White Paper

4K resolution: more than meets the eye

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The term ’4K‘ has obtained an almost mythical status in digital cinema projection. Some projector brands have made it the spear-point of their product offering for a number of years now, while others cannot wait to harvest the results of their 4K investments. Some exhibitors are convinced 4K will be THE next trend in motion pictures, while others prefer to take on a careful wait-and-see attitude. What is 100% certain is that 4K is a heavily discussed topic.

In this White Paper, we want to try to rationalize these discussions. We will explain what 4K is, what enabled it, and why it is only one of many important parameters in digital cinema projection. By no means do we want to minimize the tremendous technological effort that went into 4K and the major opportunities it promises; but we think it’s important to support the community with objective data that enable everyone to make the best choice for his or her specific situation.

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1 TECHNOLOGICAL 4K ENABLEMENT

In digital cinema projection, the terms 2K and 4K indicate the image resolution that is projected onto the screen. In contrast to digital still cameras (where owners like to impress each other with their number of 'megapixels'), in cinema the commonly used resolution parameter is not the total pixel count. Because the aspect ratio (number of pixel columns divided by number of pixel rows) is standardized, you only need to know 1 dimension to calculate the other. Multiplying them both gives the total pixel count or resolution, expressed in megapixels (just like in digital still cameras).

In the particular case of 4K we are discussing here, 4K indicates that there are close to 4000 (actually 4096) pixel columns that can be projected onto the screen. The aspect ratio used for the active chips in digital cinema projectors is 1.8962 – so it's easy to calculate that the number of rows in 4K digital cinema equals 2160. Note that the total pixel count of 8,847,360 (in digital photography, we'd call this 9MP) is actually 4 times higher than that in 2K!

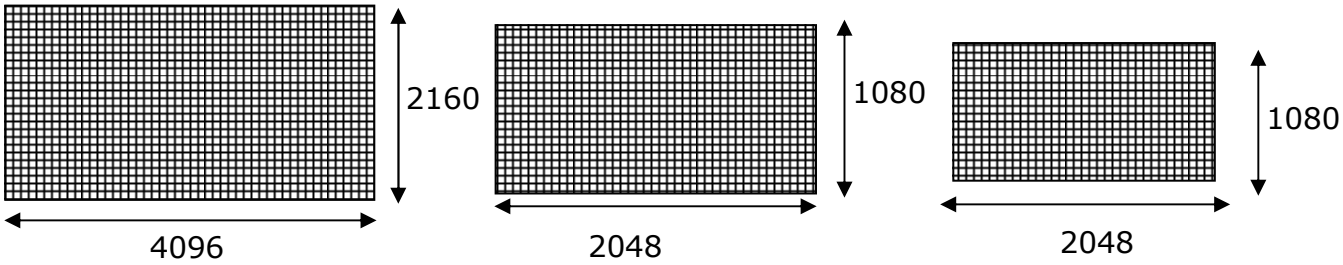

Figure 1. Comparison of the resolution and relative sizes of Digital Cinema DLP chips. From left to right: 1.38" — 4K, 1.2" — 2K and 0.98" — 2K

So, what's all the fuss about? Just add a few million pixels, right? The devil is in the details: the microscopic details of the chips at the heart of digital cinema projectors. In order to make these projectors as efficient, compact and affordable as possible, these chips must be as small as possible. Texas Instrument's DLP technology – which is the leading technology in digital cinema today – puts these 9 million pixels on a chip with a diagonal measurement of 1.38". This means that each active pixel (in the case of DLP technology, this is a digital mirror) is about 57 square microns in size. If you would place a human hair on these microscopic mirrors, it would cover up more than 40 rows or columns. (By comparison, we mention here that Sony's LCoS technology for Digital Cinema puts the 4K image onto a chip measuring 1.55" diagonally.)

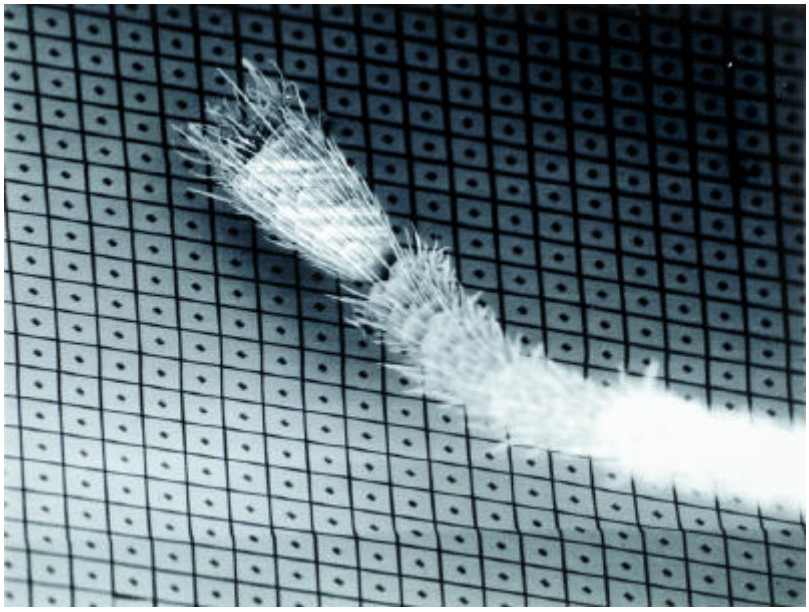

Figure 2. Micrographic photo of an ant leg on a DLP chip surface.

It is important to understand that enabling 4K projection is a major technological accomplishment by the chip manufacturers. People wondering when '8K' will be available can now do the math on the pixel miniaturization themselves.

2 IMAGE QUALITY

A crisp and bright picture on the cinema screen is enabled by a sophisticated combination of technologies that make digital cinema projectors state-of-the-art devices. As measured on the screen, image quality is defined by brightness, sharpness, contrast ratio, resolution, frame rate, color accuracy, uniformity, and many other parameters. It is important to understand that 4K only influences some of these parameters and that it's only one piece of the image quality puzzle.

When going from 2K to 4K on a digital cinema projector, the 2 main parameters that are influenced with respect to image quality are resolution and brightness. The fact that resolution is improved when having 4 times as many pixels available might seem obvious, but remember that this is only relevant when the content you project also has the 4K resolution. If this is not the case, the image will merely be up-scaled, and you won't be able to enjoy your extra pixels.

Furthermore, even when 4K content is available, the extra resolution will not necessarily be perceived by the audience in the auditorium. This is due to the limited acuity of the human eye. To support the need for 4K, some people put forward the value of 1 arc minute (or 1/60 of a degree of arc) as the holy grail of human visual acuity. The truth is that this value comes from eye tests on patterns that are not relevant to cinema and the cinema environment. On typical motion picture content, in the darkened environment of a movie theater, the human eye works in a different manner and is less sensitive to resolution.

How do you decide when the extra resolution will be noticed? That's a difficult question – we'll explain how to make this decision later on. For the moment, we simply want to present what the audience will actually experience.

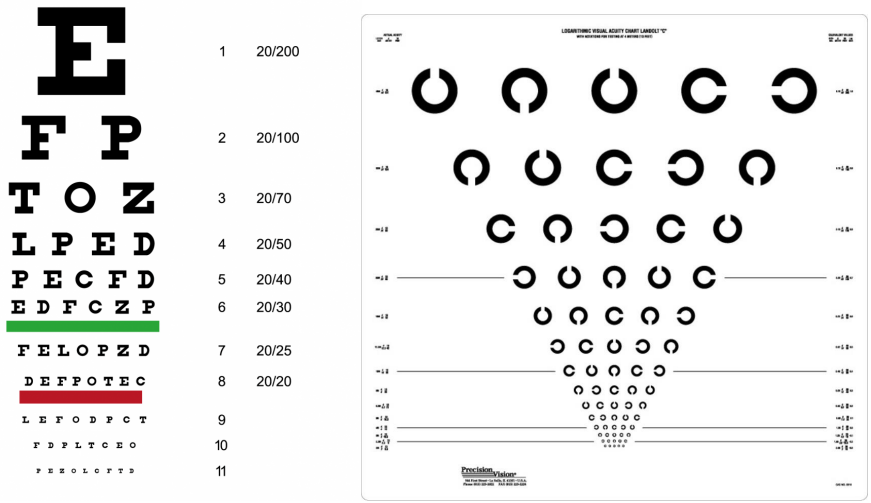

Figure 3. Snellen chart (left) and Landolt C optotypes (right) used to define the visual acuity standards of 20/20 vision and a visual angle of 1 arc minute.

It might come as a surprise to you that upgrading to 4K can also have a positive impact on brightness. This is because the 4K chip is slightly larger than the 2K chip (see above). This means that more light can be put through the optical system, which leads to higher optical efficiency (expressed as lumen per Watt, lm/W). When working with the same input power, this higher efficiency leads to higher on-screen brightness.

But again, nuance is required here, since other parameters (in addition to chip size) also affect optical efficiency. For instance, you might be tempted to think that a bigger LCoS chip would be more efficient than a smaller DLP chip; but, in fact, inherent technological advantages give DLP an efficiency advantage of more than 20% (even though the DLP chip diagonal is 1.38" compared to 1.55" for LCoS).

Moreover, in 3D, movie-goers may find that the image rendered by a 4K DLP device looks better than the one rendered by an LCoS. Indeed, because LCoS has to magnify each pixel on the device to render the projected 2K (3D) image, the inter-pixel space is also magnified.

A note for cinema owners: when comparing the various 4K technologies, be sure to compare *all* of the image parameters. Many of them are quantified in the product spec sheets (brightness, contrast ratio, color gamut, uniformity, …), and you should compare them all to determine the best technology.

3 IMPLEMENTATION

As described above, resolution is just one of many parameters that contribute to image quality. How the projector's internal parameters generate the image quality on the screen is a result of the design decisions (the 'secret sauce') each brand makes.

For example, some brands use a dedicated dual-lens system to produce 3D. Not only does this lens reduce resolution to a value lower than 2K, the setup also has an inherent inefficiency that makes the technology useless for screens more than 15 meters (49 ft) wide. To make matters worse, this lens also has an impact on sharpness. And, because it's too complicated to quickly replace the lens when switching to 2D, all your screenings are affected. So, just when you're ready to celebrate your state-of-the-art, 4K-chip-enabled projector … your supplier's design choice reduces your resolution, brightness and sharpness. As we saw above, these are three important factors contributing to image quality.

Figure 4. A (non-exhaustive) overview of 3D-enabling components that are introduced into the optical path of the Digital Cinema projector. From left to right: RealD XLS dual-lens system, RealD Z screen, and Master Image polarization wheel.

In another example, Barco has a patented sealed engine, which it has been using to protect chips since 2002, long before 4K was 'the talk of the town'. As described above, the feature size of a 4K chip is microscopically small. Protecting it from dirt and dust is of crucial importance to guarantee an error-free image and a long lifetime. This means that the value of having such a sealed setup is even more important in the case of 4K projection!

As is the case with the external parameters mentioned previously, comparing the internal parameters is critically important when assessing 4K technologies and brands. Of course, the external and internal parameters are often closely related: e.g. Barco, the official Guinness World Record holder for the brightest digital cinema projector, achieves that result by using state-of-the-art optical design, materials and coatings to enable minimal light loss in the projector's engine. Some of these factors are not immediately visible in the specs or on the screen, but should interest you because they always impact the device's lifetime or total cost of ownership. Don't be afraid to ask your supplier what he has done to optimize these parameters as well.

4 SETTING UP 4K

Now, you've read through this article, you've carefully compared different technologies and brands, and you're ready to buy one or more 4K projectors. What's next? Do you install a 4K projector in all your theaters and auditoriums, or just in some? If you choose a limited selection, which ones do you choose?

As mentioned above, there are 2 important aspects to consider when making this decision. First, the increased resolution will not be perceived by audiences on all screens. The average movie-goer will most likely not notice the difference on screens less than 10 meters (33 ft) wide; while on screens more than 20 meters (66 ft) wide, the absolute reduction in pixel size is probably high enough to be enjoyed by all audience members. What's the sweet spot of screen sizes in between? It's hard to establish a rule of thumb, since this depends on the theater layout (among other things). So, if your 4K decision is influenced by whether it will bring a visible difference to the audience, be sure to consider your screen size and theater layout.

A second aspect is the fact that 4K is only one of many contributors to image quality. From that viewpoint, you might want to limit 4K to those screens where you want to provide a premium movie experience. For those premium screens, many exhibitors install a 3D-enabled projector that can provide sufficient brightness for a vibrant image. In this case, 4K can bring extra immersion to the total movie experience. So, if you regard 4K as a tool for adding extra value to your premium screens, be sure to select a technology that also delivers a premium experience with the other parameters that make up the movie experience. Choose the brand that has the best brightness, contrast ratio, color accuracy, uniformity, and so on.

Working with 4K also impacts the projection booth setup. To support the 8 times higher data rate to the 4K chips, which comes with the higher resolution, 4K projectors have the video processing component of their playback server integrated into the projector. This integrated video processing component is commonly known as Integrated Media Blocks (IMB).

At this moment (Q1 2011), the 4K enhanced resolution is limited to 2D content by the available technology as well as by the DCI standards. As for 3D technologies, the situation has not changed: Sony offers its proprietary dual-lens system, while DLP vendors are compatible with the major 3D technologies. Be aware that this impacts the exhibitor's options with respect to cheap vs. expensive 3D glasses, white vs. silver screen, etc.

Expanding to 3D in 4K will depend on multiple factors in the different domains of the movie ecosystem. With regard to content visualization (server, projector), not all technologies will be able to support the higher 4K data rates of 48 frames per second. Furthermore, this will also require an amendment to the DCI specifications and might require as well the definition of higher compression bit-rates to sustain the high quality of DC images, at the expense of larger storage requirements. Some projection technologies even show 3D in less than 2K resolution. As for content creation (studios, directors, post-production, …), the focus is not necessarily on higher resolutions. They are also looking into other enhancements, such as higher color gamut, higher brightness, and higher frame rate. A famous Hollywood director put it like this: "*The race for higher resolution is being run by still pictures – motion pictures would benefit more from higher frame rates.*"

At this time, only DLP plays back 3D in full 2K. As the industry evolves towards higher frame rates, higher brightness and higher resolution, only DLP will be able to support all three. The other technologies have limitations on brightness and resolution in 3D, as well as inherent technical limitations to supporting faster frame rates.

5 CONCLUSION

We hope this article has improved your understanding of 4K and will help you ask the right questions when investing in this state-of-the-art technology. 4K's enhanced resolution can be an important contributor to adding extra value to your premium screens. However, not selecting wisely, disregarding other important parameters (brightness, contrast ratio, uniformity, …) can destroy your carefully constructed value proposition. As always in cinema, it's important to look at the total picture. All kidding aside, this can prove invaluable when considering such things as device lifetime and total cost of ownership.