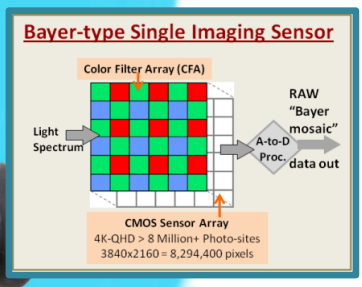
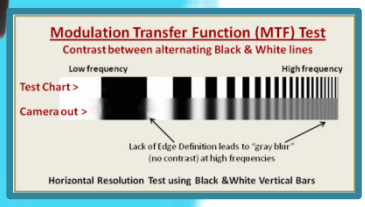
JVC KENWOOD

The 4K-UHD 2015 Report

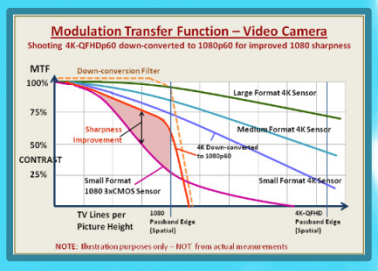
A JVC White Paper

- Major League Sports
- College Sports
- TV Studio Set
- Documentaries
- Live Events
- Roaming
- Commercials
- Episodic TV
- Reality TV
- IP/ENG Mobile News
- IP Networked Backhaul
- Movie Shoot B-roll
- Corporate
- Private MESH Network





GY-LS300
4K Super-35 Handheld Camcorder



This White Paper discusses the emerging 4K-UHD Technology and presents JVC's exciting new family of high performing yet very cost effective 4KCAM LIVE Streaming Camcorders

A JVC Professional Video White Paper issued April 2015 at NAB

http://pro.jvc.com

Table of Content

NOTE: This 4K-UHD White Paper has been authored and produced by Tore B. Nordahl/nordahl.tv LLC on behalf of JVC Professional Video, a Division of JVCKENWOOD USA Corporation.

Go beyond HD . . . right now!

The pursuit of excellence in imagery and the opportunity to lead the competition are two very important drivers in the television, video and cinema markets, to produce compelling content in the quest for artistic and financial success. Although content is still king, success today is not obtainable without pristine high definition image acquisition in a production environment of efficient work flow capable of the delivery of multiple formats to Smartphones, Tablets and PCs, and to large flat screen TVs. However, pristine HD may soon not be "good enough" as the television industry has entered another "twilight zone" as the migration from HD to 4K is gaining traction in the professional domain.

Are you ready to go beyond HD?

This white paper introduces the next very important step in the evolution of cost effective "beyond HD" storytelling, acquisition and post production. The paper presents the emerging 4K technologies and processes expected to accelerate the adoption of 4K video acquisition over the broader market within the next three years, taking lessons from the 4K implementations so far undertaken by the digital motion picture industry while starting the push of materially lowering the price of entry for 4K camcorders, displays and projectors.

JVC is now leading the broad market transition to 4K-UHD acquisition with its new 4KCAM Camcorders: the GY-LS300 4K Super-35 Camcorder, the GY-HM200 and the GY-HM170.

4K CAM

This white paper covers some of the 4K issues experienced by the digital motion picture industry, while the target audience for the writings herein is the much broader professional video and television markets, where 4K-UHD may offer interesting (and highly beneficial) applications in education, sports, surveillance, POV, digital signage, science and medical, some in concert with television program development as well as specialty (i.e. mobile B-roll) digital motion picture shoots.

JVC Professional has for some time successfully pursued a professional HD camcorder strategy based on a very attractive price/performance ratio generally in the price range from $2,000 to under $10,000 (including quality lens). Without the need to "protect" a much higher priced full size HD camcorder product line (as the other major professional HD camcorder suppliers still need to do), JVC was (and is) free to offer highly competitive leading edge performance and features in their less than $10,000 ProHD camcorder range. Not surprisingly, JVC's ProHD camera/recorder products have become best sellers particularly within the TV broadcasting and cable channel local origination segments, for shoulder-mount and handheld HD camcorders as well as for TV station news studio cameras.

Continuing the ProHD "less-than-$10,000" high performance HD camcorder strategy, at the end of this white paper, we introduce JVC's new remarkable handheld 4K-UHD Super-35 camcorder, street-priced at less than an incredible $5,000 fully fitted ready to shoot with a quality Super-35 lens, and two additional camcorders in the 4KCAM family. The GY-LS300, GY-HM200 and GY-HM170 are shipping now.

Consider this:

4K-UHD acquisition offers a number of artistic, operational and technical benefits (and advantages over 1080/720 HD acquisition) in many applications, although the finished video material may still be used/released/delivered in today's HD resolution. For those reasons, demand for cost effective 4K-UHD acquisition may enjoy substantial growth before 4K home displays are common place.

What is 4K-UHD?

In professional video, 4K refers to an image raster (video frame) where each horizontal line is made up of approximately 4,000 pixels. All newer standardized professional and consumer digital video frame formats require square pixels (as opposed to rectangular). The 1920x1080 and the 1280x720 ATSC DTV standards contain square pixels producing a frame aspect ratio of 1.78 (16:9). Using this widely applied aspect ratio, the standard vertical image height of a 4K frame becomes 2,160 pixels (1080 x 2). A 4K video frame was therefore in the past referred to as 4K2K. However, the television 4K2K image display standard has emerged as Ultra-HD or UHD, but is largely referred to as 4K-UHD. "4K" has become the buzz word in the professional video as well as in the consumer flat screen TV world. It is obvious that a next high resolution display format following the current HD standard of 1920x1080 should be based on an even multiple of that current HD raster standard, and it seemed reasonable in terms of technology advancement and audience viewing improvement to make the next level of image resolution four (4) times that of HD.

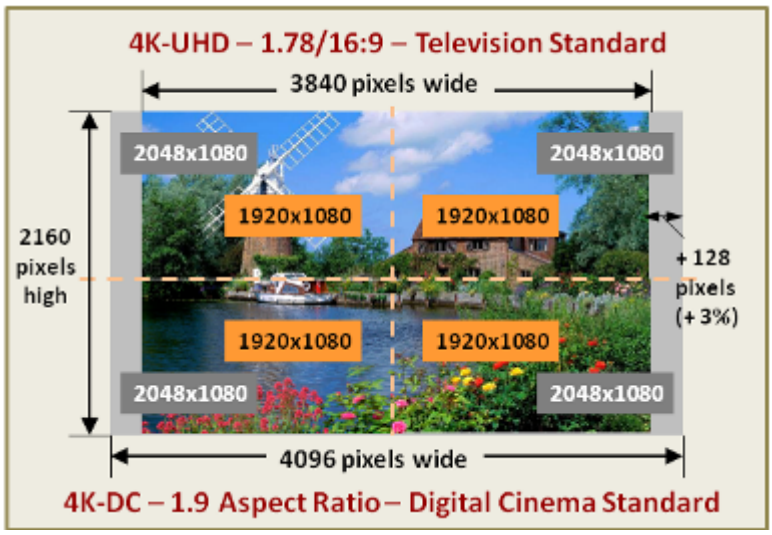
The 4K-UHD Television Raster Standard = 3840x2160 pixels
This is made up of four quadrants of 1920x1080.
The image width of 1920 pixels is multiplied by 2 = 3840 (pixels/wide)
The image height of 1080 lines is multiplied by 2 = 2160 (pixels/high)
2 x 2 = 4 times the image resolution

All HDTV sets (home and professional HD television displays) employ 16:9 aspect ratio and square pixels with an active raster of 1920x1080, thus there is wide industry agreement to the 3840x2160 raster as a television display (flat panel) standard. As home theater projectors use a different display technology from flat panel displays, 4K projector models may possibly also accommodate the 4K-DCI raster (see next paragraph).

The 4K (DCI) Digital Cinema (Projector) Standard = 4096x2160
The Digital Cinema Initiative LLC (DCI), a joint venture of major Hollywood film studios organized in 2002, released its first formal Digital Cinema specs in 2005, including the 2K and 4K projection standard to guide movie theaters in making a uniform transition from mechanical film projection to digital motion picture projection. The 2K Digital Cinema raster was fixed at 2048x1080, while 4K was made up of four quadrants of 2048x1080 resulting in 4096x2160 yielding an aspect ratio of 1.9.

"Compliant" digital cinema projectors are required by DCI spec to offer a full frame projected aspect ratio of 1.9 (whether 4K or 2K native), presumably because the majority of theater releases in recent times have been (and are) in 1.85. The motion picture industry releases motion pictures in a number of different aspect ratios, including the most popular North American screens of 1.85 (wide) and 2.35 (anamorphic, shot 2.39) and the European wide of 1.66. Any motion picture produced in a different aspect ratio (from 1.9) will generally be projected as a crop inside the 1.9 frame boundaries as letter box, pillar box etc.

Ultra-HD (UHD – 3840x2160) has already been adopted as the professional and consumer television standard for acquisition, post production, delivery and display, referring to it as 4K-UHD in here.



Looking at the illustration above, we see that the picture width at 1.9 aspect ratio (4K-DCI) is a bit over 6% (3%+ on each side) wider than the 4K-UHD 1.78 aspect ratio. But, when considering that the projected "active area" aspect ratio for the majority of U.S. movie theater releases is 1.85, the percentage width difference drops to less than 4% (<2% on each side) which is negligible in a human's perception of aspect ratio when emerged in an interesting big screen presentation. We can perhaps agree in principle that, to produce theatrical releases in 4K-UHD (3840x2160 – 1.78) rather than the slightly wider 4K-DCI release format of 1.85 (3996x2160 at square pixels), 4K-UHD for television as a digital cinema raster should certainly be acceptable. Also look at the 3840x2160 as mapping pixels exactly inside a "pillar boxed" active area of 4K-DCI.

The Hollywood motion picture crowd has been shooting digitally in a variety of higher-than-HD resolutions and aspect ratios for digital cinema releases for years, but in the end being projected within the 4096 wide 4K-DCI raster. But the future growth in 4K acquisition will increasingly be by television, particularly prime time episodic, with both acquisition, production, post and mastering in 3840-wide 4K-UHD, with releases in UHD and HD for some time.

4K . . . Not just for Digital Cinema anymore

Looking back to 2012, with 4K "non-military/non-space" acquisition at the time being nearly exclusively used by the feature film industry, the state of the art at that time was measured in an atmosphere of multi-million dollar movie budgets and up to $100,000 digital motion picture camera packages. Since then, a number of cost effective 4K-UHD capable camera/recorders have come to market at a "ready-to-shoot" package price range below $10,000. But none can compare to JVC's new 4KCAM GY-LS300 handheld camcorder street-priced at less than $5,000 including interchangeable Super-35 lens, a 4K Super-35 imager, and built-in HD stream processing.

The 3xSensor is NOT for 4K?

Professional HD cameras and camcorders have largely been based on a 3xCCD (or now often 3xCMOS) image sensor assembly, where color splitting prisms deliver red, green and blue light spectrum to each of the red, green and blue sensors respectively within the imaging block. Concurrent read-out of all three (R, G and B) sensors' photo-sites during each and every frame (i.e. 24 or 60fps) supports the objective of the 3xSensor approach to obtain a real-time high quality RGB digital data stream, commensurate with the product performance goals, with each pixel in every frame being accurately represented by full RGB data without the need for interpolation and approximation.

However, when going from 1080/720 (HD) to 4K image acquisition, requiring 4x the pixel points of HD (see table below), which increase the video frame pixel matrix from about 2 million to more than 8 million points, it becomes a mechanical nightmare (and thus expensive) to manufacture, align and to keep stable a 3xCMOS (or 3xCCD) image sensor/prism assembly so that the 8 million+ pixel points on each of the red, green and blue sensors are always aligned, pixel for pixel, sensor to sensor, to achieve stable professional performance under any shooting condition. This applies to all sizes of 8 million+ pixel sensors, but is particularly the case for small format sensors.

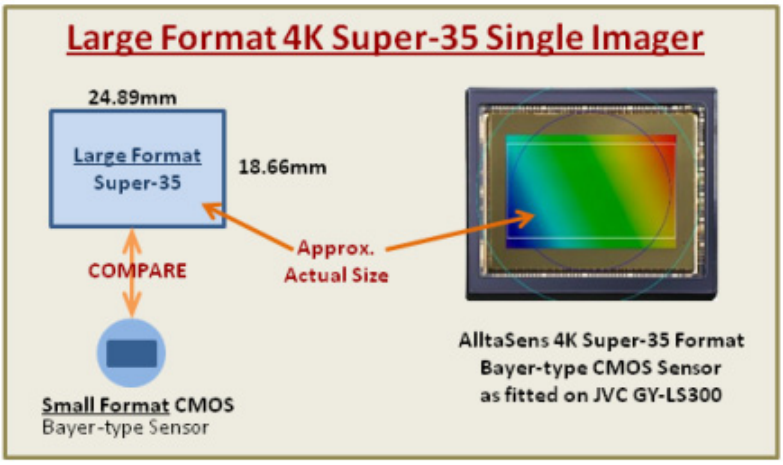
A **small format** ½-inch class sensor chip offers an active 4K-UHD 16:9 chip area of 5.952mm x 3.348mm or 19.9mm^2 (~0.03 sq.inch), containing about 8.3MP (Mega Pixels), allowing a maximum gross area for each pixel equal to 19.9mm^2 divided by 8.3 million. The single sensor "Bayer" approach is therefore favored for 4K, eliminating mechanical instability and inaccurate alignment between multiple (small format) sensors and eliminating the need for very high quality color splitting prisms. **Much more on Bayer later**.

Image Rasters vs. Pixel Points vs. Sub-Pixels

Frame Format	Image Raster	Pixel Points	RGB 4:4:4 Sub-Pixels	YCC 4:2:2 Sub-Pixels	YCC 4:2:0 Sub-Pixels
4K-DCI	4096x2160	8,847,360	26,542,080	17,694,720	13,271,040
4K-UHD	3840x2160	8,294,400	24,883,200	16,588,800	12,441,600
HD (1080)	1920x1080	2,073,600	6,220,800	4,147,200	3,110,400

The above table shows pixel data between the three different but related digital image frame formats of 4K-SDI, 4K-UHD and HD, and with the three different sampling structures of RGB 4:4:4 (digital cinema/high end post), YCC 4:2:2 (network television and HD-SDI sub-sampling), and YCC 4:2:0 (TV broadcast/ cable/ satellite/disc sub-sampled consumer delivery). "Sub-Pixels" refer to the total number of sampled points in a frame after 4:4:4 sampling (x3), 4:2:2 sub-sampling (x2) or 4:2:0 sub-sampling (x1.5).

A **large format** Super-35 "film sized" imager has an active image area (~25mm x ~19mm, or ~475mm^2), and, with supporting PCB and connections, is a relatively large mechanical assembly. Using 3xCMOS/prism technology with Super-35 Imagers will make the camera front end rather large, not to mention a different focal length due to longer light path through the prisms, thus the single Imager "Bayer" approach is preferred by nearly all major large format imager camera manufacturers.



In this new world of digital cameras, why do we need to duplicate the old "film-based" Super-35 dimension?

Because, many old prime lenses, used over many years in the past with old film cameras, can still be used with modern digital cameras designed with Super-35 imagers. Using the same focal length (distance from lens to sensor/film) as used before in film cameras, combined with the same Super-35 dimensions, enable the use of familiar 35mm lenses and related lens data to take advantage of a DP's years of experience shooting on 35mm film. Call it preserving instinctive selection of lenses and settings by DPs to achieve the depth of field (DOF) and angle of view (AOV) as experienced from the "Super-35 film camera days".

"Old" 35mm film lenses are generally of very high quality, sufficient in many cases to be "4K digital camera compliant", as negative film stock (considered to be capable of resolutions beyond 4K – even many years ago) required very high lens performance. And 35mm film lenses are plentiful and available from major rental houses around the world. An even more compelling reason for using Super-35 size imager is of course for the ability to provide the highest possible (a) electronic dynamic range (for each photo-site) and (b) modulation transfer function, to attempt to match the high imaging performance and latitudes of 35mm negative film stock.

Some Cinematographers may prefer a softer look using old lenses not quite up to 4K resolution for specific scenes, as such lenses may not match the MTF (Modulation Transfer Functions) of the camera front end. It's like adding a soft filter, with the advantage of choosing from a large selection of "old" but readily available 35mm lenses.

To employ the 3xSensor technology is therefore NOT practical in any size (large or small) format sensor-based 4K digital video camera. The single sensor Bayer approach is therefore favored for 4K, promoting a much smaller physical camera package and the ability (with larger sensor) to match the focal length of 35mm film cameras. Much more on Bayer later.

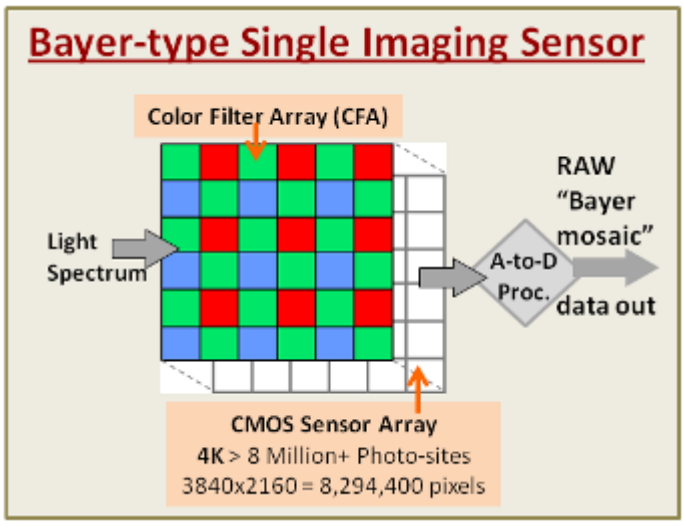
Consider this:

The 3xSensor (i.e. 3xCCD or 3xCMOS) RGB imaging/prism block, each sensor with a matrix of photo-sites matching the frame pixel array (i.e. 1920x1080), is the most accurate established way to electronically capture moving image data in real-time. But, it is not practical or economical to build in a 4K 3xSensor imaging/prism block for a 4K capable camcorder or camera, thus the 4K+ single sensor "Bayer" approach has been nearly universally adopted by digital video, digital motion picture and DSLR camera and camcorder manufacturers.

The RAW Deal:

The Bayer Mosaic Single Sensor Array

For several good reasons, including size/weight, cost of manufacture and focal length issues, the 3xSensor does not commercially work for 4K. What's the solution? Fortunately, the Bayer Mosaic single sensor technology is already here to provide the solution. It takes a single sensor array of a minimum of 8.3 million photo-sites to gather sufficient pixel point data in each frame to produce good quality 4K digital video through a Bayer-type imager. Details later.



Patented in 1979 and named after its inventor, B.E. Bayer of the Eastman Kodak Company, a Bayer mosaic color filter array (CFA) aligns red, green and blue color filter squares on top of an array of photo-sites, in such a pattern that each photo-site will only be "exposed" to either red, green OR blue light spectrum. In any "standard Bayer" array, there are 50% green, 25% red and 25% blue photo-sites. See illustration above. Bayer found that green largely determined luminance value while red and blue largely are chrominance determinants. Light hitting a photo-site generates a voltage (analog, varying with the intensity of the light) which needs to be read out and converted to data (digital). Exiting the single (4K)

sensor chip, the read-out data from each of 8 million+ photo-sites is formatted into very high data-rate signals referred to as **RAW** data. **A RAW data file is an un-processed record of the sensor data**.

The Bayer "Good" Compromise

The entertainment/television industry has already embraced the use of a single imaging sensor in 4K video cameras and camcorders, recognizing that it is impractical to demand 4K cameras with 3xImager designs. The single Bayer sensor must contain a minimum of about 8.3 million active photo-sites (up to 20+ million in very large format sensors) to produce a high quality 4K video. The Bayer "good" compromise is that, although a single Bayer-type sensor with 8.3 million photo-sites is NOT capable of mathematically producing an "entirely accurate" 4K RGB image, it is capable of producing spectacular 4K video.

The 4K-UHD is "made up" of 4x 1920x1080 quadrants. At 1080i60 (60 interlaced = 30p), the luminance sampling frequency is 74.25MHz resulting in a Nyquist-limited resulting upper pass-band edge at 30MHz (SMPTE 274). At 60p (2x 30p) 1080 has a SMPTE 274 established luminance sampling frequency of 148.5MHz with Nyquist resulting upper pass-band edge of 60MHz. BUT we have a Bayer 8.3MP single sensor . . . and as R, G and B are sampled separately (as they also are in a 3xSensor approach), Green assigned photo-sites in the Bayer sensor total 4.15 million ("only" half of the 8.3 million) sampled 60 times per second equaling a sampling frequency of 252MHz which allows a maximum pass-band of less than half of 252MHz or an upper band edge of about 110MHz (Nyquist limitation again). This is only about 2x the 1080 60MHz edge, indicating that the mathematical **academic** improvement in resolution is about 2x (between 1080p60 full count 3xSensor acquisition and 4Kp60 single sensor 8.3MP Bayer-type acquisition), and not 4x, **before** de-Bayering, interpolation and processing.

Is 4K-UHD Bayer-derived video 4x or 8x better than 1080i60 resolution?

First comparing just one (1) video frame of each of 4K-UHD and 1080i60 and assuming each being "academically perfect", the pixel count in a full frame is 4x higher in 4K-UHD. See table on page 7 and compare 8,294,400 and 2,073,600 **spatially**. However, we must consider the all important **temporal** factor of 1080i60 being interlaced, thus, in moving video, 4K-UHD-60p (the standard) delivers 60 full frames per second to the 4K-UHD flat screen TV for a total of 8,294,400 x 60 = 497,664,000 pixel points/sec while 1080i60 only delivers 30 full frames per second to the 1080p60 flat screen TV for a total of 2,073,600 x 30 = 62,208,000 pixel points/sec. Temporally, in pixel points per second delivered to the home audience flat screen TV, 4K-UHD will deliver (as it is a future delivery proposition) 8x more pixel points than current 1080i60 ATSC or Cable/Satellite delivery. How about that!

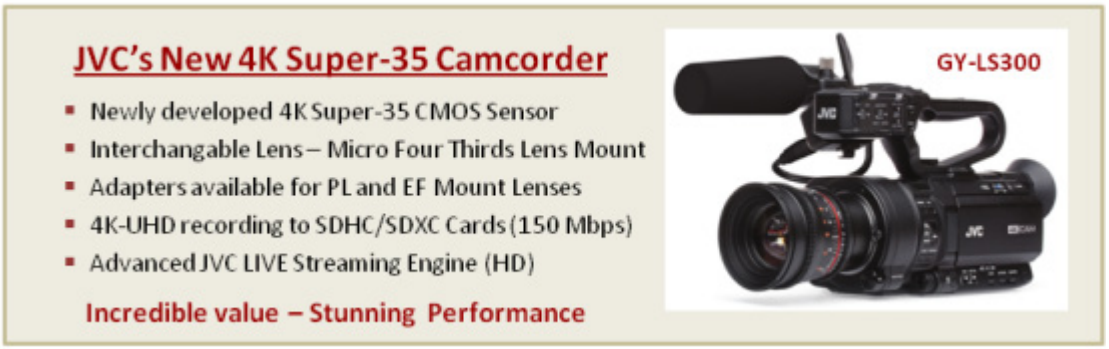
The above analysis looks at pixel points/sec, with a 4K-UHD-p60 video delivered to a 4K-UHD-p60 native flat screen TV (mapping pixel to pixel), but with a 1080i60 video delivered to a 1080p60 native flat screen TV (requiring interpolation, de-interlacing and processing within the TV to turn i60 into p60 to display).

Incidentally, we're looking at the 4K-UHD being "compromised" only at time of acquisition through any inaccuracies in the Bayer process, while the 1080i60 is being "compromised" both at time of acquisition

through interlaced capture (of fast action/sports, although by a 3xImager) and at time of viewing through the conversion from interlaced to progressive in the display.

What does this mean in the transition to a 4K-UHD world?

Although interlaced HD (1080i60) has served the television industry well over many years, most of us now agree that the sooner we can retire the 1080i60 format, the better it is. It's a progressive television world. For several years, the television industry was exploring 1080p60, and even higher progressive frame rates for sports acquisition. The transition to a 4K-UHD world is firmly underway and there is no way back. But 1080p60 (and p24) will still have a major role to play in HD television program and commercial shoots, as cross conversion to ATSC HD broadcast release formats may deliver the best possible consumer HD, although 4K-UHD video acquisition should be seriously considered for any new project.



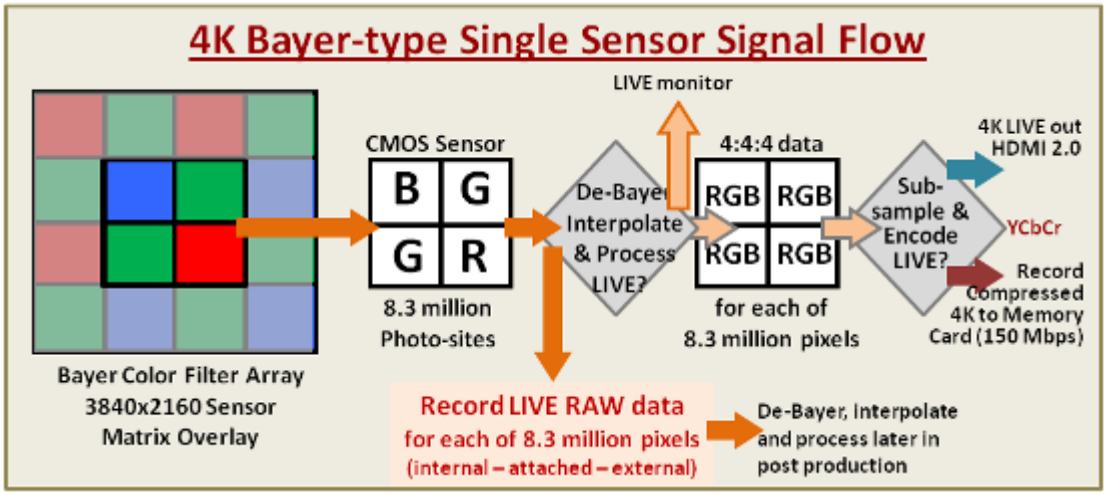
Consider this:

All Bayer-based single sensor cameras must rely on de-Bayering, interpolation and processing to substantially increase the effective resolution of the acquired image data. In a 4K Bayer-type sensor with 8.3 million photo-sites, a baseline of 2x 1080 resolution exists in the RAW data BEFORE de-Bayering, increasing to nearly 4x of 1080 resolution AFTER de-Bayering. This theoretical baseline of 2x 1080 resolution improvement is the same for any size (large, medium, small format) single sensor used to acquire 4K with 8.3 million photo-sites (compared with 3xSensor full count 1920x1080).

How many millions of photo-sites are required on a single Bayer-type sensor to achieve true 4K "mathematical" pre-de-Bayering resolution? The quick answer is 3x 8,294,400 or about 25 million photo-sites, or one R, G and B photo-site for each pixel point. However, if the total photo-sites are just doubled, to about 16.6 million, then each and every pixel point in the 3840x2160 raster will sense Green (the luminance determinant) which will bring it to true 4K (B&W) resolution, and very close indeed to 4K color resolution. (It would be similar to 4:2:2 sampling.) In the interest of lower cost, smaller physical size, lower power consumption and operational flexibility, the entertainment/television industry accepts the Bayer-type single sensor "good" compromise in 4K video cameras and camcorders.

Turning RAW into RGB

"RAW" is **not** an acronym, but named so because the data is not yet processed into a viewable video signal. The read-out of RAW data in a 4K video camera must take place in real time up to 60 frames or more per second (60p), and each time submitting complete RAW data for 8 million+ individual photo-sites (pixels). Note that a 4K digital "film" camera may only require complete read-out of 24 frames second (24p or 24fps). RAW image files are also referred to as "digital negatives", comparing it to the "negative film stock" of the old film camera days. RAW is always progressive.



Shooting 4K video at 60p with a Bayer-type single sensor camcorder generates a massive real-time stream of RAW data. With 8.3 million photo-sites sampled at (let's say) 12-bit precision 60 times per second, the RAW data-rate is about 6Gbps. The RAW data stream is NOT viewable, so this 6Gbps RAW stream needs to be converted to RGB or to YCrCb, in real-time and with minimum latency if you want LIVE monitoring or LIVE feed. This requires a large amount of processing power embedded in the 4K camera, to de-Bayer, interpolate and process the RAW into viewable LIVE 4K output in best possible resolution. (Note that JVC's new 4K professional camcorder, street priced at less than $5,000 with quality lens ready to shoot, is capable of LIVE full resolution output as detailed later in this paper.) In high end digital motion picture 4K video cameras, the RAW 6Gbps (or even higher) LIVE data stream must be recorded in real time (obviously, in order to be saved) by an internal or external RAW data recorder/player, which later playback may be converted to RGB in post production, outside of the camera, either by real-time process or sometime rendered in non-real-time for highest possible quality.

The de-Bayering, interpolation and processing of the RAW data seek to best estimate and recover the missing color components in each of the 8.3 million pixels to establish full RGB data for each of 8.3 million pixels. Note that, at the RAW stage, every one of the 8.3 million pixels are missing two (2) RGB color components: The Green assigned pixels (4.2 million) each need Red and Blue data. The Red assigned pixels (2.1 million) each need Green and Blue data. The Blue assigned pixels (2.1 million) each need Green and Red data. In every frame, up to 60 frames per second!

Consider this:

The majority of professional camcorders for HD (1080/720) continue today to favor the 3xSensor /prism assembly over Bayer single sensor (RAW) because it produces internal RGB without the need for de-Bayering and interpolation, at "design-goal quality" in real-time. There is really no commercial reason for producing professional HD camcorders for television/video with single sensors. The exceptions are HD cameras using large format sensors, based on the "Super-35 film" sensor (even larger) and focal length reasoning, however, such are designed for high end digital motion picture acquisition (and include 2K shooting) and generally NOT for LIVE transmission. (Note that the GY-LS300 provides a high quality LIVE 4K-UHD output which may be used for LIVE contribution and backhaul.)

A RAW format standard?

There is no one industry-wide RAW format standard, although there is one format (Adobe's .DNG = "Digital Negative") being promoted for standardization and supported by a number of still camera manufacturers. There are dozens and dozens of different RAW file formats, established by various video camera, camcorder, still camera, support systems and software suppliers, developed over the years as suppliers attempt to surpass the competition by implementing better de-Bayering and interpolation software with hardware advances, and to gain "proprietary advantages". It is not likely that a single RAW format will succeed as a standard. And the broad television market has NO need for a standard because RAW-to-RGB/YCC conversion software will largely be a closed no-access function "deep inside" any cost effective "broad market" 4K camcorder.

RAW Data is NOT directly viewable as Video

No RAW data stream is compatible with any professional or consumer HD or 4K video display system. Only after de-Bayering, interpolation and processing is the acquired RAW data viewable as video.

Is there a need to access the RAW data?

Not in broad-market television production. RAW access is for higher end cinematography and episodic television, where editors spend hours and hours doing color grading and related corrections, starting from the original RAW data.

JVC's new GY-LS300 4K-UHD Camcorder de-Bayers and converts the RAW data from the Super-35 Sensor internally in real-time, to output full resolution LIVE 4K-UHD while simultaneously recording the LIVE 4K-UHD compressed on economical SDHC/SDXC memory cards. No need to even think about Bayer or RAW when using the GY-LS300.

Consider this:

Obviously, RAW access has absolutely NO place in LIVE television, as there is no time to manipulate the data. Similarly, a number of 4K-UHD shooting applications are nearly live, or are much more interested in the high 4K-UHD resolution than in the ability to change the mood of a sequence of video. One such application may be sports training camp analysis, requiring immediate playback and viewing, benefitting from the 4K resolution.

Off-line RAW Access needs Data Recording . . .
And 4K RAW Data Recording needs Data Compression
. . . or, "Houston, we have a problem" (or two)

To access the RAW data later, you need to record the RAW data real-time while shooting. Data storage cost in 2015 is very economical, until we look at the immense storage capacities and data-rates required for uncompressed 4K RAW data from a 8.3 million photo-site sensor at 12-bit depth. The bit-rate and storage computations go like this:

8.3 million x 12-bit x 60p = 6 Gbits/s (uncompressed RAW bit-rate)
6 Gbits/s = 0.75 GBytes/s = 45 GBytes/min = 2.7 TBytes/hour

The first "problem" is the required sustained real-time data rate of min. 6 Gbps (could be much higher), which may be handled serially by several new high bit-rate interfaces, to external data recording unit or to an internal data recording unit. However, there is NO television industry specific interface standard for RAW (i.e. like HD-SDI and HDMI). And consider that a large format Super-35 sensor may feature 16 million pixels, doubling the RAW data rate to 12 Gbps.

The second "problem" is the huge amount of storage (nearly 1TByte) required to store just 20 minutes of real-time (uncompressed) RAW data. Attachable PC or MAC desktop hard disk storage is relatively cheap at about $100 per TB, but if the unfinished project occupies 5 hours of uncompressed 4K RAW data, the total hard disk capacity required becomes 14 TBytes at a cost of $1,400. But doubles to 28 TBytes at a cost of $2,800 if the sensor has 16 million pixels. Not a real problem unless RAW archiving is required. $2,800 sitting on the shelf for months, perhaps years, as archive? And what about the cost of 28 TBytes of flash memory? Much more costly.

The combination of these two operational "problems" can only be partly solved with data compression. Therefore, data compression becomes mandatory in RAW data storage sub-systems for 4K, a point which has already been recognized by the high end digital motion picture camera and support systems suppliers. Visually lossless (but mathematically lossy) Wavelet compression (in the JPEG2000 family) in the range of 3:1 to 18:1 is one solution offered.

RAW Access is NOT needed (or wanted) in the 4K-UHD broad-market television world.

Consider this:

The single purpose of storing RAW data is to save the original unadulterated RAW images as captured by the Bayer-type single sensor, for later recall and most flexible image manipulation. Any significant level of RAW data storage compression will introduce irreversible errors. As compression is increased, the irreversible errors multiply, to a point of diminishing returns as compared with simply converting the real-time RAW to RGB/YCC real-time video internally in the camera. Post process the converted (and stored) YCC 4K-UHD if needed, as saving the compressed RAW may NOT provide any added benefits to a broader television user base.(RAW access is for digital motion picture and high end television and commercial shoots with big budgets.)

Camcorder-based Real-time 4K RAW > RGB/YCC = Very Heavy Processing

The complete RGB (or YCC) data for each of (minimum) 8.3 million pixels needs to be interpolated from the "incomplete" RAW Bayer data in real-time by algorithms looking at all or most of the neighboring pixel data and then computing the final RGB data (or YCC data) for each pixel point, up to 60 times per second and each time for not less than 8.3 million pixels. This is in addition to the processing power required to format the RAW data train exiting the sensor assembly. Note again that 8.3 million pixels is the minimum required for a 4K-UHD Bayer-type sensor, but in many cases it will exceed that number to reach 13.5 million pixels (as in the Super-35 sensor in the GY-LS300) and even up to 20+ million in other large format 4K-UHD Bayer-type single sensor designs.

To transform the 4K RAW into 4K RGB/YCC in real-time requires heavy camera-on-board digital signal processing, which is available subject to ASIC (Application Specific Integrated Circuit) development relying on LSI (Large Scale Integration). The future of 4K-UHD video cameras and camcorders for television depends on the availability of such high speed ASIC/LSI devices, not the availability of RAW access.

How does JVC do it?

JVC incorporates heavy processing power into a single LSI chip embedded within the camera front-end, purpose-developed to de-Bayer, interpolate and process the RAW image data from the camera's single CMOS sensor in real time to provide very high quality uncompressed 4K-UHD video. Unlike some high end 4K cameras, the GY-LS300, GY-HM200 and GY-HM170 are all able to output pristine LIVE uncompressed 4K-UHDp30 images for LIVE feed or monitoring purposes in real time with virtually no latency, while concurrently record the LIVE 4K-UHD in H.264 at 150Mbps to the internal removable SDXC memory cards.

Again, RAW Access is NOT needed (or wanted) in the broad-market television world.

4K-UHD Consumer Delivery:

Consumer delivery of 4K-UHD will largely be in the 4:2:0 @ 8-bit space, compressed in HEVC (High Efficiency Video Coding/H.265). As there is no current 4K-UHD consumer delivery by the TV Broadcast Networks or by TV Stations (not starting anytime soon), substantially all 4K-UHD consumer distribution in the near term will be through OTT Internet streaming as already started by Amazon and Netflix. Such OTT transmissions take the form of compressed 4:2:0 @ 8-bit precision, at a 30p frame rate, compressed HEVC in the range 15 to 18 Mbps, achieving an incredible compression of about 185 : 1 (3 Gbps uncompressed divided by 16 Mbps compressed). In home connectivity to any "Netflix certified 4K flat screen TV" (obviously a Smart TV) is very simple: Just connect the Smart (4K-UHD capable) TV to your home Internet Router, via WiFi or, better yet, via wired RJ45 Ethernet cable. The 4K-UHD stream is decoded internally in the Smart TV. **Be assured: Every 4K-UHD consumer flat screen TV sold will feature a built-in 4K-UHD HEVC decoder. Any 4K-UHD flat screen TV without the built-in decoder will simply not sell. So, there is little or no market for any external "4K-UHD-over- IP-in 4K-UHD HDMI-out" box.**

EXCEPTION: The Satellite TV providers (both DirecTV and DISH) have announced that they will soon carry 4K-UHD programming. It so happens that every subscriber to Satellite TV needs a satellite receiver box in order to decode each and every satellite TV channel whether SD, HD or 4K-UHD, and then deliver the uncompressed 4K-UHD over HDMI to the 4K-UHD flat screen TV. In such a case, the internal decoder in the flat screen TV is not utilized. We have the same scenario for CATV and IPTV, that any 4K-UHD channel is decoded in the STB and supplied uncompressed over HDMI to the 4K-UHD flat screen TV. **The RULE will be that any new STB required for general pay-TV operations (Sat-TV, CATV, IPTV) in the future will also feature 4K-UHD decoding.** (And down-converting from 4K-UHD to HD to enable subscribers with HD-only flat screen TVs to watch programming only originating in 4K-UHD. But then again, the program may actually be delivered as a down-converted HD channel, requiring no down-conversion in the STB.)

What about an external "ROKU-type 4K-UHD box"? Does it make sense?

NOT really. As we said above, nearly every 4K-UHD consumer flat screen TV brought to market will include an embedded HEVC decoder coupled with the ability to connect up directly to the Internet, via WiFi or wired RJ45 (a Smart TV). There is no market demand for an external box or stick with 4K-UHD HDMI output to feed into a Smart 4K-UHD TV which already has such "OTT box facilities" embedded. **But then you say** "there may be a market for an external box to OTT receive 4K-UHD programming, then down-convert to 1080p/i/30/60 to supply to non-Smart 1080/720-only TVs". Possibly, but seemingly NOT exciting enough for OTT box market leader Roku, as Roku announced at the CES-2015 (Las Vegas in January) that it is expanding activities to bring Roku co-branded 4K-UHD TVs to market which TVs include an embedded "Roku platform". Checking the Roku website on March 11, 2015, the Author could not see any OTT box or stick product which included 4K-UHD features.

Bear in mind that there is very little 4K-UHD programming available in 2015 including no major TV Network programs, as compared with the vast selection of HDTV programs. External 4K-UHD OTT boxes with HD down converter (and HD HDMI output) may become available at a later time when the selection

and availability of 4K-UHD programs are plentiful. (Although adaptive streaming where a 4K stream reverts to HD only stream, when sensing no 4K capability, may eliminate the need for a down converter as such.)

HEVC (H.265) is the 4K-UHD Consumer Delivery Format

Version 1 of the HEVC/H.265 standard was approved in April, 2013. Version 2, comprising a number of extension profiles, was approved in October, 2014. HEVC will be applied extensively in professional and in consumer applications. Its compression efficiency, being about twice that of AVC/H.264, makes it ideal and necessary for consumer delivery of 4K-UHD. About half the bit-rate of AVC for comparable image quality.

The 4K-UHD HEVC compressed bit-rate (IP streaming) for home delivery of 30p 4:2:0 @ 8-bit may be around 16 Mbps over OTT Internet. Blu-ray Disc 4K may utilize up to 100Mbps peak and HEVC which is expected to produce absolutely stunning "in-home motion picture experience", with the question of whether the Hollywood film studios will embrace BD-4K as this means that "movie theater quality digital copies" will be circulating around the world, although with highly sophisticated copy protection.

The 30p 4:2:0 @ 8-bit scenario is quite acceptable as 4K-UHD delivery spec. The table below details current HD home delivery specs, illustrating that highly compressed HD produces very good to excellent large flat screen presentations. Similarly, 4K-UHD 30p 4:2:0 @ 8-bit will produce stunning presentations of 4K-UHD originated programs, subject to the contribution, distribution and delivery channel being 4K-UHD transparent. However, major league sports, particularly fast moving sports, require 60p 4K-UHD acquisition through consumer delivery to take full advantage of the 4K-UHD potential.

Consumer HDTV & 4K-UHD Delivery Chain: 4:2:0 @ 8-bit

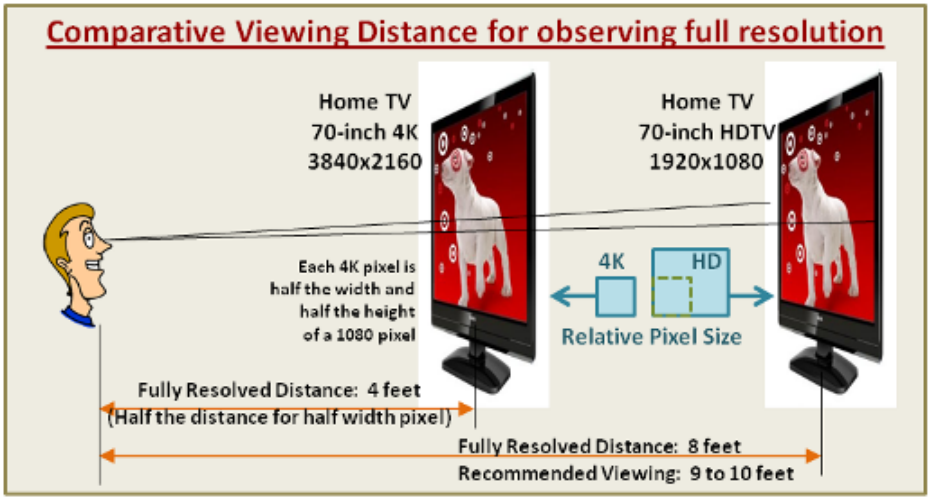
Delivery Vehicle	Format	Transmission Modulation	Video Encoding	Avg. Video compressed Bit-rate	Potential in-Home Large Screen Display Quality
TV Broadcast	1080i60 720p60	ATSC 8-VSB	MPEG-2	10 Mbps	Very good (HD)
Cable TV	1080i60 720p60	QAM	MPEG-2/4	9 Mbps	Very good (HD)
Satellite TV	1080i60 720p60	DVB-S2	MPEG-2/4	9 Mbps	Very good (HD)
OTT HD (Internet)	1080p60 720p60	IP Streaming	MPEG-4 AVC H.264	3 to 5 Mbps	Acceptable to Good (HD) (Netflix, HULU, VUDU etc.)
Blu-ray Disc	1080p24	17PP Disc	AVC/VC-1	36 Mbps	Excellent (HD)
OTT 4K-UHD (Internet)	4K-UHDp30	IP Streaming	HEVC H.265	16 Mbps	Very good
OTT 4K-UHD (Internet)	4K-UHDp60	IP Streaming	HEVC H.265	40 Mbps	Excellent
Blu-ray Disc	4K-UHDp24 (up to p60)	?	HEVC H.265 10-bit	100 Mbps	Excellent (Ultra-HD w/HDR)

Consider this:

We know that substantially all HD signal delivery to consumer destinations is by a 4:2:0 sub-sampling structure (and heavily compressed with 8-bit depth) in order to conserve transmission delivery bandwidth, only to be "reconstituted" to 4:4:4 (RGB) in the flat screen HDTV or projector. The lesson learned over the past 10 years of HD is that a 4:2:0 sub-sampled 8-bit digital video signal is quite capable of producing stunning video presentations in both the consumer and professional environments.

Viewing 4K-UHD Video

A 4K-UHD flat screen TV offers a potential resolution 4x that of a 1080 flat screen, 8+ million pixels vs. 2+ million pixels. How will this affect a consumer's home viewing habits? We can all agree that any 4K-UHD flat screen display in the home must be relatively large to make sense. Let's use a very large 70-inch (diagonal) display as the norm, which is fully resolved by the human visual system at a viewing distance of about 8 feet for 1920x1080 for a person with 20-20 vision. It's recommended viewing distance is about 10 feet for high quality HD video presentations. What does "fully resolved" mean? Simply that, upon focus concentration, the person can see each pixel making up the image. The picture height of a 70-inch screen is 34 inches, making the fully resolved 1080 viewing distance 2.8x picture height. (8 feet = 96 inches divided by 34 = 2.8)



The underlying scientific approach is to consider that the human visual system is capable of seeing details with a width of about one (1) arcminute, which is 1/60th of one (1) degree of a circle. The additional consideration is to find the average optimum horizontal viewing angle where the audience becomes emerged in the viewing experience without requiring any significant (side-to-side) head movement to digest the screen as a whole. SMPTE has recommended a home viewing angle (to the width of any 1080 HDTV) of about 33 degrees minimum, which for a 70-inch (width = 61 inches) 1080 HDTV produces a viewing distance of 9 feet (equal to 3.2x picture height).

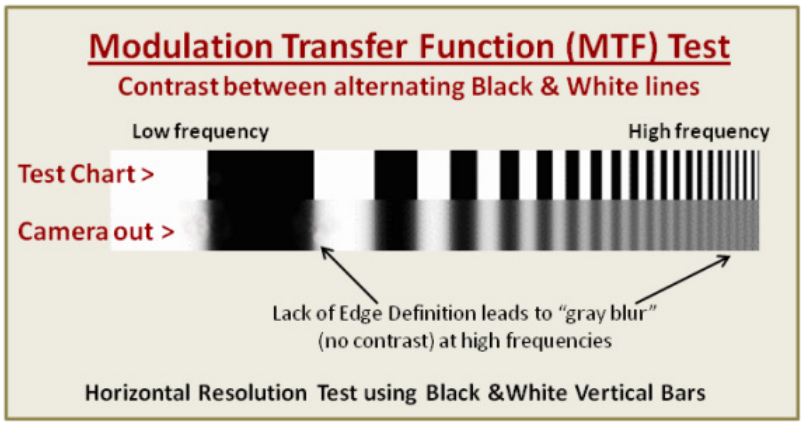
However, moving to a 4K-UHD 70-inch TV reduces the "fully resolved viewing distance" to half (4 feet) and correspondingly puts it's recommended viewing distance just beyond 4 feet. This doubles the viewing angle from 33 degrees to 66 degrees, which is excessive for comfortable in-home viewing and a difficult physical proposition as typical US living/family rooms promote seating arrangements generally 8 to 12 feet away from any wall mounted flat screen TV. Does this indicate that 4K-UHD home flat screen TVs need to be larger than 70 inches for a real 4K-UHD viewing experience for the audience sitting 8 to 9 feet away? Yes, to be close to the fully resolved distance, but no in terms of recognizing a significant improvement in perceived resolution and in the feeling of being immerged in the TV presentation, as compared with a somewhat smaller HDTV (i.e. 50-inch), viewing a true 4K-UHD originated and delivered program (down-converted to HD for the HDTV presentation).

Shoot in 4K-UHD . . .
Deliver highest quality 1080p/i
And preserve options for future 4K releases

4K-UHD potentially offers 4x the spatial resolution of 1920x1080 (9x the spatial resolution of 1280x720). With the capability to shoot 4K-UHD in progressive 24/25/30 frames per second, standard in JVC's less than $5,000 street priced GY-LS300 Super-35 camcorder (with quality lens and accessories, ready to shoot), as well as in the fixed lens models GY-HM200 (street price about $3,000) and GY-HM170 (street price about $2,000), acquiring the footage in 4K-UHD may significantly improve the perceived resolution and sharpness of any downconverted 1080p/i video clip as compared with the same video program having been acquired in 1080p/i. This is how:

Enter Modulation Transfer Function (MTF)

The combined ability of the camera front-end components to resolve and register the most detailed images on the sensor, including the sensor's photo-sites' ability to accurately convert light intensity to an analog voltage, is represented by the modulation transfer function (MTF) performance.

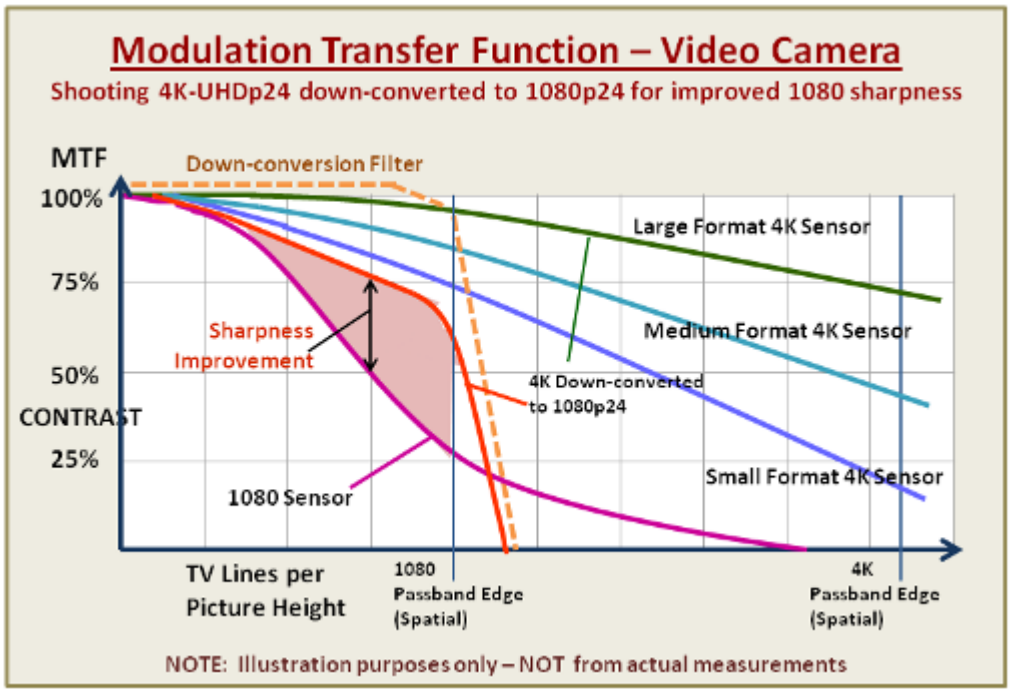


Such MTF performance is generally presented as a graph showing how the percentage of MTF declines as the frequency of alternating black and white lines increase. Let's first look at a horizontal resolution test using black and white alternating vertical bars.

Simply explained, the MTF-induced "transition blur" on the bar edge where black transitions to white (or white to black) goes through a time period of gray. Fine image details (i.e. any sharp transition edge)

contain very high frequencies, such as vertical alternating black/white test bars with a repetition frequency approaching the horizontal pixel count. When the black (or white) bar "on time" approaches the relatively fixed time period of the "gray transition blur" (high bar repetition frequency), the black/white bars become gray and undistinguishable as the MTF drops. The MTF is often referred to as a contrast factor.

The MTF performance in a 4K-UHD video camera is (or should be) by definition better than the MTF performance in a 1080 video camera at any given frequency, presuming similar levels of professional quality. One measure of resolution is the perceived (subjective) sharpness of the video presentation, which has been found to be proportional to the amount of area under the MTF curve from 0 to the pass-band edge (Horizontal axis). Look at the graph below.



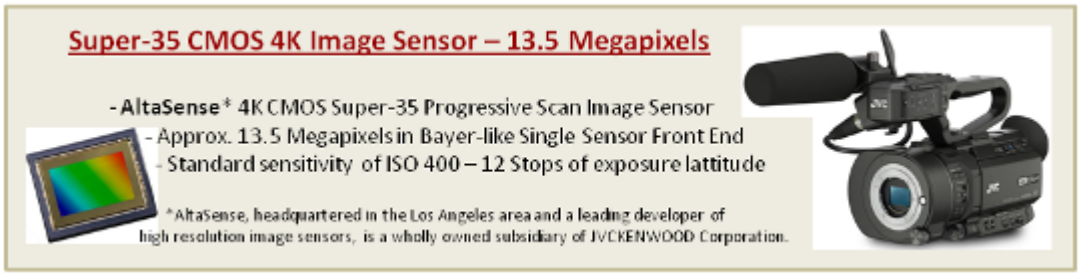
What does the above graph really compare? The purple colored MTF curve is that of 1080p24, as typical performance of a video camera with 3xCCD (or 3xCMOS) full count 1920x1080 small format imagers where each of the RGB sensors are sampled 24p, then converted to YCrCb 4:2:2, compared with a 4K-UHD video camera (green trace) fitted with a typical Bayer-CFA single large format sensor for 3840x2160 4K containing 8.3 million photo-sites, where each of R, G and B photo-sites are sampled 24p, de-Bayered, interpolated and processed to YCrCb 4:2:2 limited by Nyquist. The orange trace is the improved MTF for the 1080p24 downconverted from 4K, indicated by the pink shaded area (the increase in area under the curve). Bear in mind that there are generally two (2) down-conversion options available: (1) Shoot with the 4K-UHD camcorder in the 4K-UHD output mode, then down-convert outside the 4K-UHD camcorder in the post production process, or (2) shoot with the camera front end in full 4K-UHD mode, while down-convert in the camcorder in real-time outputting 1080p24 (or recording to SD memory internally).
An additional benefit to shooting in 4K-UHD output mode is that the program material may be stored in 4K for future 4K distribution or delivery when 4K delivery becomes more common place.

The GY-LS300 Super-35 Handheld

Professional Versatility meets Cinematic Excellence at a Price Point every cinematographer can afford

Introducing the world's first handheld light-weight interchangeable lens 4K-UHD camcorder with the exclusive and unique combination of a 13.5 megapixel Super-35 sensor and a built-in MFT lens mount.

Earlier in this White Paper, we discussed the Bayer single sensor approach and found that a 4K-UHD imager needs a minimum of 8.3 million pixels (3840x2160 = 8,294,400) of RAW read-out in order to achieve prime 4K-UHD video, after de-Bayering, interpolation and processing.



Of course, there is a compromise to be made between physical size of the single sensor and the number of pixels which can be accommodated from a given light sensitivity point of view. Smaller format 4K-UHD sensors generally have limited the maximum number of pixels to the earlier stated minimum of 8.3 million required for good 4K-UHD image acquisition, while large format sensors (i.e. JVC/AltaSens Super-35) are free to increase the number of pixels far beyond the 8.3 million, while bearing in mind the resulting requirements for much higher real time processing power to achieve LIVE 4K-UHD viewable output and/or RAW record capability. Although the Super-35 size imager (~24mm x 16mm) is not the largest sensor employed in digital video cameras today, it seems to be the best compromise between 4K-UHD video quality, lens availability, physical packaging and affordability.

The AltaSens Super-35 Sensor features a total of 13.5 Megapixels in a sensor area of some 380 mm^2, with a gross pixel matrix of 4512 x 3008 = 13,572,096 pixels, each pixel occupying an area of 5.2 x 5.2 micro-meter. Such a relatively large pixel area will assure excellent light sensitivity properties making for very good cinematic performance even under difficult lighting conditions. **Nominal Sensitivity ISO400 – 12 Stops of Exposure Latitude**

ALTASENS
A JVCKENWOOD Company

Affordable? Yes, indeed. The GY-LS300 is "street-priced" in the US at less than $5,000 including a good quality Super-35 lens, ready to shoot exceptional 4K-UHD quality footage.

The MFT Lens-mount

The GY-LS300 features the perfect union between Super-35 and Micro Four Thirds interchangeable lenses

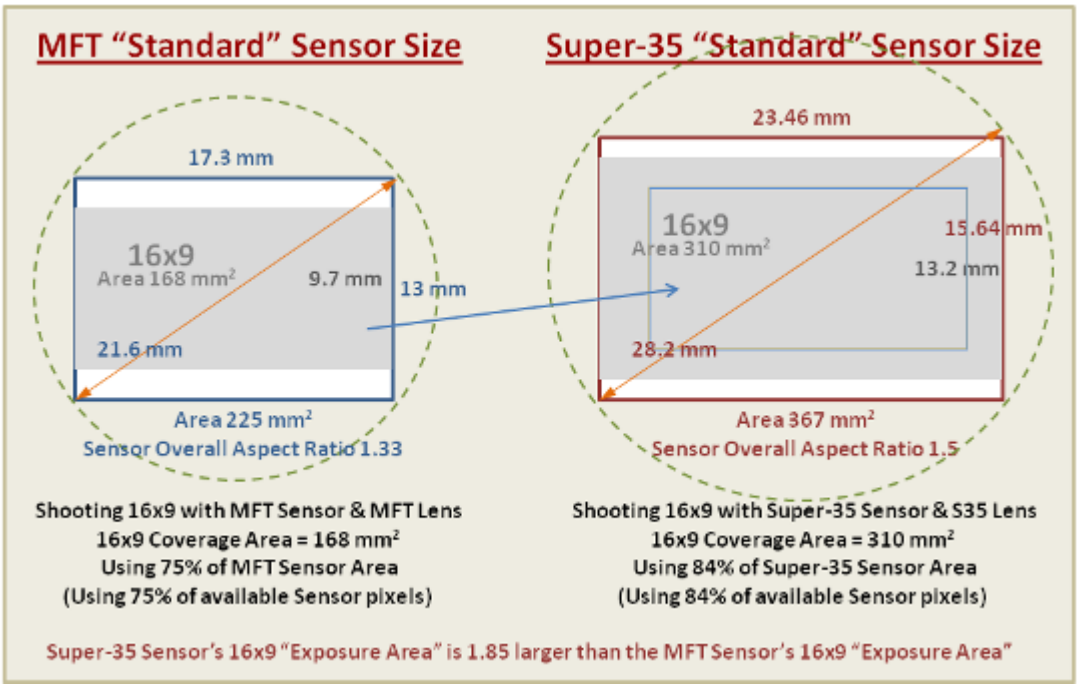
What is Micro Four Thirds (MFT) about? MFT was announced back in 2008, to standardize lens mounts and physical size of sensors for mirror-less digital cameras and camcorders with interchangeable lenses. But, to the 4K-UHD camcorder users today and in the future, it's about a standardized industry Flange Back, being the physical distance from the lens mount plane to the image sensor, in addition to the mechanical and electrical specs for lens mount itself and physical sensor size. The original **Four Thirds** (4/3 = 1.33 image aspect ratio, as in the NTSC television image recently and as in 35mm film format long time ago) featured a longer distance Flange Back and a somewhat larger mechanical lens mount.

Rokinon Super-35 Lenses with integrated MFT mount

A few years ago the DSLRs started to shoot HD video and now 4K-UHD, and, over recent years, many camera and lens companies have brought HD and 4K-UHD capable lenses to market to address the Micro Four Thirds market need, complying with mounting standard and with the **shorter Flange Back distance of 19.25 mm**. Some of these MFT-mount lenses were specified Super-35 meaning that the lens' image circle would fully cover the standard Super-35 sensor.

So, what did JVC do in a brilliant move? JVC made the standard fixed lens mount in the GY-LS300 Super-35 Sensor Camcorder fully MFT compliant (including the 19.25 mm Flange Back distance), thus the LS300 does NOT require an adapter to attach any one of a hundred+ readily available MFT-mount lenses, of which many are Super-35 type. Thanks to the short flange (MFT) focal distance in the GY-LS300, most cinema lenses can be adapted for use. Various mount adapters are available, including PL, EF, Nikon and C mounts. The LS300 mount's electrical connections are compatible with many auto focus, iris and power zoom lenses—even when using an adapter.

One important difference from most Micro Four Thirds cameras is that the GY-LS300 uses a Super-35 imager—approximately 63% larger in area than a standard MFT imager (see illustration below). JVC's mount provides full coverage of the Super-35 imager meaning that Super-35 lenses may be used without worry of vignetting. In fact, a number of S35 lenses are available that do not require an adapter. For the professional on a budget, having a camera this versatile can literally save thousands of dollars in avoided new lens purchases. Let's look at the dimensions of the sensor coverage of Super-35 vs. MFT.



Study the above illustration. We're mostly interested in shooting 16x9 in HD or in 4K-UHD, utilizing the largest possible image area of the gross active pixel matrix. The LS300 Super-35 Image Sensor comprises approx. 13.5 million pixels over a gross active imager area of 367 mm2 . The 16x9 active image area is 310 mm2 or 84% of the entire sensor, meaning that the 16x9 area of the Super-35 sensor comprises 13.5 Mpixels x 0.84 = 11.34 Mpixels. In a typical Bayer-type implementation, we get the following breakdown of Green, Red and Blue pixels:

- Green (luminance determinant) – 50% of all pixels = 5.67 Mpixels
- Red – 25% of all pixels = 2.84 Mpixels
- Blue – 25% of all pixels = 2.84 Mpixels
- Pixel Size = 5.2 x 5.2 micro-meter – square

Earlier in this White Paper, we discussed that any 16x9 sensor required a minimum of 8.3 Mega-pixels to produce a good quality 4K-UHD video, derived from the basic pixel matrix of 3840x2160 (= 8,294,400 pixels). In this case of the GY-LS300, there are 11.34 Mega-pixels within the Super-35 size sensor's 16x9 framing, with each pixel being relatively large, delivering high sensitivity, great dynamic range and stunning 4K-UHD video.

A standard MFT (Micro Four Thirds) size sensor (although materially smaller in total area, only about 60% of the Super-35 sensor area), may contain more pixels or less pixels as selected by the camera/camcorder manufacturer, as there is no "industry standard" MFT pixel matrix (as there is no Super-35 pixel matrix standard). It's obvious that a Super-35 size sensor will generally outperform a MFT size sensor, each similarly optimized for serving the same shooting purpose, because of the larger total sensor area.

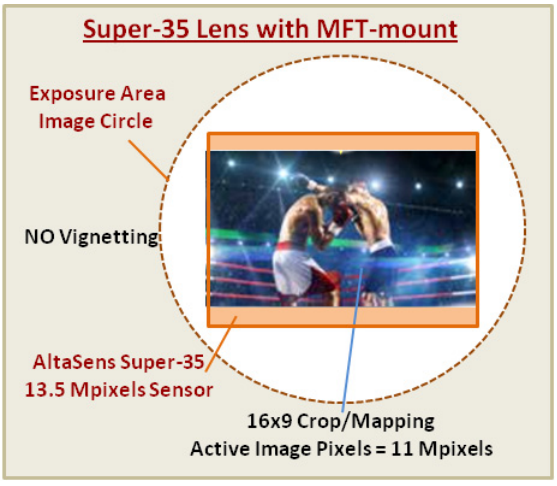
VSM – Variable Scan Mapping:

Choose from a large selection of interchangeable lenses . . .
Eliminates Vignetting – Maintains native Field-of-View for any lens

We are really only interested in the 16x9 aspect ratio, as all 4K-UHD and HDTV shooting modes use 16x9. The shooting/recording/monitoring/proxy image formats in the GY-LS300 are all 16x9 except for the one SD mode of NTSC 720x480 (PAL 720x576). JVC designed the GY-LS300 camera front end in order to accommodate the largest possible selection of lenses, whether Super-35, Super-16, MFT as well as others including older prime film lenses, subject to lens mount and availability of adapters. No other handheld 4K-UHD camcorder can match the interchangeable lens options of the GY-LS300.

The AltaSens Super-35 sensor features an active gross image area aspect ratio of 1.5 or 15x10 (compare 1.78 for 16x9). This means that we need to crop the top and bottom of the AltaSens Super-35 sensor image, while maintaining the maximum sensor width, to arrive at the largest possible 16x9 image area. Any standard Super-35 MFT-mount lens will expose the entire Super-35 image area free from vignetting. But, when using a fully MFT-compliant lens intended for a MFT sensor-fitted camcorder, the MFT-compliant lens will not expose the entire Super-35 sensor in the GY-LS300 but only the area equal to the standard MFT sensor area, creating vignetting (see picture), as the area surrounding the lens exposure area will be increasingly dark towards the edges of the captured image (if left "untreated"). Similarly when using a Super-16 lens, as the "Super-16 image circle" exposes an even smaller area of the Super-35 sensor, serious vignetting will result (again, if left "untreated").

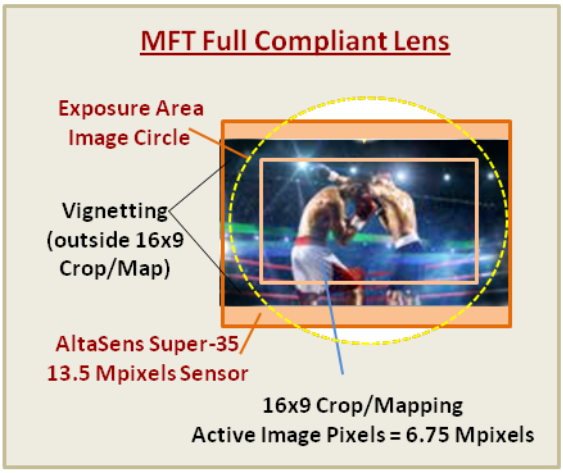
JVC's "treatment" is revolutionary, applying VSM – Variable Scan Mapping. VSM lets you choose the lens you want as it enables the camera to maintain the native angle of view for a large variety of lenses including many popular Super-35, MFT and Super-16, eliminating vignetting in the recorded 16x9 video and, of course, in the LIVE and IP outputs as well as on the flip-out LCD monitor. Let's look at details.



The GY-LS300 is designed to be a Super-35 format camera, with a native single Super-35 CMOS sensor with a total of 13.5 Mpixels (4512 x 3008) and an aspect ratio of 1.5. Any Super-35 lens with integrated MFT mount will expose the entire sensor, avoiding vignetting.

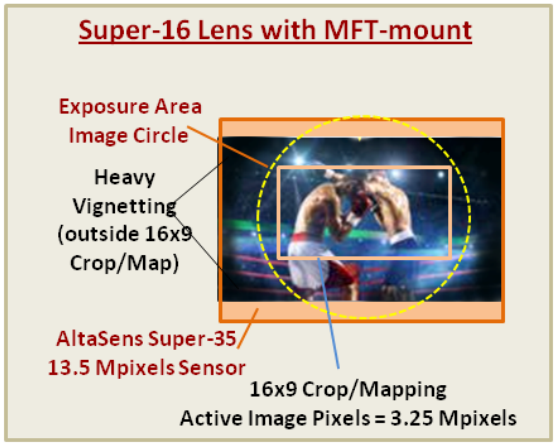
Our interest is in a 16x9 framing, as such is always the aspect ratio of HD and 4K-UHD output video. Taking nearly the full sensor width of 4500 pixels require a picture height of 2531 pixels to create the maximum active cropped 16x9 area (4500x2531) containing about 11.4 Mpixels, or 37% more pixel-points than in the standard 4K-UHD raster of 3840x2160. The 11.4 Mpixel-point data stream is

de-Bayered, interpolated and processed in real time to produce the LIVE 4K-UHD or HD output. **VSM-mode is set to Super-35 and VSM makes sure that the 16x9 crop results in the largest possible 16x9 area.**



The illustration immediately to the left presents the exposure area (image circle) produced by attaching a fully compliant MFT lens to the GY-LS300. Again, our interest is in a 16x9 framing and to eliminate any vignetting inside the 16x9 framing.

The maximum useable width is the native width of a standard MFT sensor or about 17.3 mm. Applying the 16x9 aspect ratio to that width produces the image height of 9.7 mm or an area of 168 mm2. With the gross active area of the Super-35 sensor being 367 mm2, using the fully MFT compliant lens produces an active 16x9 cropped area equal to about 46% of total Super-35 sensor area, or 6.2 Mpixels, which is sufficient to sample RGB in the HD mode (1920x1080 = 2,073,600 pixel points x 3 = 6.2 M) producing excellent HD. **VSM-mode is set to "MFT" making sure that the 16x9 sensor crop is within the standard MFT area and image circle, which will avoid any vignetting inside the 16x9 crop.**



The illustration immediately to the left presents the exposure area (image circle) produced by attaching a Super-16 lens to the GY-LS300, using MFT adapter. Again, our interest is in a 16x9 framing and to eliminate any vignetting inside the 16x9 framing.

The maximum useable width is the native width of a standard Super-16 frame or about 12.5 mm. Applying the 16x9 aspect ratio to that width produces the image height of 7 mm or an area of 88 mm2. With the gross active area of the Super-35 sensor being 367 mm2, using the a Super-16 MFT mount lens produces an active 16x9 cropped area equal to about 24% of total Super-35 sensor area, or 3.25 Mpixels, which is more than sufficient to acquire excellent HD. **VSM-mode is set to "Super-16" making sure that the 16x9 sensor crop is within the standard Super-16 area and image circle, which will avoid any vignetting inside the 16x9 crop.**

NOTE: The term "Crop" in here refers exclusively to cropping a 16x9 frame, NOT to any focal length Crop Factor.

VSM – Variable Scan Mapping – From Sensor to Video Out

In simplified terms, the VSM maps the active pixels (inside any 16x9 crop) to the output format of HD (1920x1080/1280x720) or 4K-UHD (3840x2160) video, after de-Bayering, interpolation and processing, while discarding all pixel sensor data outside the 16x9 crop area.

In the case of the Super-35 lens, minimal top and bottom cropping occurs to conform to the 16x9 image height, using 11.4 Mpixels (of the Super-35 sensor's total of 13.5 Mpixels) being de-Bayered, interpolated and processed to output any 16x9 available camera format in HD (1920x1080/1280x720) or 4K-UHD (3840x2160) video.

In the case of the fully compliant MFT lens, significant cropping is applied on all sides to eliminate any vignetting inside the resulting 16x9 frame, in the end using only around 54% of all pixel points available in the Super-35 sensor 16x9 crop (11.4 Mpixels). 54% comprises about 6.2 Mpixels of the total 11.4 Mpixels inside the 16x9 crop). In other words, there are 6.2 Mpixels of active data which may be de-Bayered, interpolated and processed to output any 16x9 available camera format in HD (1920x1080/1280x720) or 4K-UHD (3840x2160) video.

In the case of the Super-16 MFT lens, a large amount of cropping is applied on all sides to eliminate any vignetting inside the resulting 16x9 frame, in the end using only around 29% of all pixel points available in the Super-35 sensor 16x9 crop (11.4 Mpixels). 29% comprises about 3.25 Mpixels of the total 11.4 Mpixels inside the Super-35 16x9 crop. In other words, there are 3.25 Mpixels of active data which may be de-Bayered, interpolated and processed to output any 16x9 available format in HD (1920x1080/1280x720) or 4K-UHD (3840x2160) video.

Framing your Lens of Choice . . . Really!

One could assume that the Super-35 sensor and an MFT mount is a mismatch, being the MFT sensor is about 35% smaller than the Super-35 sensor. But, thanks to the Variable Scan Mapping, the GY-LS300 is compatible with a wide array of lenses and mounts enabling photographers to choose just the right lens, with the perfect aperture and choice field of view for any scene, and maintaining the native angle of view for any and all compatible lenses. Let's review the lenses compatible with the GY-LS300. Recall that the fixed lens mount is MFT compliant, but with an over-sized Super-35 sensor.

- Any MFT compliant lens (intended for camcorders with MFT size sensor)
- Any Super-35 lens with MFT mount (i.e. Rokinon)
- Any Super-35 lens fitted with MFT compliant adapter
- Any Super-16 lens fitted with MFT compliant adapter
- Any PL, EF and C lens fitted with MFT compliant adapter

4K-UHD Broadcast Quality Recording . . .

150Mbps H.264 to removable SD Memory

No one has more experience than JVC in professional SD memory card in-camera recording technology. JVC introduced this highly cost effective consumer-based (but very reliable) technology in its ProHD camcorders in 2009 when the two major competitors (you know whom) were introducing rather expensive custom designed memory cards and optical disc recorders to go for propriety. Needless to say that JVC's approach is still going strong while the competitors' proprietary storage is not.

Dual SDHC/SDXC card slots make the GY-LS300, GY-HM200 and GY-HM170 truly versatile camcorders, offering such benefits as simultaneous recording and relay recording. In relay recording mode, you can shoot continuously and seamlessly over multiple cards. When one card is full, the camcorder switches seamlessly and automatically to the other card. And because cards are hot swappable, there is in effect no limit to the continuous shooting time in any mode, even with lower capacity cards.

Video/Audio Internal Recording Specifications – SDHC/SDXC Cards
JVC 4KCAM Camcorders GY-LS300 – GY-HM200 – GY-HM170

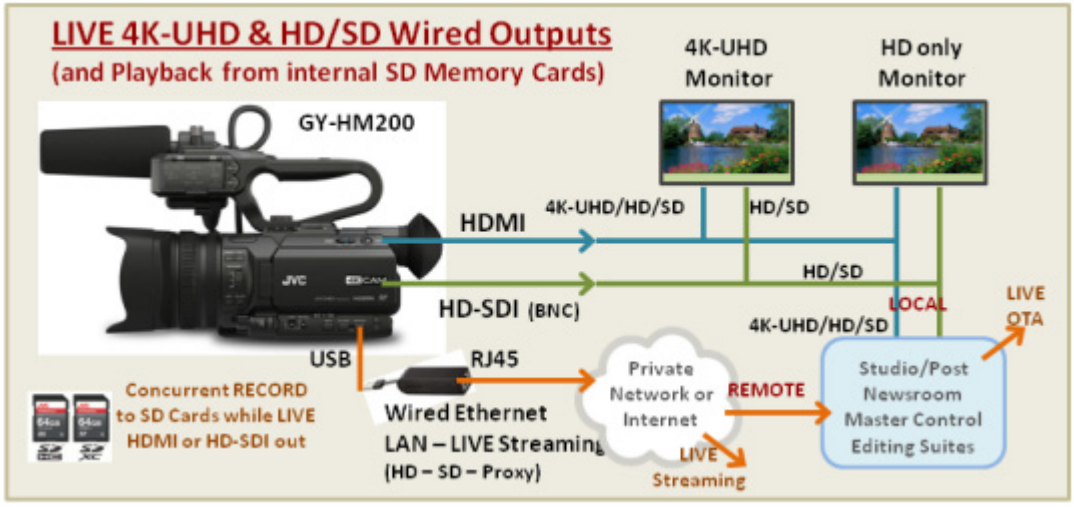
Video Recording Format	Compressed Bitrate	Encoding Format	Frame Rates	Recording Capacity 128GB Card
4K-UHD	150 Mbps	H.264	24/25/30	> 100 minutes
HD 4:2:2	50 Mbps	H.264	24/25/30/50/60	> 5 hours
HD XHQ	50/35 Mbps	H.264	24/25/30/50/60	> 7 hours (35 Mbps)
HD	28/17/9/5 Mbps	AVCHD	50/60	Many hours
SD	8 Mbps	MOV/AVCHD	50/60	Many hours
Proxy	3/1.2 Mbps	H.264	24/25	Many days
Audio – 2 CH.	Included in video	LPCM – AC3 - mlaw		Included in video capacity

NOTE: Frame Rates of 24, 30 and 60 are 23.98, 29.97 and 59.94 respectively

LIVE 4K-UHD & HD/SD Outputs

The early "pre-production" 4K-UHD class of consumer flat screen TVs provided 4x HDMI inputs with each HDMI input serving one HD quadrant of the 4K display. Obviously, this is no longer being used, as the newer HDMI standards provide for sufficient bandwidth to carry uncompressed 4K-UHD over a single HDMI cable, and the 4K-UHD flat screen TV manufacturers quickly adopted the single HDMI port, as nothing else "single" was available.

HDMI 1.4 (2010) extended max bitrate to 10Gbps, to carry uncompressed 4K-UHD/30p.
HDMI 2.0 (2013) extended max bitrate to 18Gbps, to carry uncompressed 4K-UHD/60p.



HDMI is uncompressed

As we have indicated earlier in this document, any compressed HD in a standard consumer delivery format is 4:2:0 at 8-bit depth. However, any uncompressed HD format, being exclusively professional (i.e. HD-SDI and 3G-SDI), is generally 4:2:2 at 10-bit depth. HDMI connected video is indeed uncompressed but generally 4:2:0 at 8-bit depth (higher sampling and bit depth are permitted).

Two of the 4KCAM camcorders (GY-LS300 and GY-HM200) feature identical LIVE wired HD-SDI and HDMI outputs, while the GY-HM170 only features HDMI. IP streaming is not included in the GY-HM170.

The camcorder HDMI output may supply uncompressed 4K-UHD or HD or SD to an external HDMI input monitor, as selected by the cinematographer, and in a remote setting relying on concurrent separate LIVE (or internal SD card playback) streaming output to transport the video back to the TV Station. Professional 4K-UHD video monitors may feature both HDMI and HD-SDI ports, although the HD-SDI cannot deliver 4K-UHD video. In a local setting, where the camcorder is shooting LIVE inside the TV studio (or simply used as a playback device), "limited length" HDMI cabling may reach desired TV studio facilities.

Why HDMI . . . and not HD-SDI?

HD-SDI (SMPTE 292M) provides for 1.5 Gbits/s transmission by a single 75 ohm coax cable, while the newer 3G-SDI (SMPTE 424M) provides for 3 Gbits/s. HD-SDI generally connects uncompressed 4:2:2 at 10-bit depth for 720p60 and 1080i60, while 3G-SDI connects 1080p60 and various digital cinema formats at 24p. HDMI provides for up to 18Gbps and now includes professional specs. There is currently NO SDI spec for 4K-UHD, however, SMPTE is working on a 12G-SDI which will accommodate 4K-UHD over a single 75-ohm coaxial cable. But, do we need it? Now that HDMI already covers 4K-UHD (and 4K-DCI) with professional extensions. And video-over-IP formats are also being standardized.

Consider this:

The television industry is poised to take the next step into the IP world, by replacing SDI facility routers with IP-based routers, and to expand their use of IP networking for LANs as well as WANs in achieving ultimate video transport and delivery to any destination at any time, LIVE and FTP. Note that JVC's ProHD and 4KCAM camcorders currently have IP packetizing and processing functionalities embedded, for IP streaming backhaul over 4G-LTE, WiFi and Ethernet. These current IP facilities may in the future be expanded to interface with new IP router/networking architecture as adopted by television facilities.

F.A.S.T.
Fluent Adaptive Streaming Technology

Built-in features in GY-LS300 and GY-HM200

JVC's Camera-embedded approach to LIVE streaming backhaul (including HD-ENG) is simple as it is sophisticated. Now in its third year, it's getting better and better, and it's a winner for the customers as software updates are free (to the extent no hardware is required). JVC decided on a name change for 2015 to better describe this incredible streaming technology: **F.A.S.T. for Fluent Adaptive Streaming Technology**. The updates for 2015 include an increase in maximum streaming bitrate up to 12 Mbps, subject of course to available network/Internet bandwidth, and Zixi multi-view delivery (viewing multiple inputs on the same screen) via the ProHD Broadcaster Server (BR800).

Resident software clients (4G, WiFi and Web Server Clients) inside many ProHD and 4KCAM Cameras support the efficient operation of a single 4G-LTE USB modem (or a single WiFi USB modem) plugged in to the Camera's USB Host port. In addition, a "Feeder Client" supports the formatting and feeding of IP packets contained in the video/audio/metadata LIVE backhaul stream including FEC (Forward Error Correction) as required. The Web Server Client makes it possible to operate, monitor and control the Cameras remotely, by WiFi or 4G wireless (or LAN Ethernet wired) access from anywhere in the world, next door or next continent, by using the browser of any PC, tablet or Smartphone, addressing the Camera by its unique IP address.

JVC and USTREAM simplify video streaming.

Select JVC cameras with built-in HD streaming offer simplified delivery of live video via Ustream's unmatched scalable, HD, easy-to-use video platform. Video can be streamed or recorded for immediate or on-demand viewing via one-button access.

Two of the three new 4KCAM camcorders, the GY-LS300 and GY-HM200, feature support for the industry-standard Real Time Messaging Protocol (RTMP) for streaming video over the Internet. JVC will soon also add the protocol to its three latest ProHD streaming camcorders, the handheld GY-HM650 and the shoulder-carried GY-HM850 and GY-HM890. RTMP is compatible with Ustream's industry-leading scalable, reliable platform as well as a number of content distribution networks (CDNs).

JVC cameras with RMTP support allow easy access to Ustream services, and up to four Ustream channels can be stored via the camera menu, so initiating a live webcast directly from the camera/camcorder is simply accomplished by pressing just one button. The camera connects to the Internet via Wi-Fi, or users can plug in an LTE modem via USB or use a mobile hotspot. Stream status is available in the viewfinder and on the flip-out LCD monitor.

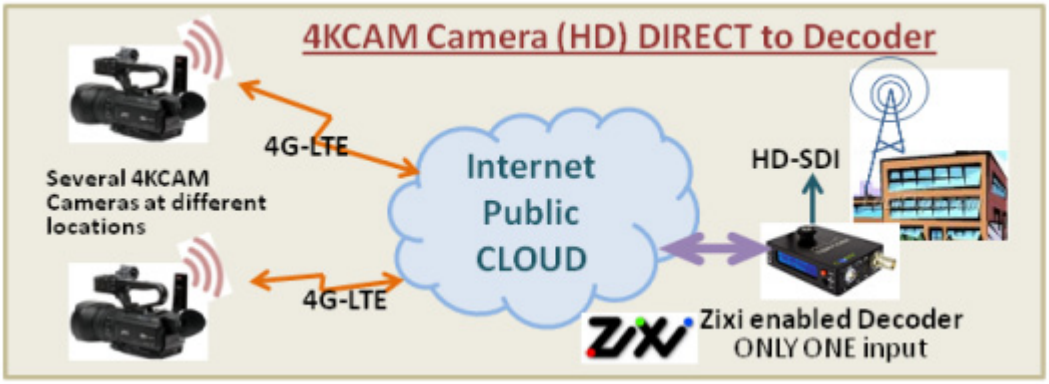
LIVE Streaming is not yet available for 4K-UHD for the primary reasons (1) that the necessary HEVC-H.265 compression format and licensing details are not yet finalized, and (2) that it is technically and operationally not possible to assure a high level of transmission reliability over the public internet at the relatively high LIVE streaming compressed bitrates required for 4K-UHD.

JVC's "UN-bonded" Streaming Solution

- F.A.S.T. is standard in nearly many 4KCAM and ProHD camcorders
- Just plug in one (1) 4G-LTE USB Modem (or WiFi) into Camera USB Host port
- Low, less than 2-second LIVE latency for News quality HD, two-way LIVE interview
- 5-second LIVE latency mode for high quality HD, one way LIVE contribution
- Streaming Connection and Link monitoring in Viewfinder & LCD flip-out
- Camera remote control over IP connection (LAN, WAN and Internet world-wide)
- Include FTP and Metadata transfer functionality
- F.A.S.T. works in concert with JVC's Professional Streaming Services (PSS)
- High-level PSS operation require the ProHD Broadcaster Server
- The Server is installed locally or CLOUD-based as a Platform Service

Camera to Decoder – Direct

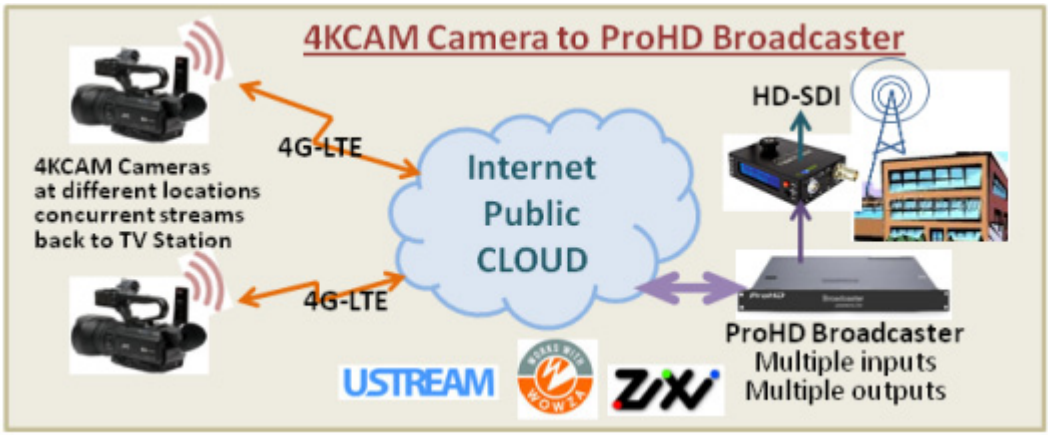
The illustration immediately below shows the Base Level approach to LIVE backhaul streaming taking full advantage of F.A.S.T. without the need for the ProHD Broadcaster Server. This is suitable for a single TV Station where the only objectives are two-fold: (a) to receive reliable remote LIVE HD streams which are immediately decoded to HD-SDI for Master Control LIVE OTA, and (b) to receive FTP transfers, for facility routing, storage and editing. With this basic Direct Service level, any video processing required of the LIVE HD backhaul (and FTP) for Website (or other) purposes must be performed as a separate function by the TV Station.



The above Illustration shows a Zixi enabled Teradek Decoder connected to the Internet via wired Ethernet (RJ45) or, if desirable, via TV Station's WiFi LAN. The Decoder is reached by the Camera specifying the unique IP address of the Decoder. Note that the Decoder is a single channel device in the HD-SDI output mode. If two or more Cameras are streaming at the same time, then each Camera require a separate Decoder back at the TV Station, each with a unique IP address, to provide multiple HD-SDI concurrent outputs. The cost of F.A.S.T. (CAPEX and OPEX) is only a small fraction of the cost of Bonded Cellular Backpack and Bonded Camera-Backs! Ever tried to attach a Bonded Cellular Box to a handheld size camera?

Cameras streaming to local ProHD Broadcaster Server

The illustration below shows a F.A.S.T. solution for a major TV station operating a number of 4KCAM (and perhaps ProHD) Cameras, where the **ProHD Broadcaster Server** (BR800) may be installed locally at the TV station/News Room, making it possible for the TV Station to pre-program the sharing of LIVE streaming to one or more Cameras simultaneously to additional destinations, such as sister/duopoly TV stations, Websites etc. with each stream capable of being in a different format as required.



The **ProHD Broadcaster Server** offers multiple (virtual IP) inputs and outputs, specified as "unlimited" number of listed unique IP addresses. There is obviously a limit on the ability to receive and process concurrent LIVE streams from multiple Cameras, but this limit is believed not to be operationally significant in any TV Station application. Note that the ProHD Broadcaster may connect with Internet streaming services like USTREAM, Wowza and Zixi for public and private LIVE and recorded streaming services.

Advanced IP Network Communication and Streaming

The GY-LS300 and GY-HM200 feature JVC's latest IP communications engine, giving you remote control and monitoring of vital camera functions from a tablet, smartphone, or computer anywhere in the world. JVC's F.A.S.T. includes Zixi powered Forward Error Correction with ARQ, delivering high quality streams even under challenging network/Internet conditions. Connect your GY-LS300 or GY-HM200 to an optional Wi-Fi or LTE modem and share your program with an audience anywhere in the world via content delivery networks such as USTREAM and YouTube. Just press the button and you're streaming HD to the world!

Cinematic Excellence in 4K-UHDp24
Broadcast Quality in 1080p/i60 4:2:2 50Mbps

Compact, convenient, and ultra high definition, JVC's new GY-LS300 is equipped with a 4K Super-35 CMOS sensor and uniquely accommodates a wide range of cinema and photographic lenses and adapters for dazzling cinematic effects. Create hours of pristine recordings on SDHC/SDXC media in a variety of image formats including 4K Ultra HD, Full HD with 4:2:2 sampling, SD and web friendly proxy formats. Its dual codec design allows you to make 2 copies of your program simultaneously. You can even stream live HD over the internet to content delivery networks such as USTREAM while recording full HD. Conventional DSLR cameras simply can't match the high reliability, long recording time and ergonomics provided by JVC's GY-LS300. No other removable lens video camera offers this much flexibility in such a compact, easy-to-handle form factor.

Three 4K-UHD Camcorders:
Exceptional Performance – Great Value

We have already detailed the unique and flexible interchangeable lens options in the GY-LS300, combining Super-35 sensor with MFT lens mount. The GY-HM200 and GY-HM170 feature a 1/2.3-inch 12.4 Mpixel CMOS sensor matched to a 4K resolution capable precision integrated 12x F1.2-3.5 optical zoom lens, designed to deliver stunning, life-like 4K-UHD video over a wide range of lighting conditions. 35mm equivalent is 29.6-355mm.

24x Dynamic Zoom

When shooting in the HD mode, **Dynamic Zoom** combines optical zoom and pixel mapping to create seamless and lossless 24x zoom. This allows the camera to have a long zoom range within its small form factor. Dynamic zoom is standard in the GY-HM200 and GY-HM170.

4KCAM Feature Comparison

Feature / Model	GY-LS300	GY-HM200	GY-HM170
Image sensor	**Super-35**	**1/2.3-inch**	**1/2.3-inch**
Lens included	No	✓	✓
4K-UHD Recording (24/25/30p)	✓	✓	✓
4:2:2 50Mbps HD (24p-60p)	✓	✓	✓
SDHC/SDXC	✓	✓	✓
Dual codec recording	✓	✓	✓
Proxy recording	✓	✓	✓
Digital output	**HD-SDI, HDMI**	**HD-SDI, HDMI**	**HDMI**
XLR Audio input	✓	✓	No
ND Filters	**3**	**2**	**2**
IP connectivity	✓	✓	No
Live streaming	✓	✓	No
Handle unit included	✓	✓	No
Shotgun microphone	**Included**	**Optional**	No
Battery & AC Charger	**Included**	**Included**	**Included**
US - MSRP (as of NAB-2015) Subject to change without notice	**$4,395**	**$2,995**	**$2,195**

Summary

This 4K White Paper explains 4K today and details how 4K acquisition can substantially benefit the professional video and television community in today's mature HD world, gaining 4K experience as we are early in the transition to a 4K-UHD world. If there is one major "4K lesson" to take away after reading this 4K White Paper, it is that there is no need or reason for the professional broad market television production facilities to have access to RAW, particularly in the LIVE and near-LIVE world. RAW is a distraction to cost effective operations.

The JVC 4KCAM establishes a new class of camcorders, a broad market 4K-UHD class in which performance is measured by affordable price, "point-and-shoot ease", by simplified editing, and by LIVE full 4K-UHD resolution viewing on 4K-UHD flat screen TVs and through projected presentations. **At a "ready-to-shoot" street price range from about $2,000 to about $5,000, the 4KCAM cameras deliver a remarkable performance/price ratio.**

A JVC Professional Video White Paper issued April 2015 at NAB

About JVC Professional Video

Headquartered in Wayne, New Jersey, **JVC Professional Video** is a division of JVCKENWOOD USA Corporation. The company is a leading manufacturer and distributor of broadcast and professional video equipment, D-ILA front projection systems, and Super LoLux HD video security products.

As an early pioneer in the capture, display and recording of moving images, JVC has a rich legacy of technological innovation. In the analog world, JVC developed the color recording technology that made VCR's possible, exemplified by the company's invention of the VHS format. JVC's work in digital compression algorithms is now part of the MPEG standard used in virtually all digital formats including Blu-Ray, and digital broadcasting.

For further product information, visit JVC's Web site at http://pro.jvc.com email proinfo@jvc.com or call toll free (800) 582-5825.

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4K CAM

Super-35

4:2:2 60p 50Mbps

ProHD

On Air. On Time. On Budget.

JVCKENWOOD

A JVC Professional Video White Paper issued April 2015 at NAB