
Sony Digital Cinema 4K
A new chapter in digital cinema
Exploring the economics of laser projection to make the right investment decision
SONY
www.pro.sony.eu/dcinema



There are a number of challenges facing the cinema exhibition industry. Without generating an exhaustive list we could note that offering patrons a movie experience not achievable at home, simplifying operations and reducing operational costs are high on the list.

Taking Digital Cinema where it has never been before

The Virtual Print Fee system was introduced to support cinema operators with the initial round of investment in digital projection but it has to be recognised that in this post VPF era any new offering to the cinema industry must either contribute to increased box office revenues in the long term or reduce operating costs.

Projectors employing diffused laser light sources have been recognised as offering the opportunity for higher brightness levels together with enhanced image quality and potential reduction in maintenance overhead. Practical implementations of a laser illuminated projector for cinema bring together a number of technology options for addressing the light source itself, the optics and method for implementing 2D and 3D display. The first commercially available models entered service in the past year. That being said, laser illuminated projectors are still at an early stage with recognition that there are still developments to come to make them suitable for widespread deployment. Here we examine the technology options in the context of the investment considerations to be made by cinema operators.

Sony has not yet released a laser illuminated projector for cinema onto the market but we have been actively investigating all of the options for large screen laser projection with particular emphasis on solving the conundrum of combining the benefits of laser illuminated projection within the economic constraints of cinema exhibition.

Sony Semiconductor began manufacturing laser diodes in 1986 and subsequently became a leading supplier to the CD, DVD, Blu-ray and games console markets. By October 2010 Sony had already achieved shipments of 3 billion laser diodes. In 2003 Sony began development of high powered laser diodes that were used to create the 60,000 lumen laser projection exhibit at the 2005 Aichi Expo onto a 50 metre wide screen. An impressive technology exhibit but it was too early to consider commercial development. The early scanning laser methodology gave way to diffused laser illumination combined with development of our own, DCI compliant, large screen LCoS display devices and in 2012, we showed the viability of High Frame Rate 3D projection with a laser light source using advanced de-speckling techniques for high quality images on a silver screen.

The new light source

Xenon lamps have served cinema exhibition well for over fifty years but since the move to digital and the resurgence of 3D we have become familiar with a number of limitations. High power xenon lamps for digital projectors are about 7KW, generate in the order of 33,000 lumens brightness and struggle to achieve the widely accepted target of 4.5ft-L in 3D on large screens which out of necessity is far below the 14ft-L level specified by the Digital Cinema Initiatives (DCI) for 2D. For any given screen, projectors employing xenon lamps are not able to achieve the two target brightness levels for both 2D and 3D using the same lamp. A lamp chosen to give the accepted 4.5ft-L brightness for 3D will be too bright for 2D, even at minimum power and a lamp chosen for reference brightness in 2D would be far too dark for acceptable 3D display. In theory the theatre should change lamps depending on whether 2D or 3D movies are being shown.

From a cost of ownership point of view, high power xenon lamps are expensive, have a very short life of just a few hundred hours and suffer a rapid drop-off in brightness during the first few hours of use. They are also electrically very inefficient because they generate a full spectrum of wavelengths from ultra-violet, through the visible spectrum and into the infra-red region. The projection process only requires narrow-band light in the Red, Green and Blue regions and all other light energy is filtered out and wasted.

Laser light sources utilising semiconductor laser diodes offer the potential to closely match the needs of modern cinema exhibition. Multiple high powered laser diodes can be combined to achieve brightness levels well above the capabilities of xenon lamps and achieve the desired 14ft-L reference brightness on large screens for 3D as well as 2D. This method offers good scalability with the right number of laser modules being employed to suit the scale of the screen and different numbers of modules can be switched ON/OFF depending on the light level needed for a particular image format. There is a significant improvement in electrical efficiency because the laser diodes generate just the Red, Green and Blue wavelengths required.

Cinema operators are freed from regular lamp changes because laser modules have the capability for very long life times combined with a very slight reduction in brightness. Industry expectations have already settled in the region of 20% reduction in brightness over a 30,000 hour life which equates to about 8 years under typical cinema operation.

The image quality improvements to be expected are brighter 3D images, better uniformity and the potential for more vivid colours. Xenon based cinema projectors reproduce a limited colour gamut known as DCI P3 but laser light sources make possible the display of a far wider colour space, known as Rec 2020, allowing us to see more of the deeper, saturated colours we experience in real life that have not be possible to reproduce on other displays.

Laser light sources utilising semiconductor laser diodes offer the potential to closely match the needs of modern cinema exhibition.

The image quality improvements to be expected are brighter 3D images, better uniformity and the potential for more vivid colours.

	Xenon	Laser
Brightness	• Limited to circa 33,000 lumens • 3D@4.5ft-L on large screens	• 60,000+ lumens • 3D@14ft-L on large screens
Scalability	Must exchange lamp to achieve wide power range	Vary number of laser modules switched ON/OFF
Efficiency	Much input energy wasted generating unwanted wavelengths	Laser modules generate only the desired wavelengths
Light source life time	Short life high powered lamps require frequent replacement	Long life laser modules require no maintenance
Image quality	Current DCI P3 colour space	Rec 2020 extended colour space



The challenges

Laser light sources for this application are still in their relatively early stages of development and there are a number of technical challenges to be overcome or at least carefully managed.

Lasers generate heat during the course of operation and if the temperature of the light emitting area is not controlled the laser may be degraded and suffer a reduction in reliability and operational life. The first commercially available RGB laser illuminated projectors have employed extensive, active cooling systems which add to system complexity and costs of ownership.

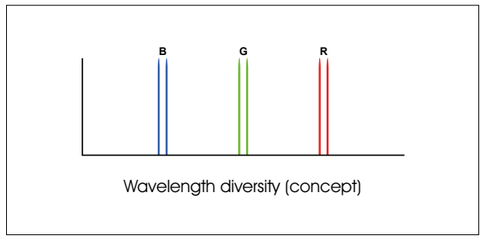
Semiconductor Red and Blue laser diodes are readily available but high power semiconductor true Green lasers have not been easily achievable. The Green laser light employed in projectors available to-date is synthesised using a process known as Second Harmonic Generation (SHG). An infra-red wavelength laser diode is combined with a non-linear crystal material which doubles the frequency, and therefore halves the wavelength, to produce visible green light.

The SHG approach requires more complex, costly and bulkier laser modules. The future availability of true Green semiconductor laser modules will enable smaller, more efficient Green laser light sources at a lower cost and this is seen as a key development required to make laser illuminated projectors suitable for widespread deployment.

Along with image improvements comes one notable image impairment known as speckle. Laser light is coherent, narrow band and speckle is caused when its light rays reflecting from an uneven surface such as a screen interferes with the incoming light rays. The visual effect is the random bubbling of light and dark points we have all seen in the dot of a laser pointer which manifests as a random shimmering visual noise across a cinema screen, most noticeable in large patches of colour and especially evident in the Green channel.

Manufacturers have developed a number of speckle countermeasures such as vibrating the screen in order to randomise the reflected rays, rotating diffusers and the use of a low gain white screen with its smoother surface is itself an anti-speckle measure compared with using a high gain silver screen.

Xenon lamps do not suffer from speckle because of the wider bandwidths of the Red, Green and Blue channels optically filtered from the white light. The laser equivalent, known as wavelength diversity, is created by operating multiple lasers a few nanometres apart in wavelength for each colour channel. Each manufacturer has its own configuration of how wavelengths are used.



Wavelength diversity (concept)

New industry standards are expected to become effective across the world by the end of 2016 for laser illuminated projectors.

Safety standard revision related to laser projectors

Although laser beams present a hazard risk to the human body (especially to eyes), the laser light projected from a laser illuminated projector does not present the same risk because the coherency that is a potentially harmful feature of laser beams is lost. Under this consensus, the International Electrotechnical Commission (IEC) revised the standard of laser safety last year to classify the light from laser illuminated projectors in the same way as lamp-based projectors. Additionally, the IEC specially developed a new standard that is appropriate for the optical safety of image projectors in June 2015.

Europe and Japan are proceeding with the legal acceptance of these new standards. On the other hand, in the US, the FDA which has jurisdiction over the safety of this technology is examining legal acceptance at this moment thanks to the activities of the Laser Illuminated Projector Association (LIPA) which has Sony as one of its founding members.

These new standards are expected to become effective across the world by the end of 2016, and, in that case, laser illuminated projectors will finally receive the same treatment as traditional lamp-based projectors.

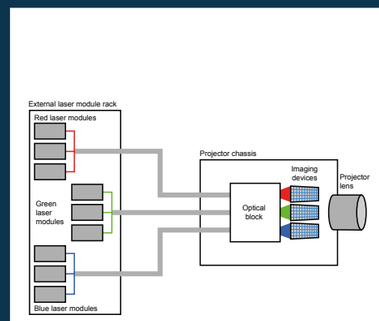
Laser projector architectures

Commercial developments of laser illuminated projectors for cinema have centred on three core architectures. The first two implementations are full RGB laser projectors that utilise semiconductor laser diodes for the Red, Green and Blue channels. The third is a hybrid configuration which employs a laser source to pump, or excite, a phosphor coating to emit light as the primary light source. Sony began its current phase of development in laser illuminated projectors for cinema in 2010 and elected to investigate the merits of all three options.

RGB fibre coupled laser: This implementation utilises optical fibre cables to route the laser light from Red, Green and Blue modules housed in a rack over to the projector head. The advantages of this architecture are to allow the laser modules with their noisy cooling system to be located in a distant room away from the projector head and to populate the rack with the optimum number of laser modules to match the screen size.

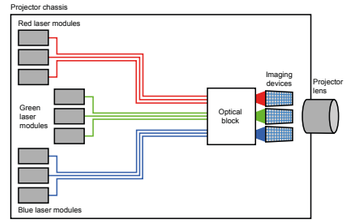
However, while the optical fibre itself exhibits low loss, the practical implementation of the coupling system including input and output of the fibre and the coupling into the projector's optical system introduces significant loss. The adoption of fibre coupling suggests the projection system would require a significant overhead of laser light capability just to overcome losses in the fibre system. This may not be a desirable strategy given the laser modules constitute a significant proportion of the projector cost.

RGB Fibre coupled



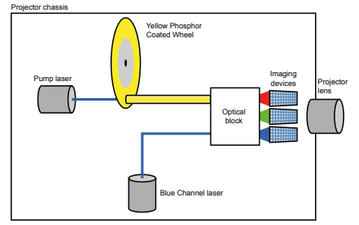
- ✔ High Brightness
- ✔ Scalability
- ✔ Rec2020 colour space
- ✖ energy loss in fibre

RGB Direct coupled



- ✔ High Brightness
- ✔ Scalability
- ✔ Rec2020 colour space

Blue Pumped Phosphor



- ✔ Lower Brightness: phosphor is the light source
- ✔ Limited scalability with multiple phosphor modules
- ✔ P3 colour space

RGB direct coupled laser: In this configuration laser modules comprising matrices of Red, Green and Blue laser diodes are housed in the projector chassis allowing the light to be injected directly into the optical block. The efficiency of the direct coupling mechanism needs to be taken into account but it provides an efficiency improvement over fibre coupling.

Fewer laser modules are required to achieve the same brightness level compared with fibre coupling but the projector chassis needs to be larger to accommodate the many laser modules required to achieve high brightness, especially if current implementations of SHG green laser modules are to be used.

Blue Pumped Phosphor: Also known as a phosphor wheel projector, utilises a laser to "pump", or stimulate, a phosphor coated wheel to emit light as the main light source. A blue laser is used for convenience and cost efficiency, hence the name 'Blue Pumped Phosphor'. This technique was first introduced by a number of manufacturers, including Sony, within their business projector ranges and manufacturers in the cinema industry have been developing refined versions capable of meeting the additional performance requirements of cinema. In order to meet the P3 colour space requirements for cinema, the basic white coating on the phosphor wheel used in a business projector is replaced by a hybrid light source comprising a yellow phosphor wheel to provide the Red and Green channels along with a dedicated direct laser source for the Blue channel.

Since the primary light source is phosphor rather than laser based, it is not possible to achieve the large screen brightness or Rec 2020 extended colour performance associated with RGB laser projection. The attraction, however, is that Blue Pumped Phosphor projectors benefit from the long life and reduced maintenance of the laser diodes at a substantially lower cost. The first cinema projector employing Blue Pumped Phosphor that appeared on the market achieves 2D reference light levels on high gain screens up to 11m. Development work on this technology continues with the aim of reaching higher brightness outputs to encompass a wider range of screens.

It is interesting to note that from the first generation of laser projectors released onto the market, three of the main cinema projector manufacturers elected to launch models based on a separate architecture. Early adopters requiring high brightness are able to choose between an RGB fibre coupled system employing dual projection for 3D and an RGB direct coupled projector that retains the triple-flash method of 3D display. At the other end of the scale, there is also a Blue Pumped Phosphor projection system for smaller screens.

It has to be recognised that the cinema exhibition industry has made a huge investment in conversion to digital projection over the past few years and in addition to offering new laser projector models, the projector manufacturers have a part to play in offering replacement light sources for the existing installed base. However, it is one thing to design a laser projector given a clean sheet of paper but adapting the new light source configurations to efficiently integrate into chassis and light paths designed for xenon and high pressure mercury lamps brings with it an additional set of challenges to be overcome.



3D technology

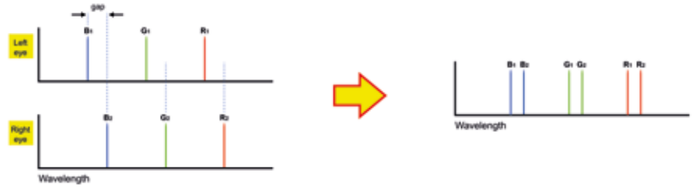
The desire to produce brighter 3D has been a key motivation for the development of laser illuminated projectors. 3D had been an unexpected but welcome bonus in the early days of the digital roll out but dark, under-performing images from xenon lamp projectors are regarded to have contributed to a decline in 3D movie audience levels and box office. This new chapter in projection technology is providing manufacturers with the opportunity to revisit their approaches.

The core principles in 3D projection for cinema remain the same. The projector displays the separate Left eye and Right eye streams of images and optical filters are used to maintain separation to ensure that the appropriate images only reach the eye for which they are intended. Traditionally, projectors require a filter arrangement fitted to the projection system to separately encode the Left and Right eye images which are subsequently decoded by corresponding filters (lenses) in the audience's 3D glasses.

The most popular 3D visual encoding method used in cinema today is based on circular polarisation with separation achieved using clockwise polarisation for one eye and anti-clockwise polarisation for the other eye. Polarisation benefits from optical simplicity, cost effective (disposable) glasses with acceptable image crosstalk or 'ghosting'. However, a high-gain silver screen is required to maintain polarisation of the light reflecting from the screen which traditionally suffers from hot spots and poorer off-angle brightness.

Colour separation 3D from Dolby provides the main alternative technique. In conventional xenon lamp projectors, dichroic filters in the projector separates each of the Red, Green and Blue primary colours into two separate shades, which could be represented as R1, G1, B1 and R2, G2, B2. One set of primaries is used for the Left eye and the other set for the Right eye. Corresponding filters in the audience's glasses maintain image separation. This technique is attractive because of its suitability for use with conventional low gain white screens, which avoids hot spots, gives near equal distribution of brightness to all seats in the auditorium combined with minimal or no perceivable ghosting. It is therefore regarded as higher quality 3D but brighter projectors with more powerful, costly light sources are needed to overcome higher light absorption of the white screen and losses in the colour separation filters which has tended to limit this system to smaller screens. Additionally, the 3D glasses utilise optically complex lenses which are relatively expensive so require re-use with all the additional costs involved in collection, washing as well as replacement of damaged or stolen glasses.

Colour separation 3D process



The projector uses 6 primary colour lasers:
- Red (R1), Blue (B1), Green (G1) for the Left eye
- Red (R2), Green (G2), Blue (B2) for the Right eye

The six Red, Green and Blue primary lasers are all projected onto the screen

The introduction of high brightness laser light sources provided the opportunity to apply the image quality of colour separation 3D to larger white screens and finally achieve the desired 14ft-L brightness levels anticipated to restore 3D box office figures. The low efficiency colour separation filters previously used in the projector to create the R1, G1, B1 and R2, G2, B2 primaries are replaced by laser diodes tuned to these six wavelengths - hence the name 6P – to provide a more light efficient 3D.

It could be noted that the 6P technique acts as a form of wavelength diversity, reducing speckle when both sets of primaries are used to display the same 2D images. However, looking ahead to the future use of 2D Rec 2020 extended colour space content in premium screens, it would be necessary to run these projectors in 3P mode to achieve the precise primary RGB points of the extended colour gamut. This diminishes the anti-speckle benefits of 6P for 2D.

It could be suggested, however, that the core economic fundamentals have remained unchanged; brighter, more expensive light sources are required to overcome losses with the low gain white screen and the expense of purchasing and maintaining the 3D glasses make it less attractive to deploy this type of system across the broader number of 3D capable screens typically found in a multiplex.

The cost effectiveness of 3D polarisation already highlighted can also be applied to laser illuminated projectors and could offer a technique suitable for more widespread deployment.

The requirement for a silver screen still remains but we anticipate that speckle can be reduced by the latest generation of special surface silver screens which also benefit from improved brightness distribution reducing the traditional concerns over hot spots and off angle brightness performance. Wavelength diversity provides the main speckle reduction from a comprehensive combination of Red, Green and Blue wavelengths.

We have found that high efficiency light throughput can be achieved with LCoS imaging devices thanks in part to the natural polarising effect of its liquid crystal imaging system. Polarised light in a dual stack system offers very useful anti-speckle advantages, 2D images displayed with both clockwise and anti-clockwise polarised light reduces the reflected light interference that would give rise to speckle. Furthermore, stronger wavelength diversity can be applied to each eye in the form of additional Red, Green and Blue wavelengths without the concerns about affecting image crosstalk as could be experienced with colour separation 3D.

A dual polarised system has advantages for display of enhanced colour Rec 2020 content in 2D. Whereas a 6P system would need to drop down to 3P mode to achieve the precise Red, Green and Blue colour primary co-ordinates, a dual polarised system would benefit from Red, Green and Blue primaries displayed by both the clockwise and anticlockwise image channels.

Total cost of ownership

Lasers are generally targeted to have a 30,000 hour life resulting in zero light source replacement costs over this period. During this time a xenon lamp projector would undergo many expensive lamp changes, especially when a double-stack xenon system is used to achieve equivalent brightness. Recent discussions regarding cost of ownership heralded this as the key and significant saving when moving to laser.

Additional savings are found in the areas of power consumption as well as removing many operational maintenance activities such as carrying out lamp changes and subsequent realignment.

It should be recognised that laser light sources are a new and expensive technology which will add significantly to the initial projector purchase cost compared with the xenon equivalent. When purchasing a laser illuminated projection system you are effectively "buying all of your lamps up front".

It is suggested here that Total Cost of Ownership including initial hardware is the more useful metric for comparison and that laser illuminated projectors start to become economically viable when their total cost of ownership approaches that of the xenon equivalent over the same period.

For further information visit **www.pro.sony.eu/dcinema**

Sony Digital Cinema 4K

© 2015 Sony Corporation. All rights reserved. Reproduction in whole or in part without permission is prohibited. Features and specifications are subject to change without notice. All non-metric weights and measurements are approximate. 'Sony' is a registered trademark of Sony Corporation. All other trademarks are the property of their respective owners.

Distributed by

Sony is the leading supplier of AV/IT solutions to businesses across a wide variety of sectors including, **Media and Broadcast, Video Security, Medical, Digital Cinema and Displays**. It delivers products, systems and applications to enable the creation, manipulation and distribution of digital audio-visual content that add value to businesses and their customers. With over 25 years' experience in delivering innovative market-leading products, **Sony** is ideally placed to deliver exceptional quality and value to its customers. Collaborating with a network of established technology partners, **Sony** delivers end-to-end solutions that address the customer's needs, integrating software and systems to achieve each organisation's individual business goals. For more information please visit **www.pro.sony.eu**

@SonyProEurope / www.twitter.com/SonyDCinema4K **www.facebook.com/SonyDigitalCinema**

HCT_Laser_Projectors_White_Paper_J4270_ENG_24/07/15

SONY