long term. Due to light diffraction in the panels, LCD panels don't provide the same high contrast as DMD panels.

LCOS addresses these problems by combining liquid crystals with a reflective layer. By moving the switching transistors from the grid around the pixels to the back of a reflective layer, the liquid crystals can be packed extremely tightly, yielding a very high pixel density. Since light is not being absorbed in a transmissive grid of transistors, the majority of heat problems linked to LCD have been solved. Sony's SXRD system has refined the LCOS technology further by aligning the liquid crystals in a vertical direction, something that increases the contrast ratio substantially. Thanks to the application of SXRD, Sony was able to provide the first commercially available 4k D-cinema projector, which also became DCI compliant after some refinements.

Sony came late to the D-cinema market and needed a competitive edge against the three other manufacturers, which all use the Texas Instruments' DLP system (Barco, NEC and Christie). Sony decided to commit to the 4k resolution platform, a premium feature they were alone to offer until late 2010. By September 2011, Sony has passed the 10.000 unit mark for their 4k system (Sony press release, October 2011), thereby securing a market share of more than 25 percent.

The Sony 4k system is fully compatible with 2k or 4k systems from competing manufacturers. The system can play back the same DCPs as all other servers/projectors, since all hardware and software have been designed with DCI compliancy in mind. A 4k system of any brand will play back any 2k film as easily as a 2k system.

Some differences between Sony's projector and the DLP based projectors from Barco, Christie and NEC should be mentioned:

* Sony's projector systems are always 4k, while other systems are most often 2k, some of which can be upgraded to 4k.
* Sony 4k systems cannot be equipped with xenon lamps with higher wattage than 4.2 kW. This means that the projector's light output is in the range of approx 20.000 ANSI Lumens. The light output is sufficient to provide the SMPTE standard of 14 footlamberts in 2D on a CinemaScope screen of 20 meters in width without the use of an anamorphic adapter. With an anamorphic lens, the maximum screen width can be increased to approximately 24 meters.
* Even though the DMD panel switching speed is high at 5 milliseconds, the speed is not sufficiently high for 3D systems utilising an alternating frame approach. Currently, only the 3D systems from Real-D and Panavision can be combined with the Sony 4k system. Both systems utilise a dual-lens approach when applied to Sony's 4k projectors, requiring a lens change between 3D screenings and 4k 2D screenings. The benefit with a dual lens approach is that the 3D colour resolution is the same as for 2D images.
* The higher pixel density associated with SXRD panels compared to 2k DMD panels, yields a smoother looking image, even if the content played is only 2k.
* Despite their reflective nature, the SXRD panels are more sensitive to heat than DMD panels. In the long term, this may affect the longevity of the SXRD panels, particularly for projectors equipped with high-wattage bulbs. However, Sony does offer a warranty

package, which offsets this risk. Furthermore, hardware failures in general have proven less frequent with Sony systems than other systems.

* The SXRD panels are more prone to colour shading over time than DMD panels. Therefore, colour calibration will have to take place more frequently than with DMD based projectors. This is particularly visible when projecting black-and-white film, where colour shading is more visible.
* The Sony 4k system is normally supplied with Sony's own server and media block. While it is possible to install "alien" servers/media blocks (a server system from Doremi is currently available for this purpose), very few systems are.
* In the early days of D-cinema, customers reported more playability problems linked to DCP file inconsistencies with the Sony 4k server than other servers. Particularly, DCPs with subtitles could cause issues. Some of the problems were linked to DCPs not being fully DCI-compliant, while other problems were linked to system software bugs, which have since been ironed out. At present, no DCP compatibility issues are known with the latest versions of software and firmware in the field.

16. Which 3D system is the best? Do I have to get a new screen for 3D?

Choosing a 3D system is not the simplest of tasks, and which system is the best, depends on the priorities of the operator as well as certain properties of the cinema or projection systems.

Issues to consider include:

1) Is 3D image quality my core priority when selecting a 3D system?
2) To what extent do I care if my 3D installation affects the quality of the 2D images?
3) Do I have the staffing and infra structure to handle multi-use glasses?
4) What screen size do I plan to satisfy?
5) Do I have a Sony 4k projector (in which case the choice is reduced to Real-D and Panavision)?

The main problem with 3D systems is their limited light efficiency and their tendency to yield imperfect segregation between the left and right image, the latter causing a visible artefact known as "ghosting". Some systems are more prone to one of the two problems than the other.

Three core technologies are being used to separate the left and right stereoscopic images: Polarisation, sequential light blockage through active glasses and colour discrimination providing a double set of RGB colour triplets.

Real-D, DepthQ and MasterImage are all using polarisation, XpanD utilises active glasses and both Dolby and Panavision utilise dual colour triplets.

Real-D is the most light efficient of the 3D systems (up to 28 percent efficiency when using the XL system), but the circular polarisation used has two core disadvantages. First, a silver screen is required. Such screens have a directional reflection pattern (the screen gain is 2.6 or more), causing the image to look unevenly lit. The effect is always present, but to what extent it is disturbing depends on factors such as room geometry, relative image size, image position versus audience position, etc.

Secondly, circular polarisation offers a rather poor channel separation. 3D systems in the 1950s used linear polarisation with reasonably good image cancellation, however, the cancellation was reduced whenever the glasses were slightly rotated compared to the projection filters. Also, linear polarisation is impossible to combine with rotating disc systems such as MasterImage. Consequently, 3D systems for digital cinema use circular polarisation despite its fairly poor separation properties. The result is a certain level of ghosting, particularly prevalent with electronically activated polarisation adapters, which

Real-D is using (Z-screen or XL *). Real-D has introduced an ingenious technology to counter the problem, referred to as "ghostbusting":

Ghostbusting software anticipates the visible light leakage in every single left and right frame and manipulates the frame content so that the visible leakage is minimised. In the early days of digital 3D, special DCPs with ghostbusted images were distributed to cinemas using Real-D. However, since the other 3D systems don't require ghostbusting and will be disturbed by a ghostbusted file, dual inventory became necessary. The film studios demanded a change to avoid such a logistics nightmare, and since late 2009, the ghostbusting process has been performed by the cinema servers on the fly. Even with ghostbusting applied, ghosting is visible from time to time.

One of the primary benefits with Real-D, is that it is possible to use passive disposable glasses, which are inexpensive. This is particularly important for cinemas with large audiences or with a lack of staffing to collect and clean glasses between shows.

Another big plus with Real-D is that the system is available both for SXRD projectors and DMD projectors. The same glasses and screens are used regardless of projector type, and in a cinema with multiple screens using different kinds of projectors, this is obviously an attractive feature.

The Real-D system is leased rather than sold, and the fee structure depends on the nature of the cinema. For an archival cinema, the best strategy would be to try to negotiate a preview room deal, where one pays a fixed amount per screen per year. For large commercial cinemas, the calculation with regard to the cost of Real-D compared to the competitors is more complicated since Real-D will normally charge a fee per ticket. Some cinema circuits have chosen against Real-D for cost reasons, however an archival cinema will be likely to find Real-D's system attractively priced as long as a preview room deal has been secured.

*) Real D supplies two different kinds of light modulators for DLP projectors: The Z screen and the XL system. The latter system polarises the light twice by "re-cycling" some of the lost light in the first polarisation process, polarising it again for projection of a second superimposed image, thereby increasing efficiency. The disadvantage with the system is that it is slightly complicated to align and set-up, and it also takes more space. For SXRD projectors, Real-D uses standard fixed circular polarisation filter, one for each lens in the Sony dual lens adapter.

DepthQ is one of the recent additions to the range of 3D solutions for D-cinema. It is developed by the companies Lightspeed Design Inc in the US and LC-Tec Displays AB in Sweden, and it is rather similar to Real-D in that it has an electronically activated LCD-based light modulator in front of the projection lens, which polarises the light in opposite circular directions in sequence.

The advantage compared to Real-D is that its light modulator is extremely fast at 50 microseconds, meaning that the system can accept a shorter dark-time between images than other systems. In turn, this optimises light efficiency. Also, DepthQ is compatible with future high frame rate 3D systems (beyond 240 fps) thanks to the fast switching speed.

From a business standpoint, DepthQ is very straightforward without any leasing or complicated contract systems. The system is purchased outright, has a three year warranty and is fairly low in cost.

The disadvantage with DepthQ is that it can't be used for SXRD based D-cinema projectors, and it does not exist in an "XL version", meaning that the light efficiency is only better than Real-D's Z-screen, not the XL system. The light efficiency of DepthQ is

not published, but the maximum projectable image size is announced by the company to be 17.7 meters. (Maximum projector output for the system is 30.000 ANSI Lumens.)

From an image quality standpoint, the channel separation is said to be sufficiently good to render ghostbusting superfluous, though a certain level of ghosting is noticeable during high contrast / large image separation sequences.

MasterImage is also based on circular polarisation, but instead of using electronically activated polarisation adapters, MasterImage use foil style polarisation filters glued to a rotating glass disc. The system is in the medium range, light efficiency wise. It is not as light efficient as Real-D's XL system, but it is more efficient than RGB colour triplet systems.

The foil style polarisation filters are said to be sufficiently good at cancelling light that ghostbusting isn't required. For this author, it is a surprising claim given that circular polarisation is used. Field experience does indicate that ghosting is an issue, but the same can be said about most other 3D systems.

The glasses used by MasterImage are compatible with Real-D's glasses since both are using passive circular polarisation.

MasterImage cannot be combined with SXRD projectors, and a silver screen is required.

MasterImage's primary business structure is based on sale rather than lease. In many cases, MasterImage will turn out cheaper than Real-D.

XpanD, previously known as NuVision, is based on alternating frames and active glasses. The primary benefit with the system is superior image cancellation and no need for a special screen. Also, XpanD claims a light efficiency with their latest generation glasses, which is only surpassed by Real-D's XL system. (Initially, the light efficiency was in the 15 percent range, while the improved version is said to be in the 20 percent range.)

The core disadvantage with XpanD is that the system requires active glasses. Active technology can fail, and batteries do get depleted. With liquid crystals straight in front of the eyes, active glasses have a slight tendency to cause some diffraction blur, though the latest generation XpanD glasses provide brilliant results. Furthermore, costly as they are, the glasses have to be collected and cleaned between shows. Even though the latest generation XpanD glasses have been vastly improved compared to the early NuVision style glasses, these core disadvantages still apply. Finally, the system cannot be combined with SXRD projectors.

Cost wise, XpanD is particularly attractive for small and medium size screens.

Dolby digital 3D has licensed the RGB colour triplet filter technology referred to as Infitec from Daimler-Chrysler (see APM 7.5.1 for further details). In the projector, a filter wheel is installed in the light path between the integrator rod and the light modulators. The filter wheel has a "left RGB" and "right RGB" sector, allowing the projector to project alternating frames with different RGB characteristics for the left and right eye.

The advantage with the system is that the channel separation is excellent and that no silver screen is needed. Since the separation is good, there is no need to implement ghostbusting in the playback system. Furthermore, the glasses are passive, meaning that they are less likely to fail than XpanD's re-usable glasses. However, their relatively high cost means that the glasses can't be disposed and should be collected and cleaned between shows.

The core disadvantage with Dolby 3D is the very low light efficiency (only about 12 percent of the light output from the projector reaches they eye). While a silver screen is not required per se, a high gain screen is often mandatory to yield sufficient screen brightness (at least a gain of 1.4 to 1.8 is recommended). Another disadvantage is that there will inherently be a very slight colour difference between the left and right eye (after all, different wavelengths of light will reach the two eyes). On a well calibrated system, the difference is very hard to spot, but calibration is critical.

While Dolby 3D could be combined with an SXRD projector from a technical standpoint (using a dual lens approach and applying some changes to the spectral response of the projector), Dolby has so far not taken the trouble to adapt its system to the Sony projectors. This means that Dolby 3D is less flexible than Real-D in terms of projector choice.

Panavision is one of the last entrants to the D-cinema 3D market with their Panavision 3D System developed jointly with Omega Optical. The technology is very similar to Dolby 3D, but it has some distinct advantages. Firstly, the system is compatible with both film and digital projection. Even though the lenses and filters are different for 35 mm and D-cinema, the glasses are identical. Secondly, it is the only system other than Real-D, which is compatible with both SXRD and DLP/DMD projectors. Thirdly, Panavision claims that the light efficiency is higher than Dolby's at 17 percent. Panavision admits that there is no standard of defining light efficiency for 3D projection, so whether their technology offers brighter images than Dolby in real life remains to be confirmed by independent field experience.

Due to lack of personal field experience with the Panavision 3D, it is premature to give a conclusive advice about the system's suitability for archive cinemas. However, based on the information available, it seems to be a very strong candidate due to its versatility and its presumable high image quality. Indeed, the system's compatibility with certain old-style single-strip 3D systems (see APM p 185), the system is particularly attractive for archival cinemas with aspirations to project classic 3D films on 35 mm film.

To summarise, which system to choose will depend on priorities and physical properties of the cinema. All of the systems are capable of providing high 3D image quality. A certain level of personal preference may also apply to those making the 3D purchasing decision.

It is my view that screen brightness is by far the most important matter. It is of limited interest if the channel separation is good as long as the image is dim and little ghosting can be seen anyway. The initial de-facto brightness standard for 3D projection was as little as 3.5 footlamberts, while ambitious cinema designers today seek to achieve up to 6 footlamberts. Since screen brightness varies in the field, conscientious 3D film makers such as James Cameron have provided multiple versions of their films with different grading tailored to different screen brightness. Even so, no grading can compensate for the reduced dynamic range linked to low screen brightness. Therefore, every attempt should be made to maximise light output.

The sad fact is that the most light efficient system requires a silver screen. Due to their reflection characteristics, such screens will affect the perceived evenness of illumination. The result is that the projection quality of all films, including 2D films, will suffer. The awareness of the problem is rising by the day, and in France the national film board CNC is planning on introducing a standard (Afnor), which practically excludes the use of silver screens to protect the integrity of the images (Variety, March 9th 2012). The measure would mean that the 1,200 silver screens in France will have to be replaced by 2017.

Columbus's egg is in my view to install a silver roller screen in cases where the light efficiency of Real-D is required due to screen size. Such screens can be rolled up

whenever 2D films are being screened. The added benefit is that it becomes much easier to balance the light between 2D and 3D film presentations.

For cinemas using SXRD projectors while having screens larger than around eight meters in width, the author's choice would be Real-D in combination with a silver roller screen. For smaller screens, Panavision may be the most attractive alternative (though no personal field experience as of yet can confirm this assumption).

For cinemas using DLP/DMD projectors, the choice is wider, particularly if the screen is fairly small (8 meters wide or less) and the projector is powerful. From a pure image quality standpoint, XpanD, Dolby and Panavision are likely to provide the best image due to the excellent channel separation, pending that sufficient screen brightness can be achieved. All these solutions cause certain logistics challenges, particularly for large screens where the high number of glasses is both a cost and a handling issue. As the glasses wear and get scratched, diffraction in the glasses can reduce the image quality.

Of the three systems, Dolby 3D is least likely to produce a sufficiently bright picture. On a small screen, however, the system can reproduce awesome 3D projection.

For large screen 3D projection, Real-D and DepthQ are most likely to reach brightness minima.

The only system which in the author's view has few other benefits than low cost is MasterImage.

If the screen is large and the budgets are generous, dual projector 3D could also be considered. With two projectors, the choice of options is very wide indeed, though some content providers have been sceptical to two-projector set-ups due to assumptions that two projectors are much harder to align and keep aligned. Those assuming so have probably never installed single-projector 3D systems: They all need careful alignment and maintenance. The advantages with two projectors are plenty: Excellent light output, redundancy for 2D projection and the possibility of using a matte white screen. Also, the problem of balancing the light output between 2D and 3D is minimised with two projectors.

17. The image is too bright even with lowest lamp setting – what can I do to fix this?

It is a common problem with 3D projection that the image will be too bright in 2D because the lamp cannot be turned down sufficiently.

The best way to address this problem is to use a high gain roller screen in 3D (silver screen if polarisation systems are utilised) and a matte white screen in 2D. This solution is beneficial also if a non-polarisation system is used since it will make it far more likely that sufficient screen brightness is reached, even when the xenon bulb is not new.

A similarly good solution is to install dual projector 3D, though cost will often prohibit this approach.

The low-budget solutions to the problem are far from ideal. The most intuitive and cost effective solution is to replace the lamp between 2D shows and 3D shows. However, this requires a skilled projectionist and ample time between shows.

Another option used in the field is to defocus the lamp in 2D, something which drops the light output. However, it requires some skill to do this, and one may cause heat damage

to the projection system. Some manufacturers may prohibit this practice, which again may cause the warranty to be void.

Theoretically, a good option would be to install a variable iris in the projection lens. Schneider Optics did provide projection lenses for 35 mm with this feature (Schneider Premiere), and one would think that the same should be possible with D-cinema lenses. A skilled cinema engineer with good optical knowledge may be capable of customising such a system.

Another attractive option would be to install a small aperture in the optical path of the projector. Some DLP projector manufacturers did provide such apertures in the past for preview theatre projectors, and if they could be actuated by electro mechanic means, the light balancing could even be automated.

Finally, it is possible to mount neutral density filters in front of the projector lens.

It does however seem rather wasteful to run 2D films consistently with higher wattage than needed, so the two-projector or roller screen option comes across as being far more attractive.

18. 3D films look very dim – how can I fix that?

If your 3D films look very dim, you are in good company! Many systems are being sold without taking sufficient care in selecting equipment. Here are some ways to fix it:

* Install a new porthole glass. This should already have been done when you converted to digital, but many cinemas are still using glass with a light loss of more than ten percent. Use Schott Pyran S AR or an equivalent type of anti reflex coated and fire hardened water white glass. The loss will be reduced to approximately two percent. This will benefit the image quality for all your presentations.
* If you have a series one DLP projector of the old generation, you are probably running 3D on a reduced part of the chip (and hence, only a part of the light cone is being used). The reason is that the old style format boards (EFIB board) didn't have sufficient bandwidth to accept full resolution images at the 144 fps frame rate required for triple-flash 3D. You can gain about 30 percent of light by replacing the EFIB board with an FFIB board and reformat the 3D preset to full resolution. You can also upgrade to a Series 2 projector and achieve the same. A less ideal solution is to go from triple flash to double flash, but the disadvantage is movement artefacts noticeable to some.
* Make sure that your projector is set up with automatic zoom presets so that the image is always as high resolution and as high brightness as it can get (for fixed image height screens). Many set-ups only utilise 858 pixels for both CinemaScope and widescreen 1.85:1, wasting resolution and brightness in widescreen.
* Consider using an anamorphic lens if your brightness problem is only noticeable in CinemaScope (for fixed image height screens).
* Install a higher wattage lamp or a high brightness version of the same wattage, if it is available for your projector.
* Install a high gain screen (1.4 or 1.8) if you are currently using a matte white screen. Unless the screen is curved, this should be a roller screen to avoid that the 2D image quality is compromised. To harmonise brightness levels between 2D and 3D, a roller screen is always the preferred approach.
* If none of the above leads to satisfactory results, you will have to re-consider your entire set-up. You may opt for a more light efficient 3D system, a more powerful projector or a dual projector set-up.

19. Do 3D DCPs use the same colorspace as 2D DCPs?

The colour resolution is lower in 3D than 2D when projected on DLP type projectors due to signal transport limitations. To reduce bandwidth requirements for transmission from the server to the projector through the dual HD-SDI interface, the 4:4:4 colour resolution applied to 2D films is reduced to 4:2:2 due to the double amount of images required for 3D (48 fps). The "Stereoscopic Digital Cinema Addendum Version 1.0" published by DCI specifies 4:2:2, 12 bits, Y'C'xC'z.

On Sony SXRD projectors the colour resolution remains at 4:4:4, since this projector is not using the time domain to project two images.

Note that the reduced colour resolution is a transport matter rather than a DCP matter.

20. Can I connect a D-cinema system to my existing sound system?

You can connect a D-cinema system to an existing sound system, but depending on server and cinema processor type, you are likely to require a sound converter, which converts the digital AES/EBU audio to six-channel analogue audio. Having said that, it does make sense to review the entire audio system since D-cinema audio is uncompressed and consequently much cleaner than digital or analogue audio on 35 mm film. To take the full advantage of this, it is critical to review the speaker type/size, amplifiers and processors.

21. Do I need a 4K projection system to play a 4K movie?

No, the DCP layout is so that a 2k system will ignore the image data for 4k during playback, only utilising the 2k core. This is possible since JPEG2000 is a modular compression system, which uses a "low resolution" 2k file as a core for the high resolution 4k version. In other words, the 4k add-on file consists of the difference between the 4k image and the 2k image.

However, only a 4k system is capable of reproducing the full resolution 4k image.

April 16th, 2012
Torkell Sætervadet

FIAF Technical Commission 2012