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NEC Display Solutions

The Future of Digital Cinema

What is the big screen of the future?

Summary

Cinemas must carefully consider how they invest in order to remain attractive and competitive. For the vast majority of cinemas, upgrading the viewing experience appears to be one of the most effective strategies to emphasize the core reason for visiting a cinema: an absorbing and entertaining social activity.

The diversity of visual technology is rapidly growing. Digital projection started with Xenon lamps ten years ago, now UHP lamps and different laser light sources are available. Laser Phosphor is mainly fitting the demands of smaller and medium sized screens, where RB laser is an ideal technology delivering compelling benefits in terms of quality and cost for medium and large sized screens; while RGB laser provides the ultimate visual experience for premium and larger sized screens. Fine pitch LED screens newly enter the stage and offer another potential screen alternative today. This creates new opportunities while raising the important question for cinema operators as to which technology will take the lead in the cinema of the future and into which technology they should be investing today.

When deciding on future cinema screen technology, operators must consider four major decision criteria which will have strong impact on the cinema experience. These decision criteria centre around achieving the best viewing experience; attaining a low total cost of ownership, influenced by operational and organisational efficiency; plus identifying potential additional revenue streams.

The latest developments in laser projection as well as LED provide effective possibilities. While projection is already the standard in cinema with deep understanding and experience meaning a safe and future-proof investment for cinemas today, LED has just entered the stage and is looking to find its place.

While LED mainly provides advantages in brightness and contrast ratio supporting crisp images, projection is the more mature technology offering benefits towards screen size flexibility, 3D support and sound.

Cinemas will need to find a viable audio solution for LED screens, one which can provide an immersive sound, since the speakers cannot be installed behind the screen as it is with projection. In terms of purchasing and operational costs, there are huge differences between projection and LED today; the question lies whether LED can become more cost-competitive, and cinema operators must also be aware of the challenges of maintenance, servicing and protection required for LED.
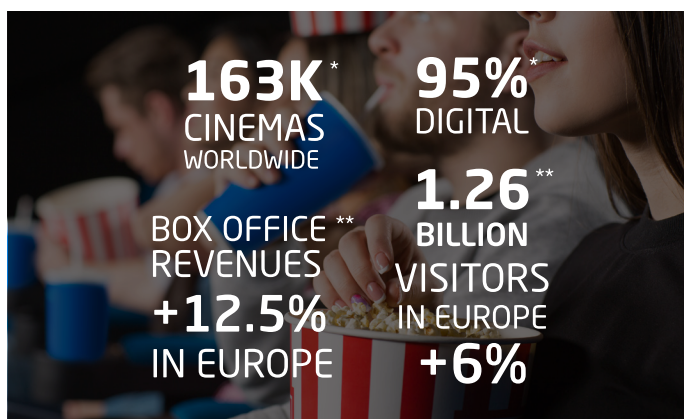
In order to make a safe and future-proof decision, cinema operators should make use of an objective evaluation from cinema screen experts providing answers to the many questions that are still open and have yet to be answered. NEC Display Solutions, with its deep industry knowledge and technical understanding is active in both cinema projection as well as LED screen technology meaning it is well placed in providing hardware-agnostic consultancy, always focussing on the users demand.

Introduction

A new era of projection technology began when, since 2005, digital projection technology became the preferred choice for the motion picture industry, now accounting for more than 95% of all the 163,000 cinema screens worldwide*. The question at that time was whether this technological development might harm cinema business and negatively influence the motivation to visit the movies, i.e. to enjoy an immersive audio-visual experience in a very social atmosphere. In fact, on the contrary, since then many developments in projection have taken place, supporting many new motivations to go to the movies such as 3D, Premium and special format screens as well as mobile cinemas. These changes also created new forms of cinemas and new ways to increase per-seat revenue. The speed of change coming from new, more frequent technological developments is posing a big challenge for cinemas and decision making needs to keep pace, leaving cinema operators wondering which innovations to adopt and which to ignore.

This whitepaper offers a compact overview covering the different digital visual technologies that are available for deployment in cinemas today or are poised to play an important role in the future. It will support cinema operators in understanding the technological differences between projection and LED screens. Many cinemas are looking to replace their first digitised projector as they reach critical operational times. This paper is therefore also intended as a reference guide to assist in making the most appropriate replacement choice and offer guidance as to a future-proof investment in the delivery of an immersive cinema experience for movie-goers today and tomorrow.

How do cinemas provide an unrivalled viewing experience, one that people can't experience elsewhere?

Cinema is still gaining in popularity, proven by the fact that cinema attendance has been growing in Europe by more than 6%, reaching 1.26 billion admissions in 2015 resulting in a double-digit box office revenue growth**. The cinematic experience has seen further enhancements in recent years with, for example, special cinema formats and entertaining digital visualisation in foyers and restaurant areas; yet going to the movies remains an affordable social activity compared to concerts, sporting events or eating out for instance, where prices have increased significantly.

For the cinema operator, there are many considerations to be made such as: how to continue to attract future generations; how to compete against the lure of streaming services and how to increase concession revenues and general advertising through digital signage. Another important consideration, and one which we hope to arm you with the knowledge you need to make an informed choice, is which medium is best placed to deliver the ultimate cinematic experience and which makes the most economic sense for cinema operators? Is it projection or will LED video panels begin to prevail? Before giving a very encouraging prediction about the future of cinema technology, we will provide a deeper look into the different technologies and explain what cinemas need to know when choosing cinema technology

What requirements do cinema operators have regarding screen visualisation?

These four requirements are essential for cinemas and must be considered for every theatre screen deployment. We will provide a detailed comparison of projection and LED technology in the following chapters.

1) Offer your audience the best possible viewing experience

Cinemas must position themselves as a destination delivering an unparalleled viewing experience. In order to entice their audience away from their home screens, cinemas must offer a significantly better viewing experience where screen size and image quality plays a major role. Image quality depends upon many factors such as colour, brightness, uniformity, contrast, resolution and frame rate. In addition, the display device must comply with DCI specifications ensuring a uniform and high level of technical performance and quality as well as reliability and security.

2) Strive for a Low Total Cost of Ownership

The Total Cost of Ownership (TCO) encompasses not only the initial purchasing cost but includes operational costs such as maintenance, consumables and power throughout the product's lifetime. Reducing the TCO can be achieved by considering the lifecycle of the theatre's audio visual equipment, making savings in purchasing, maintenance and consumables as well as lower electricity costs.

3) Create the utmost operational efficiency

Cinemas are looking to reduce their costs and efforts in daily operation in order to increase their profits. It's achieved through high availability of fully working theatre rooms by reducing maintenance requirements and cost effectively. Non-operational cinemas are worst-case scenarios avoiding any chance for income at the box office as well as at the concessions.

4) Extend the revenue streams

Increasing revenue streams through innovative big screen presentations such as live streaming from concerts, eSports and gaming events, or corporate launch events helps to attract new audience groups and increase the return rate. The display technology must be able to support these trends in terms of versatility and performance level.

Which technology is available to deliver an unparalleled viewing experience?

Cinema Projectors:

The projection device projects a moving image onto the screen and is normally located in a dedicated projection booth situated directly opposite the big screen. By using interchangeable lenses, projectors can be adapted to suit different screen sizes and positions. As the emitted light is reflected onto a surface, the cinema screen is another important factor in determining the resultant image quality. Today's cinema projectors are digital, projecting the content delivered via a cinema media server complying with the DCI specified security requirements. Whilst the first generation of projectors used Xenon lamps, today, laser light source is offering many advantages in terms of durability, reliability, low maintenance and image quality and is the preferred option. Different light source technologies such as Laser Phosphor, RGB and RB laser provide special characteristics for different use cases and screen sizes. More details are available under

https://www.nec-display-solutions.com/p/ssl/en/technologies.xhtml

LED Cinema Screens:

LED is the big newcomer for cinema screens, presented the first time in 2017. Instead of projecting an image onto a screen surface, the screen space is filled by multiple LED modules which combine to create one, customised giant video wall. It uses an array of light-emitting diodes as pixels for a video display. Since the LED diodes actively emit the light very efficiently, the brightness levels achievable by LED are very high. The resolution of an LED video wall is predetermined by the pixel pitch, which is the distance between the individual pixels that are fixed on the screen surface. As the pixels are installed on the surface, the overall screen size can be altered only by adding or removing pixel cards. The resolution can be adapted by choosing different pixel pitches. As of today, pixel pitches between 2.5mm and 1.9mm appear to meet cinema requirements. Similar to projection, image processing is digital and managed by special cinema servers.

What influences the image quality and what makes a good cinema experience?

Some major requirements regarding image quality have been determined by the global DCI specification, these include:

Brightness: The luminance indicates how much luminous power will be detected by the eye when looking at a surface from a particular angle of view. The brightness level must allow clear perception of contents while supporting high contrast ratios yet avoid dazzle which can negatively affect the audience if the brightness is too great in a dark environment typical of a cinema theatre. The standard brightness of a cinema screen image today is 14 foot lamberts 48 cd/m^2.

Where the brightness level of projection closely correlates to the current cinema standard of 14 FL (48 cd/m^2) or Dolby Cinema level of 31 FL (100 cd/m^2) and therefore determines the choice of projector in the majority of cases, the brightness output of LED is extremely high in comparison. The first prototypes for cinema demonstrated a maximum brightness level of 500 cd/m^2. Where projection has to offer enough brightness output for special applications such as 3D (which is subject to a loss of light efficiency), LED needs to respond to the darkness of a typical cinema environment and ensure its native high brightness levels are not so bright as to cause eye strain. A higher brightness level supports "lights-on" use cases for cinemas screening alternative content such as live-streaming, eSports or company presentations since the higher brightness output would ensure crisp images even in not completely darkened environments. For LED cinema applications the screen needs to perform with wide adjustment from a comparatively very low brightness level up to 500 cd/m^2 for 'lights on' applications.

Contrast: The contrast ratio is defined as the ratio of the luminance of the brightest colour (white) to that of the darkest colour (black) that the system is capable of producing. HDR (High dynamic range) is a term that has gained momentum recently and is starting to become common in movies. As HDR is not standardised (as yet), a general description is the provision

of higher contrast ratios, mainly with partially brightly-lit areas of the image. Where theoretical contrast ratios of 1,000,000:1 or even Infinite:1, promise perfect image with high contrast, the true contrast ratio inside the theatre is mainly determined by the movie content as well as environmental factors. Cinemas can support high contrast levels by minimising the ambient light as far as possible in order to generate a low black value since this strongly influences the real contrast ratios in the cinema.

As the real perception of contrast in a real life scenario differs greatly compared to test chamber environments, a contrast ratio of 1,000,000:1 is not realistic with either projection or LED technologies. However, LED is very effective in creating high brightness outputs combined with true dark image playback, thus creating high contrast for HDR content. As laser projectors provide more constant and brighter light output than lamp based products, the next generation RGB laser projection is also striving to meet the HDR requirements.

Colour gamut: According to the DCI specification, cinema screens have to follow the DCI-P3 colour gamut. It's a wide gamut video colour space for digital cinema projection supporting vivid and natural colours to match the full gamut of colour film. This gamut has more pronounced greens and reds compared to Rec 709. The newly introduced colour space Rec 2020 covers a large percentage of the full colour space. It's intended for implementation in Premium cinemas and is seen as a future end-to-end colour space standard for diversification through image excellence in digital cinema.

Both technologies, Projection and LED, are capable of meeting the DCI-P3 colour gamut requirements for cinemas. Today, only RGB laser projection can match Rec 2020 colour space requirements completely, delivering a unique colour reproduction within this device category. Today, LED video screens are achieving around 90% of the Rec 2020 colour space which is, in reality impressively close.

Frame rates: The frame rate is the frequency at which consecutive images are displayed on the (cinema) screen. The frame rate for motion picture film cameras was typically 24 frames per second (fps). High frame rate (HFR) refers to even higher frame rates of 48 fps, 60 fps or even 120 fps. Advocates of the format say that the higher refresh rate improves the

quality of the image, especially for 3D images, by reducing stuttering and motion blur. Today, movies shot and projected in higher frame rates are still rather rare, but increasing. Whilst some people believe in the 24 fps thinking that the "cinematic look" will be lost with the use of high frame rates, others recognise it as an opportunity for differentiation and is mainly driven by attitude and therefore demand.

The majority of movies will come with 24 fps, even in the future. However, cinema technology should ideally support higher frame rates in order to support any specialist movie as it becomes available. In general, both technologies present the technical preconditions to support higher frame rates and don't demonstrate any significant differences in this aspect.

Resolution: The number of pixels defines the level of detail. Higher levels of detail allow crisper images and shorter viewing distances. The major standard resolution is 2K (2,048 × 1,080 pixels) but more and more movies and playback systems support a higher resolution of 4K (4,096 x 2,160 pixels). It appears consistent that technical developments will allow even higher resolutions such as 8K and will continue to innovate in this way in the future.

The minimum resolution requirement today is 2K. More cinemas today use systems which support 4K playback to ensure their equipment is future-proof and can deliver high resolution content. Both projection as well as LED video panels provide high resolution playback capabilities. The resolution of LED is achieved by the combination of the size of the screen and the pitch of the LED used. Whilst blanking can be used with projection screens to change the resolution and aspect ratio, with LED the maximum resolution is set according to the size of the screen and pixel pitch, although scalers can be introduced according to the content being input to fill the screen as effectively as needed.

Uniformity: The uniformity defines the consistency of brightness over the entire image. A low level of brightness variation in intensity across the entire screen supports a homogenous and captivating image.

The image uniformity (measured on white level) for projection and for LED is very high (>90%) in general, requiring more expensive high quality LEDs for cinema to fulfil these high demands. It's therefore almost impossible for human eyes to detect differences in brightness consistency on the screen surface. Both technologies fulfil the requirements satisfactorily.

Screen size: Screen sizes vary greatly, mainly driven by environmental criteria such as theatre size and space. The majority of screens provide a width of between 5m and 30m. Technology that easily adapts to the many different screen sizes offers a more flexible solution and eases installation.

The projected image size can be adapted according to the cinema screen size very precisely and fit to almost any screen size request. This flexibility is a huge advantage over LED since the screen size here is mainly related to the pixel pitch and the desired resolution. If different pixel pitches become available in the future, the flexibility of LED will become greater, but still not as adaptable as projection. Customised image sizes purely relating to

available space will become more difficult. For smaller cinemas, extremely high resolution LED screens would be required to meet space and viewing distance requirements, adding another level of cost-up to these cinema operators. E.g. a 2.5mm pixel pitch 4K screen will always have the same width of 10.2m, size adjustment can only be attained by changing the pitch size.

Aspect ratio: The majority of movies are shot and projected using various ratios such as 2.35:1 (anamorphic & Cinemascope) or 1.85:1 (flat widescreen). Advertisements are mainly produced and shown in 16:9 aspect ratio.

Both projection and LED technologies support 2K and 4K resolution and in addition, support the different aspect ratios used today. The aspect ratio is considered to be well covered by both LED and projection. When switching aspect ratio with projection many cinemas use curtains, or mask within the image. This is not so easy with LED, and the audience may question why only part of the LED screen is being used.

3D: A 3D film is a movie that enhances the illusion of depth perception, hence adding a third dimension. 3D movie technology creates a more intense viewing experience and gained popularity in 2009 with the movie "Avatar". Several technologies (active and passive 3D) are used to create and playback 3D movies. The cinema infrastructure must respond to these requirements in case 3D is requested.

3D movie playback is widely supported by the latest projection technology. It appears that passive 3D such as stereoscopic is now the most successful way to deliver 3D in projection. Currently, stereoscopic 3D is not supported by LED. Alternatives with LED technology such as polarizers or active 3D systems either reduce the image quality or aren't convenient and appear not to be very attractive today.

Sound: The sound is the second most decisive factor in creating an immersive experience next to the on-screen image. Audio in cinema is a huge, separate topic. Influencing screen visualisation in cinemas today is the fact that cinema screens are perforated in order to allow transmission of sound from the central speaker which is installed directly behind the screen.

As the projection screen surface is perforated, the speakers are placed behind the screen, to allow sound to travel through it. This supports easy and discrete installation of speaker systems creating the cinema audio quality cinema-goers have come to expect. Since an LED cinema wall cannot be perforated, the speakers have to be positioned elsewhere creating several additional challenges to be considered and solved. Sound appears to be one of the major challenges for LED in cinema with innovative potential for the future.

How to extend revenue streams with image display technology

Both technologies, projection and LED, provide an easy upgrade path and flexibility in terms of connectivity and functionality, ideal for alternative screenings such as eSports, live-streaming of concerts and events or company presentations. Where LED provides higher brightness levels for lights-on activities 'out-of-the-box', for projection, the increased brightness requirements will have to be taken into account and a brighter projection solution may be required.

Newly constructed cinemas can take advantage of the reduced space needed for projection whereby some of the space previously reserved for the projection booth can be freed up for additional seating capacity. For LED screens there is no booth space needed at all, thus more seating and greater income.

Which technology supports a Low Total Cost of Ownership?

CAPEX-related investment cost
How much does a cinema have to initially invest into the different cinema technologies?

The initial purchasing cost for a 10m cinema screen will show a huge differential. Whilst a cinema projector suiting a 10m wide screen will cost between 50,000 and 80,000 €, the cost of an LED screen is multiple times this investment, adding up to several hundreds of thousands of Euros.

When comparing the initial cost of these two technologies, an important differentiator must be considered. When Laser light source brought a super-effective alternative to Xenon lamps, the lifetime estimation of the cinema projection light source was extended to around 20,000h – 30,000h. The need to buy, store and replace lamps has disappeared entirely, this also means that the act of replacing lamps on a regular basis (around every 1,000h to 2,000h) is no longer an incremental part of operational efforts and cost, an enormous benefit. It also erases the need to store different lamps for 2D and 3D projection. The lifetime of LED exceeds the performance levels of Laser based projection systems, reaching an estimation of up to ca. 100,000 hours of operation. A projector's lifespan equates to around 10 years of operation running for ten hours a day; comparing at the same level of operation, LED provides a superior lifetime of more than 25 years. One major question however will be whether such a long life span might outlive the pace of innovation and changing customer preferences, thus potentially making the solution obsolete before it has had a chance to achieve its ROI.

Whilst LED frees up space otherwise needed for a projection booth, an important consideration will be to clarify the additional demand for cooling inside the theatre. In contrast to projection where the display device is not installed within the theatre itself, the heat emission from the LED must be controlled to avoid heat build-up in the auditorium where temperatures could become uncomfortable for the audience thus requiring additional air conditioning to be planned and installed. This consideration doesn't appear to be absurd since the maximum power consumption of a 10m wide LED video wall when operating at full brightness is around 10,000 kWh. Even when considering less brightness and normal operating conditions, realistic power consumption around 3,500 kWh might require specific preparation to ensure a relaxed viewing experience particularly in the front row seats.

For newly built cinemas, with LED a separate projection booth is no longer required thus reducing construction costs and providing additional revenue-generating space for seating.

The installation of an LED wall might be more time-consuming and require more planning and preparation compared to installing a projector. This impact is more significant for locations where the infrastructure for projection already exists and simply requires a refresh.

* Preconditions: Projector: normal 1,3 kWh; LED: normal 3.5 kWh;
Cost per kWh = € 0,291 (Source: bdew.de, 2015)

OPEX related shifts

The energy costs relating to an LED video wall will be approximately € 0.64 higher for each hour of operation compared to a projector. This results in increased energy costs of ca. € 2,330 per screen per year*. Additional costs for cooling in the main auditorium might have to be factored in. Laser based projection eliminates the need for exhaust vents and therefore allows less power-hungry projector cooling; in addition to the lower power use for some laser phosphor models.

The introduction of laser light sources for projection reduces maintenance efforts and costs for consumables (bulbs) significantly. Apart from cleaning the air filters, the maintenance efforts for laser based projection systems are compellingly low. The same appears for LED; apart from recalibrating the video panels when needed, maintenance efforts are low.

How to improve operational efficiency

Cinema operators have to find an efficient way to service and handle defective screen technology. While projection technology can receive updates behind the scenes in the projection booth, servicing LED would have to take place on centre stage. In general, recalibration of LED walls is possible, although cinemas will have to find an effective way to ensure a uniform image performance when replacing a worn LED module with decreased brightness output with a new module providing higher brightness levels compared to the rest of the wall.

In order to protect the cinema screen against external impacts such as knocks or liquids, the protection of the LED screen surface with special coatings or similar should be considered. If a drink is dropped and it splashes over the screen surface, cleaning the projection screen doesn't cause any issue; in contrast, this could well be a problem for an LED surface. It is recommended with LED that a silicon cover is installed in front of the LED modules which is anti-reflective and also removable for cleaning.

Cinema operators have to bear in mind that certain LED systems are proposed to work with specific server and speaker systems. A system that provides high system flexibility means that the preferred system components can be selected to ensure lower investment efforts as well as lower maintenance and follow-up costs. If the operator is forced to commit to specific components this may well up the costs when it comes to servicing.

Conclusion: Making the right decision

How to remain attractive and competitive for classical cinema-goers and newly attracted audiences is a key question that cinemas must consider carefully. For some cinemas luxury seats with massage options or ordering concessions from your seat or concierge service might create possible ways of differentiation. For the vast majority of cinemas though, upgrading the viewing experience appears to be the most effective countermeasure when strengthening their position.

Promising developments in both laser projection as well as LED widen the choice. While projection is a mature and flexible technology and is established as the standard in cinema today, LED is the new entrant trying to find its place in cinema, providing some technical benefits whilst paired with higher cost. Making the right decision requires an objective evaluation from experts providing answers to the many questions around LED that are still open and have yet to be answered. Cinemas need to find a way to achieve the ideal screen size for LED whilst currently the pixel pitch limits free size scaling. Similarly, they need to establish a sound experience comparable to speakers mounted directly behind the screen if they opt for LED. A number of areas still need further investigation: does LED require specifically graded versions of movie content due to the inherent higher brightness levels; what thermal management is required; how can maintenance and service be operated most effectively; what about 3D playback... plus much more.

Today, many different LED technologies such as Chip on Board are on the horizon allowing for tighter pixel pitches and may bring about lower costs. The possible technology shift towards LED might lead to different considerations with reference to content for film producers.

Whilst LED is making its first steps in cinema, projection is a mature technology providing a sustainable upgrade path benefitting from the compelling advantages of a laser light source. All the requirements for an immersive cinema experience such as Hollywood Image Quality, operational safety, longevity and service support are fully available and established providing a bright choice for cinema operators with a complete portfolio. Cinema operators must maintain the same security levels against piracy and misuse behind the back of an LED screen as they would do in the projection booth.

A trusted consultancy partner can provide cinemas with the confidence to follow a future-proof path for cinema-wide operational efficiency

The launch of cinema LED displays is widening the choice for cinema operators in achieving an immersive cinema experience. Cinemas should balance carefully the pros and cons of the theatre room technology available and consider which technology best fits to their targets, preconditions and competences. NEC, a hardware-agnostic display solutions provider that delivers cinema-specific consultancy continues to work closely with cinema operators worldwide as it has for more than 10 years. The deep level of understanding incorporating both projection as well as LED video screens, ensures a high investment security and best choice for cinema operators. In addition to the cinema screen, NEC provides modern display solutions ranging from touch-screen self-ticketing kiosks to digital concession menu boards, interactive movie posters and wayfinding. NEC effectively supports theatres in creating a cinema-wide world of visual excellence enriching the customer experience whilst maximising operational efficiency. NEC knows the specific demands of cinemas and can provide customised finance and service proposals for the main event as well as for captivating signage solutions encompassing both the outside façade and inside in the lobby and concessions area.