WHITEPAPER

Comparing High-speed Camera Solutions for Live Broadcast Applications

Introduction

Background

Slow-motion and super slow-motion replays have been an important part of media storytelling in nearly all live sports productions for many years. But, more and more often they are also used in other entertainment productions such as game or dance shows to deliver a new level of emotional connection to these types of studio productions.

There are several options for the speed of the image acquisition and replay. Every option has its own strengths and limitations. What are the typical requirements for the different applications? Why are there only a very limited number of the possible scenarios that have been widely accepted?

The following paper explains all these points in more detail with guidance for choosing the right technology for the application.

Why Triple-speed for *Live* Applications?

In nearly all slow-motion applications, the replays are done in ⅓ of real time. This speed became the *de facto* standard many years ago. Three times slower than real time offers the best balance between the additional time needed by the viewer to see the motion information and the additional time needed to play back the video.

Replay at four or five times slower generally does not offer the viewer much additional information while consuming too much time in the show for the replays. Reducing the replay speed to only two times is not long enough for the viewer to see additional motion, thus defeating the purpose of slow-motion replay.

Ideally the speed of the image acquisition is directly related to the slow-motion replay speed. For example, if the slow-motion replay speed is ⅓ of real time, the camera needs to operate three times faster to capture the additional motion information. During the slow-motion playback, each of the pictures generated by the camera will be shown once.

Grass Valley Cameras
Breda, Netherlands
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The next highest logical speed is to double the frame rate from three to six times. The higher frame rate is then available for special slow-motion, e.g., to show the highlights of the most important actions during a break, which could then be played back even slower with full quality. During the rest of the show, the standard ⅓ real time replay is used and the image is kept smooth by showing every second frame during live playback.

Note that speeding up the camera introduces other factors that impact image quality. For example, each image has a shorter exposure time, which reduces the amount of light available to the imager to generate a signal for each image. For most typical super slow-motion applications, image capture at three times the speed provides the best possible quality through an optimal compromise of sensitivity and motion resolution.

Workflows

In most cases, the high-speed signals are delivered from the camera to the playback system as individual phases and can be played back immediately. An additional benefit of high-speed cameras is the generation of a regular camera live signal by interpolating the various high-speed phases.

Ideally, all signals should be available in the same video format for both live sources and slow-motion playback. However, in many UHD productions, for cost and bandwidth reasons, the high-speed cameras are operated in an HD format and upconverted to UHD during replay by the replay system. To achieve playback that is free from scaling artifacts such as moiré and aliases, it is important that the HD signals are as good as possible and captured in a progressive image format. Where this upconversion from HD to UHD still seems acceptable for slow-motion playback, this is rather unsatisfactory for a regular camera live signal.

High-speed Camera Solutions

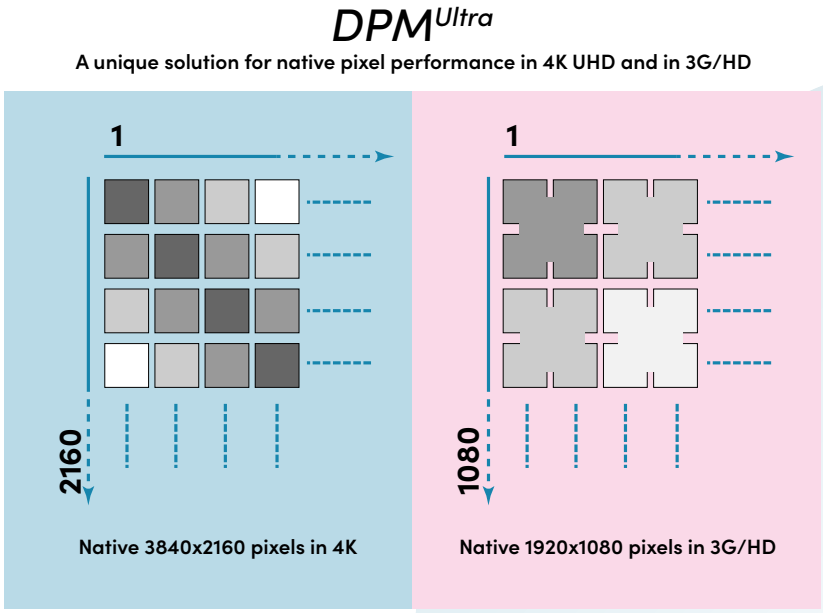
Native HD Operation

The LDX 86 or LDX 96 cameras from Grass Valley offer the best possible performance in native HD operation at up to 6x speed due to the large HD pixels in their imagers. The large HD pixels offer the best possible sensitivity and noise performance combined with an outstandingly wide dynamic range of more than 15 f-stops.

The LDX 86^{N} or LDX 98 offer the possibility to combine four of the small UHD pixels into one large HD pixel each by using the DPM^{Ultra} function. This results in great advantages, especially in HD high-speed operation, compared to an operation where only a part of the UHD pixels are read out.

HD with UHD Imagers

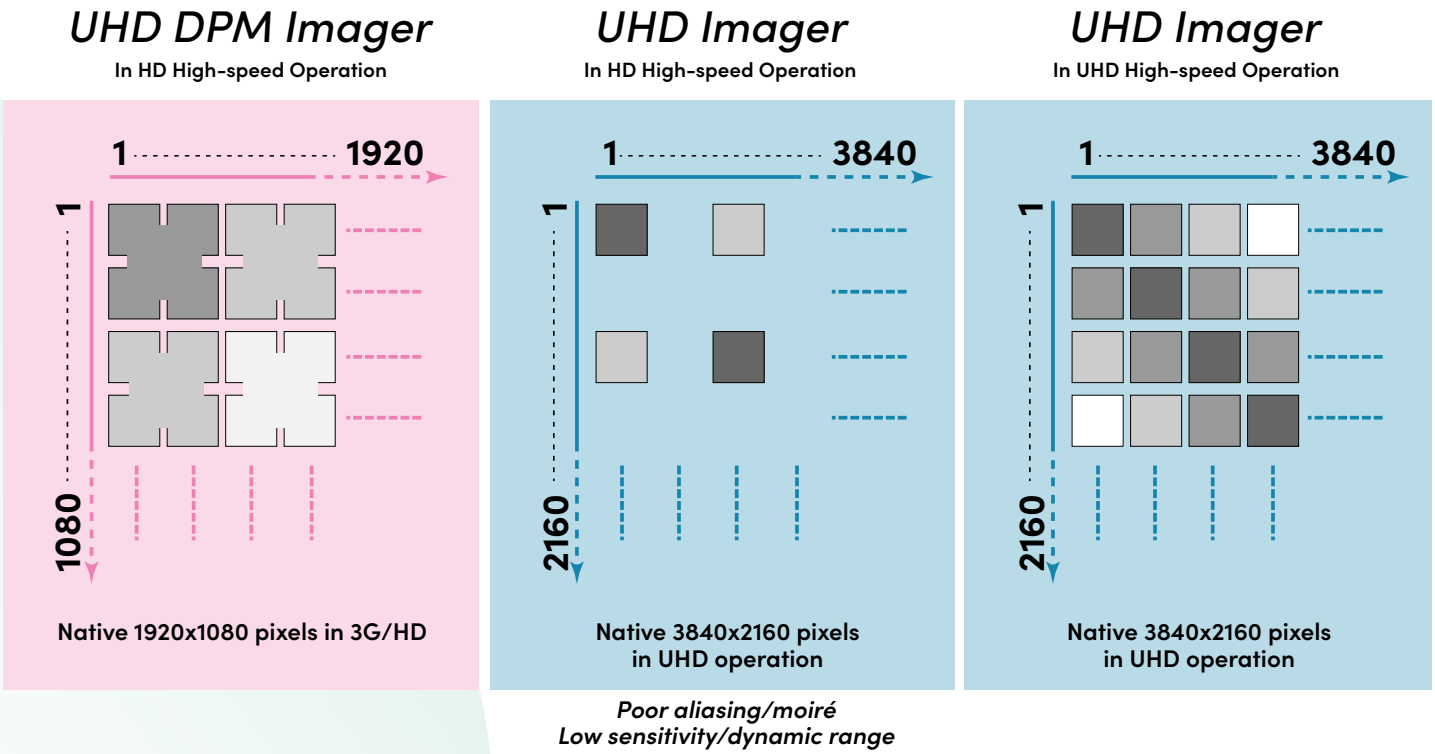
Since it is not possible to read out all pixels of the sensors at the required speed with most UHD cameras in high-speed mode, typically only every second pixel and every second line is read out. This has consequences in the image quality, especially in the moiré behavior in critical scene content, which does not reach the same level of a camera with native HD pixels. Furthermore, the image quality achieved after upconversion to UHD is far from that of a native UHD camera. Of all the possible technical solutions, this is probably the worst by far and is therefore not offered by Grass Valley.



HD downconverted from UHD

The best solution is to use cameras with native UHD resolution even in high-speed mode. If, for cost reasons, the replay system can only work with HD signals, it is still possible to use downconverted HD signals from the different motion phases. The oversampling by the sensors results in visible image sharpness advantages with the necessary upconversion during slow-motion playback. A possibly even greater advantage of such a solution is the availability of a high-quality UHD live output signal.

One challenge with high-speed UHD applications can be the bandwidth required. However, lossless compression of multiple output signals directly in the camera with low latency can provide a solution that operates with the lowest possible bandwidth requirements.



Comparing High-speed Camera Solutions			
	Native HD operation	HD with UHD imagers	HD downconverted from UHD
Grass Valley Cameras	LDX 86, 96, 86N, 98	Not available from Grass Valley	LDX 100, 150
Resolution high-speed	Acceptable	Acceptable	Good
Resolution live output	Acceptable	Acceptable	Very Good
Sensitivity	High	Acceptable	Acceptable
Dynamic range	High	Acceptable	Acceptable
Moiré/Aliasing	Low	High	Very Low
Bandwidth requirements uncompressed	Medium	Medium	High
Bandwidth requirements compressed	Very Low	Very Low	Low

Summary

In an HD-only production, high-speed cameras with native HD sensors typically offer the best solution.

In a UHD production, where only the high-speed signals are recorded in HD resolution, cameras with native HD sensors and upconversion to UHD of the HD replay signals offer an acceptable solution. In this case, if the live images from the cameras are also to be used, limitations in the image quality must be expected due to the upconversion from HD to UHD.

However, cameras with native UHD sensors that can be read out at the required high speed offer several advantages. In particular, the availability of an uncompromised UHD live output that can be used as a live source without restrictions is a major advantage. Furthermore, in most cases the high-speed signals generated by downconverting UHD to HD are better than native HD signals when subsequently upconverted.

Cameras with UHD sensors that cannot be read out at the required high speed and where only a small portion of the pixels are used in high-speed operation offer the worst solution of all variants. These cameras should not be used for demanding applications.