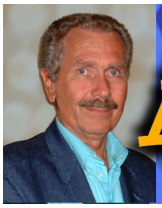

4K & U Executive HDTV Report nordahl.tv SM
4K & UHDTV Technologies & Economics of the Next TV Transition

Pre-NAB-2013 Issue —By Tore B. Nordahl— Responsible for publishing: nordahl.tv LLC at Porter Ranch, Calif.
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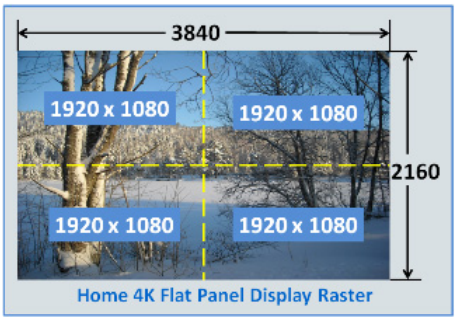
Ultra-HDTV (UHD-4K) implies Bayer sensor camera . . . No more 3xCCD/3xCMOS ?

NHK has promoted 8K television for a number of years (difficult to see why). Hollywood has embraced 4K as the digital motion picture shooting, post and projection format (makes sense). And, at the NAB Convention one year ago, the professional video camera manufacturers were introducing UHD/4K cameras. High end television acquisition seems ripe for using UHD cameras as the Hollywood motion picture production companies have already been "Bayer shooting" 4K for several major features for some time. But UHD flat screen TVs do not make sense in the home, at least not for a long time. Anyway, in here we deal with a very interesting issue confronting the television industry, from episodic to documentary to commercial production to news: Accepting and getting used to working with UHD video cameras with single sensor Bayer CFA (color filter array) because 3xCCD and 3xCMOS camera front ends are impractical and too expensive for UHD if one wants to achieve professional camera performance. **Read on—you may enjoy it**.

History of 4K & UHD

The standard DTV full HD raster is 1920x1080 with square pixels producing an aspect ratio of 1.78. In professional video, 4K refers to an image raster (video frame) where each horizontal line is made up of approximately 4,000 pixels. The vertical image height of a 4K frame is set at 2,160 pixels (2x 1080). A 4K video frame is therefore sometimes referred to as 4K2K. The first 4K standard to emerge about 7 years ago was the 4K motion picture image specs, developed by DCI (Hollywood film studios JV). The image width was set to 4096 pixels across (more than 2x consumer 1920) to protect the majority of motion picture theatrical releases in North America having an aspect ratio of 1.85. The DCI 4K spec is 4096x2160, square pixels with 1.90 aspect ratio, marginally wider than the new consumer 3840x2160 just adopted by the CEA a few months ago and formally named **UHD** after Ultra-HDTV. UHD has exactly 4x the pixel points of 1920x1080:

2x 1920 = 3840 — 2x 1080 = 2160 — 2x2 = 4.
Aspect ratio same as ATSC-DTV = 1.78



Home 4K Flat Panel Display Raster

The UHD acquisition goal is 4x the capture resolution of 1080

The most important element of that capture is the effective size of each pixel photo-sites on the sensor, although several other effects come into play including the lens. In a 3xCMOS front end design, any size HD full count sensor chip (each of 3) contains about 2.1 million pixel photo-sites while any size UHD full count sensor chip (each of 3) will contain about 8.4 million pixel photo-sites.

Using the same size sensor (any size, but let's say 1/2") for both UHD and HD, each UHD pixel can only occupy ONE QUARTER of the space afforded each HD pixel, resulting in poor UHD resolution and sub-standard low light performance. So, we really need to substantially increase the physical size of the UHD sensors to optimize the MTF for the UHD camera front end. **But here's the problem**: 3x large format sensors require a longer distance behind the lens (protecting field of view), in turn requiring the sensor prism block to be physically large, and engineered and built with high precision and stable mechanical properties. **This is expensive and makes for a heavy unbalanced camera**, presuming that it may be used as a shoulder-mount.

Additionally, in a 3xCMOS design, the required sequential read-out from each of the three UHD sensors (RGB, each 8.4 million photo-sites) for each frame simultaneously is a very data and computational intensive operation and thus expensive to implement compared to the single sensor Bayer approach.

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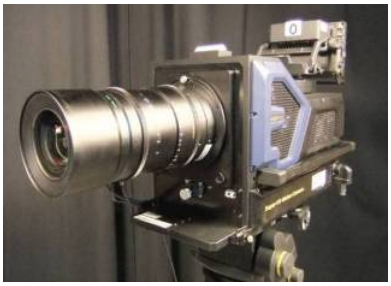
Speaking about heavy and being power hungry . . . and expensive

A recent issue of the SMPTE Motion Imaging Journal reported on an incredible 3xCMOS (large format sensors, each being 33Megapixels!) camera system for Super Hi-Vision (8K) acquisition, described as a prototype designed and built in Japan for shooting 8K promotional material, stating "the camera shall be of a size that promotes mobility and operability in outdoor shooting". **The camera head weight is 65 kg (143 lbs) and it consumes 300W. Cost was not mentioned.** This illustrates the size of the problem in commercially bringing to market a 3xSensor (large format) 4K camcorder. Although a 4K 3xCMOS version will weigh less and consume less power than this 8K camera, it will be much larger, heavier and much pricier than a high performing single sensor 4K camera.



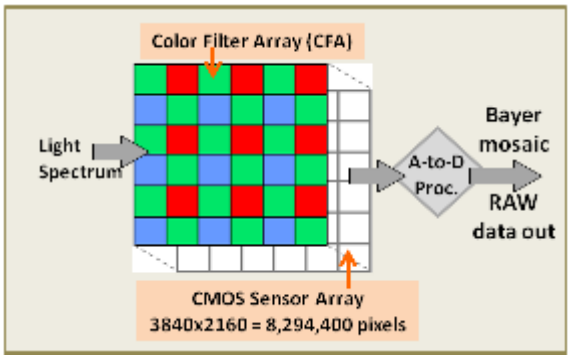
Bayer single CMOS sensor replacing Prism 3xCMOS sensors ?

YES—as stated above, the penalty of 3xCMOS at UHD resolution is size, weight and cost, and additional electronics. To be "television market enabled", all future UHD cameras need to deliver LIVE RGB output (or derivatives YCC) in one form or another, as uncompressed UHD new format stream on "5Gbps certified" BNC/coax and/or on new extended version HDMI, AND compressed H.265 IP centric. But, to address the digital motion picture market as well (one UHD camera, addressing all markets), all future UHD cameras must have LIVE RAW data output, or at least the ability to record RAW inside the UHD camera/recorder for removal on memory cards or SSD.

We have established the following logic:

- Prism design with 3xCMOS may NOT be a viable business model in the future UHD camera market
- For that reason, single Bayer-type sensors become universally adopted in substantially all professional UHD camera/recorders (and even in new HD-only cameras also for cost reasons)
- All future "broad market address" UHD camera/recorders require LIVE outputs for both YCC and RAW, which dictates internal real-time conversion from RAW data to YCC video stream, as RAW is the first stage of data access off the single sensor assembly

One full count UHD sensor for each of R, G and B requires each about 8,300,000 pixel points, times 3 sensors = applying about 25 million active pixel points total. In a single sensor Bayer-type approach, only one sensor is used, although often significantly larger than each of the R-G-B sensors in a 3xCMOS prism design. Never-the-less, nearly all professional camera manufacturers have accepted the single sensor compromise for UHD, where a single CMOS sensor containing about 8.3 million pixel points, of which Green is assigned 50% of the total pixel points, Red 25% and Blue 25% by the application of a Color Filter Array (CFA) mosaic layer on top of the CMOS sensor array.



In addition to the direct (but sequential in the case of 3xCMOS) read-out from each photo-site, the missing brightness and/or color data for each pixel are computed using the neighboring photo-sites' data to arrive at the most "accurate" interpolated RGB image reproduction. Just remember that the digital motion picture cameras have for several years utilized the single sensor Bayer approach with great success, even at full HD 1920x1080. But up to recently, digital motion picture cameras did not provide for LIVE full resolution output, as the RAW LIVE output was recorded to a data recorder when shooting, for later conversion to RGB through a real-time or off-line software interpolation process. (Note that RAW is NOT video monitor viewable.)

Time is (was) NOT of the essence

In television, time is of the essence most of the time, requiring to deliver footage to post fast, or even to finish editing in the field or in the newsroom fast. Digital motion picture shooting lacks such urgency, as they may shoot the same scene over and over again. So, up to now, TV has stuck with 3xCMOS HD cameras, while digital motion picture (even at HD-only) has preferred the Bayer single (large format) sensor camera, for the ability to have image artistic control and use of a wide variety of film lenses (old standard high quality 35mm lenses) at the omission of LIVE full resolution output, with the advantage of a lower camera price. **But, remember that, all else being equal, 3xCMOS beats Bayer capture performance every time.**

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So, at UHD resolution, there will NOT be a choice between 3xCMOS and Bayer

Unless the market in sufficient numbers are willing to pay $100,000 or more for a new professional 3xCMOS UHD camera/recorder, and accept a heavy and power hungry product, substantially all future UHD cameras will be based upon the a single sensor approach a la Bayer (unless some other bright new single sensor ideas emerge). **And this in turn means that nearly all new professional cameras to be introduced in the future, including HD-only cameras, will be the single sensor type.**

There will be lower-cost UHD cameras addressing the lower markets where high-end digital motion picture features are not included (such as RAW access), AND there will be high-priced high-end digital motion picture cameras largely ignoring some features essential to the broader lower markets, but . . . all have single sensors.

Bayer RAW to UHD LIVE RGB/YCC output

Fortunately, ASIC video processing power (such as JVC's powerful Falconbrid chip) can now provide cost-effective real-time interpolation from RAW to RGB and YCC internal to the UHD camera/recorder, as well as compression, thus many of the future UHD camera models may be universally used in television as well as in commercial production and digital motion picture shoots.

And there is a rich and versatile "software library" of ways to interpolate and process the RAW data by dozens of capable companies, developed over years of Bayer sensor use, whether resident in a camera, in a external recorder/processor or in an external workstation to achieve color correction, artistic control and conversion to RGB/YCC.

By 2015, new professional cameras will nearly all be of the single sensor type with "full rez" LIVE output. And we include 1080-only cameras as the prism 3xCMOS approach is eclipsed by much lower cost of the Bayer-type single sensor camera front-end and its "certainly good enough" image capture performance.

Prism design with 3xCMOS/3xCCD perhaps will be remembered on Wikipedia! (Could I be wrong ?)

END