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# Role of the 2/3-inch Image Format in 4K UHD Production


4K


Written by Larry Thorpe

*Customer Experience Innovation Division, Canon U.S.A., Inc.*




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**Page**

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## Abstract

*4K digital production is today firmly entrenched in the world of theatrical motion picture production. Separately, digital 4K has now been internationally standardized for television production under the banner of UHD or 4K UHD (a consequence of the slightly different digital sampling format to that of Digital Cinema 4K). It is already being used for some high-end television production.*

*The Super 35mm image format size had long reigned in the many decades of motion picture film production and it became the pivotal format during the transition from film to digital. Meanwhile this image format has become quite popular for many program genres in broadcast HDTV production that favor the accompanying cinematic look.*

*It was inevitable that broadcasters would begin to explore the possibilities of 4K UHD for the globally popular world of outside broadcast sports coverage and the past couple of years have seen a great deal of related trial projects. The 2/3-inch image format size issue soon surfaced as the limitations of focal ranges of presently available Super 35mm zoom lenses quickly became apparent. Only two years ago the first 2/3-inch 4K UHD digital camera appeared – retaining the long-established and standardized B4 lens-camera mount. By NAB 2016 no less than four major camera manufacturers were showing 4K UHD camera systems based upon the 2/3-inch image format.*

*This paper is intended to provide a background to the emergence of 2/3-inch lens-camera systems for 4K UHD production and the optical performance expectations of associated 4K lenses. The paper will review Canon's involvement in the development of those lenses and will describe our initial 4K UHD lens family and the associated design strategies to achieve this impressive level of optical performance. The paper will explain the unprecedented strategy of introducing two categories within this new 4K UHD lens family – namely, 4K and 4K PREMIUM. The distinct performance difference between the two reflects Canon's recognition that different 4K program genres will require different levels of overall cost / performance.*

## 1.0 ARRIVAL OF 2/3-INCH 4K UHD LENS-CAMERA SYSTEMS

At NAB 2014 Grass Valley ignited the 4K 2/3-inch movement with the unanticipated showing of a prototype of what is now the LDX 86 Universe three-CMOS sensor camera system that has the ability to switch the camera from 4K UHD 1X operation to HD 6X extreme-speed operation. This was followed mid-year 2014 by Hitachi's introduction of their SK-UHD4000 HDTV Studio, Field Production four-CMOS sensor Camera system. At NAB 2015, Sony introduced their HDC-4300L 4K/HD three-CMOS sensor camera system. And, at this same convention, Ikegami unveiled a 4K 2/3-inch three-CMOS cameras as part of their special UHD technology exhibit. At NAB 2016 Grass Valley introduced an additional UHD camera using three 4K CMOS imagers.

**Figure 1** *The new 2/3-inch 4K UHD cameras from left to right – Grass Valley, Hitachi, Sony, and Ikegami*

## 2.0 Industry Expectations of 4K UHD 2/3-inch Lens-Camera Systems

The rising number of sports leagues, broadcasters, and mobile production operators who have been expressing interest in the possibilities offered by the 2/3-inch 4K UHD acquisition system generally voice five key expectations:

**2.1 Zoom Focal Ranges** – Emergence of field, studio, and portable 4K UHD lens-camera systems that are similar to those widely deployed in current HDTV production – most especially in terms of focal ranges of the long zoom box field lenses

**2.2 Lens Controllers** – Desirability to use the same lens controllers on these new lenses that are so widely used today on HDTV lenses

**2.3 4K UHD Image Performance** – Overall optical performance that is perceived as a credible enhancement over that of the best HDTV lens-camera systems

**2.4 Depth of Field** – Achieving the same depth of field that is familiar in the world of 2/3-inch HDTV production

**2.5 Lens Aperture range** – Desirability that control range of lens aperture would reflect that of contemporary HD lens-camera systems

The first two points above are central to operational practices that have evolved over the past forty years as all entities involved in global outside broadcast sports production drove developments in 2/3-inch lenses and cameras. Presently available Super 35mm zoom lenses fall short for most television studio needs, and they fall hopelessly short on focal ranges for long-zoom field lenses compared to contemporary 2/3-inch lenses. In addition, production choreographies have evolved between directors and television camera operators that center about long operational familiarities with the all-important zoom and focus controllers.

The third point is the pivotal discussion surrounding the small 2/3-inch image format size and this will be examined in some detail.

Depth of field is a variable dimension of motion imaging that is separately exploited by the creative production teams involved in moviemaking and those who do television production. Shallow depth of field is a central creative variable that has become synonymous with the “cinematic look” of theatrical motion picture production. Deep depth of field can be an essential in newsgathering and some documentary television productions – and it can be central to the motion imaging practices of television sports productions. This is a topic that needs some discussion as there is a broad misunderstanding about what can be achieved here in 2/3-inch 4K UHD lens-camera systems.

Equally significant, the effective range of lens aperture settings of 4K UHD lenses also needs reviewing.

## 3.0 Sports Coverage is the Primary Driver of Global 2/3-inch 4K UHD Television Productions

At this juncture it is apparent that outside broadcast television production is the spearhead of the still slow adoption of 4K UHD. Just looking across the first half of 2015 conveys a sense of the growing interest: Widespread 4K coverage of a variety of sporting events in the U.S; a 4K UHD Mobile Facility made its debut at NAB; BT Sports Showcase launched a new 4K UHD sports channel in the UK; the French Open tennis tournament covered all games in UHD; Sky Deutschland covered major soccer games; both Australia and New Zealand covered major cricket matches; both Sky and BBC conducted UHD test broadcasts of sporting events. In many of these events 2/3-inch UHD lens-cameras were being tested for the first time. The pace of coverage of sporting event worldwide escalated in 2016.

Much has taken place in a remarkably short space of time with respect to 2/3-inch lens-camera system designs intended for 4K UHD. Canon Inc has been deeply involved in these developments from the outset. A great deal of critically important information was gained from those tests.

## 4.0 First Canon Priority – Long-Zoom 2/3-inch 4K UHD Field

In light of this global activity in UHD, Canon gave a first priority to developing the long zoom field box lenses and portable lenses that are central to outside broadcast television productions. In September 2015 Canon announced two new 4K UHD Long zoom field lenses – the UJ86x9.3B PREMIUM UHD lens and the UJ90x9B UHD lens.

This introduction is unprecedented in that Canon almost simultaneously brought to market two new 4K lenses – *but with a distinct overall separation in optical performance between them*. The rationale behind this strategy was the recognition that some production entities will seek the very best possible 4K performance above all other considerations – anticipating that as UHD viewing expands the consumer will be transitioning to ever-larger UHD screens. This does come at a cost as the PREMIUM lens entails additional glass elements, more expensive glass materials and optical coatings, and a variety of associated design and assembly strategies.

The alternative 4K Lens UJ90x9B produces an optical performance that fully complements the 4K UHD performance of the available UHD cameras.


**Figure 2** *Showing the PREMIUM UJ86x9.3B and the UJ90x9B long zoom 4K UHD field lenses*

In August 2015 Canon announced the world's first 4K wide angle portable lens – the CJ12ex4.3B – which supports a 96 degree horizontal viewing angle. This was closely followed by a modestly telephoto portable 4K lens – the CJ20ex7.8B

**Figure 3** *The portable long zoom CJ20ex7.8B is shown top left and the wide-angle CJ14ex4.3B is bottom right*

By the middle of 2016 Canon was delivering this family of four 4K UHD 2/3-inch lenses on a worldwide basis – Figure 4. Meantime, by mid-2015 industry interest in a 2/3-inch 4K studio box lens was beginning to emerge in the U.S., Europe, and Japan and Canon was diligently working on the development of the same.

<table>
<tr><th colspan="3">2/3-INCH IMAGE FORMAT SIZE</th></tr>
<tr><th colspan="3">Television Production<br>4K UHD (3840 x 2160) and HD (1920 x 1080)</th></tr>
<tr><th colspan="2">Television Outside Broadcast and Electronic Field Production</th><th>Television Studio</th></tr>
<tr><td>• Sports<br>• Live Events<br>• House of Worship</td><td>• Sports and Live events<br>• Documentary<br>• News Magazine</td><td>• Episodic<br>• Drama<br>• Game Show<br>• Performance Reality</td></tr>
<tr><td></td><td></td><td>Under Development</td></tr>
<tr><td>Long Zoom Field Lens</td><td>Wide angle Portable</td><td>Studio</td></tr>
</table>

**Figure 4** *Showing the two long zoom field box lenses and the two portable lenses that are the initial priorities of Canon in developing a complete family of 2/3-inch 4K UHD lenses*

## 5.0 Next Canon Priority – Broadcast Studio 2/3-inch 4K UHD Lens

In September 2016 Canon introduced the anticipated broadcast studio lens that will support 4K program origination. From the point of view of operational specifications (especially focal range and angle of view at the wide setting) it was felt that the high worldwide success of the HDTV XJ27x6.5B offered a perfect model for the first 2/3-inch 4K studio lens. Accordingly, the new UJ27x6.5B reflects that same 27 times focal range and the same 6.5mm wide angle setting. It is a fast lens with a maximum relative aperture of F-1.5. It offers a 73 degree horizontal angle of view at the 6.5mm setting.


**Figure 5** *The new 2/3-inch broadcast studio lens for 4K program origination – the PREMIUM UJ27x6.5B*

It should be emphasized that this new lens is squarely in the PREMIUM category of overall optical performance that had been established in the long zoom 4K field lens. The discussions with international broadcasters who sought a studio 4K lens clearly identified the fact that they sought the very best that was possible in a 2/3-inch 4K studio lens.

## 6.0 Critical Issue of Resolution in a 2/3-inch 4K UHD Lens-Camera

Perhaps the biggest question relating to the viability of a 2/3-inch 4K UHD lens-camera system centers about resolution and image sharpness. It must be remembered that 4K means four times the number of spatial samples across the image plane compared to that of HDTV. That is a very substantial increase.

Canon engaged with the camera manufacturers developing 4K UHD cameras where the central topic was the quest for genuine 4K resolution. The early work with each centered about benchmarking the latest generation of HD lenses to help identify the various optical performance parameters essential to advancing 2/3-inch lens to 4K UHD image quality. Of particular interest to all of the camera manufacturers were the following:

1. Optical resolution at picture center must fulfill the resolution capabilities of their respective 4K cameras
2. Behavior of picture sharpness across the image plane
3. Degree of alteration to picture sharpness over the focal range of the lens
4. Alteration to picture sharpness as the subject distance changed

While the separate discussions with each of the camera manufacturers entailed a diversity of requests with respect to the points listed – a general summary is illustrated by the conceptual improvements suggested in Figure 6.

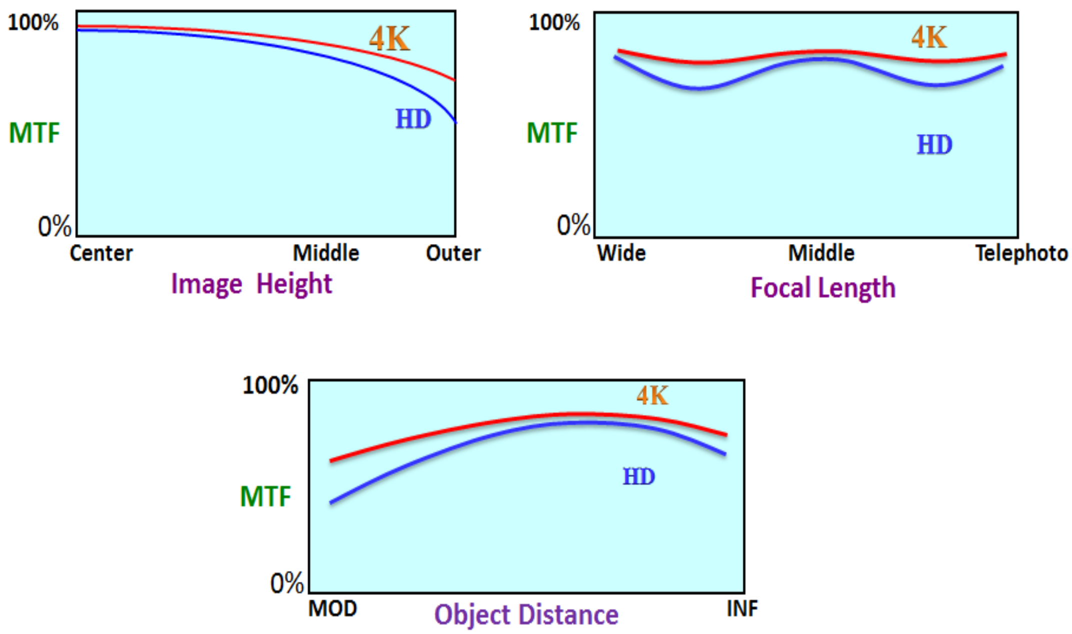



**Figure 6** *Simplistic illustrations of the recommendations of the 4K UHD camera manufacturers with respect to improvements to resolution in the new 4K UHD 2/3-inch lenses*

In addition, optical aberrations – both monochromatic and chromatic – were a central discussion as Canon began the quest to clarify comprehensive specifications for the 4K UHD lenses.

## 6.1 Lens Resolution at Picture Center

4K UHD is fundamentally defined by the spatial sampling lattice of the image sensor in a 4K camera. This entails 3840 horizontal samples and 2160 vertical samples – for a total of 8,847,360 spatial samples.

In sampling theory it has been long-established that a given spatial sampling frequency can only faithfully reproduce spatial frequencies that are half that number. The limit of such spatial reproduction is known as the Nyquist frequency – which is simplistically explained for the 4K image sensor in Figure 7.

For the lens – the related optical Nyquist frequency entails consideration of the image format dimensions projected by the lens onto the image sensor – as shown on the right side of Figure 7. The calculation shows that the optical Nyquist frequency for a 2/3-inch lens is 200 line pairs per millimeter (LP/mm) using the acknowledged optical methodology for specifying optical spatial resolution.

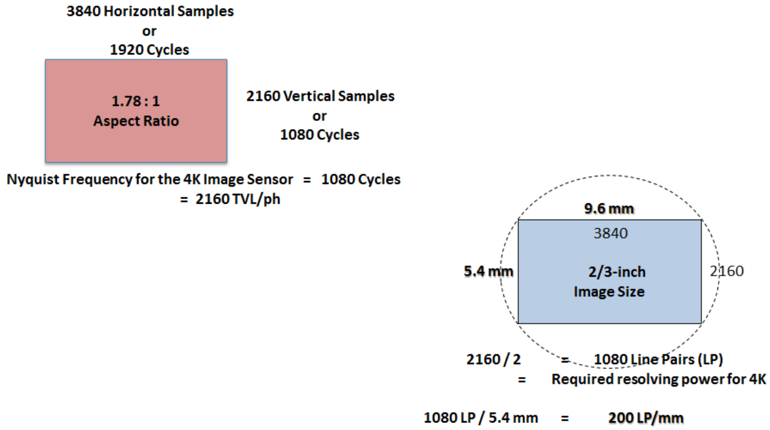



**Figure 7** *On the left is the sampling structure of a 4K UHD image sensor and the Nyquist frequency associated with that sampling; the image on the right represents the spatial detail of a 4K 2/3-inch lens that can fulfill the resolution capability of that 4K image sensor*

It was quickly identified by the camera manufacturers and Canon that all of the latest generation high-end 2/3-inch HDTV lenses did indeed have quite adequate levels of optical MTF – *at picture center.* While this may surprise some it needs to be noted that HD lenses are now in their fourth generation – reflecting more than twenty years of vigorous competitive developments driving the optical performance ever higher. Ever-evolving optical materials, optical design tools, and accumulated design experiences have all contributed to that steady progressive march in HD performance.

Optical MTF at the image center of a lens is well-behaved and tends to fall linearly with spatial frequency. The electronic MTF of the typical HD camera falls more rapidly than that of the lens – primarily because of the optical pre-filter and the electrical post-requirement that is necessitated by the requirement to control aliasing associated with the spatial sampling of the image sensor. Figure 8 below simplistically illustrates the linear MTF of the HD lens compared to the hypothetical MTF of both an HD and a UHD image sensor.

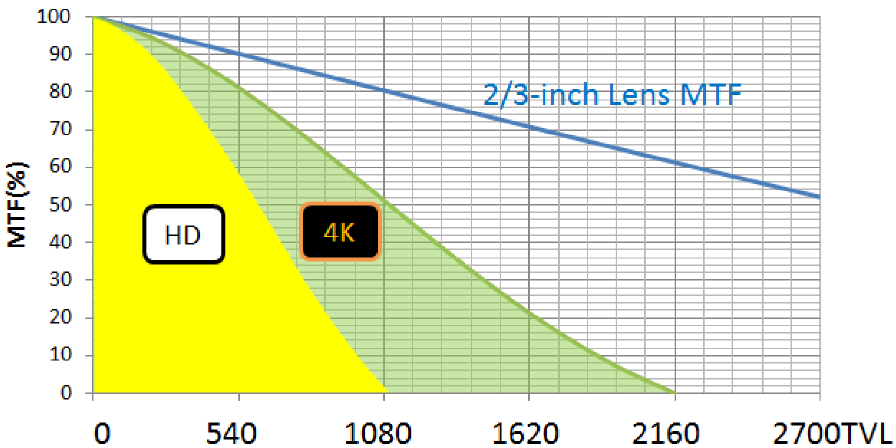



**Figure 8** *Showing the relative MTF roll-off of a 2/3-inch 2K and 4K camera and a typical high-end 2/3-inch lens – all at the center of the image*

Of special note with respect to Figure 8 is that a 4K UHD lens used on an HD camera will produce an elevation in the MTF of the final output HD video. Similarly, a 4K UHD lens-camera system – that subsequently down converts its 4K UHD video – will produce a superior HDTV video signal.

## 6.2 Lens Resolution across the Image Plane

A central struggle in the optical design of multi-element zoom lenses is controlling the roll-off of MTF from its high level at picture center when moving progressively toward the image extremities. Over many years three specified image zones have guided Canon's multifaceted design strategies for HD lenses – shown in Figure 9. Every possible effort is made to limit the MTF fall-off within the Zone A – which has a diameter equal to picture height. The area encompassed by that zone was established in concert with many users worldwide as being important to ensure highest image sharpness for close-up and medium close-up images of talent. The larger Zone B was identified as being important for wide-angle imagery containing a lot of picture detail. Image extremities are defined by the third Zone C.

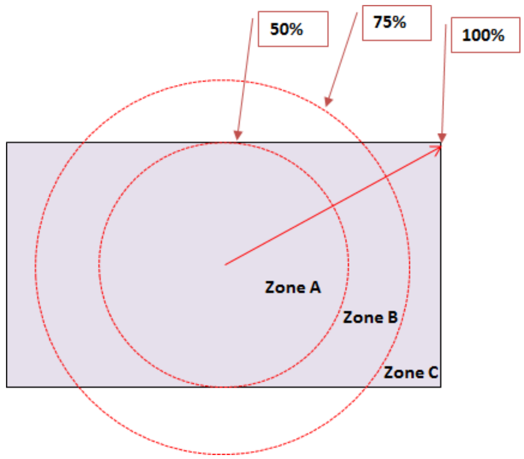



**Figure 9** *The three zones used by Canon to specify levels of MTF across the UHDTV lens image plane*

The latest generation of high-end HDTV lenses has full 4K resolution at their picture center. Figure 9 (left side) offers a general indication of the nature of the fall-off in sharpness in image Zones B and C. The center and right side images illustrate the design targets set by Canon for the new 4K and 4K PREMIUM lenses.

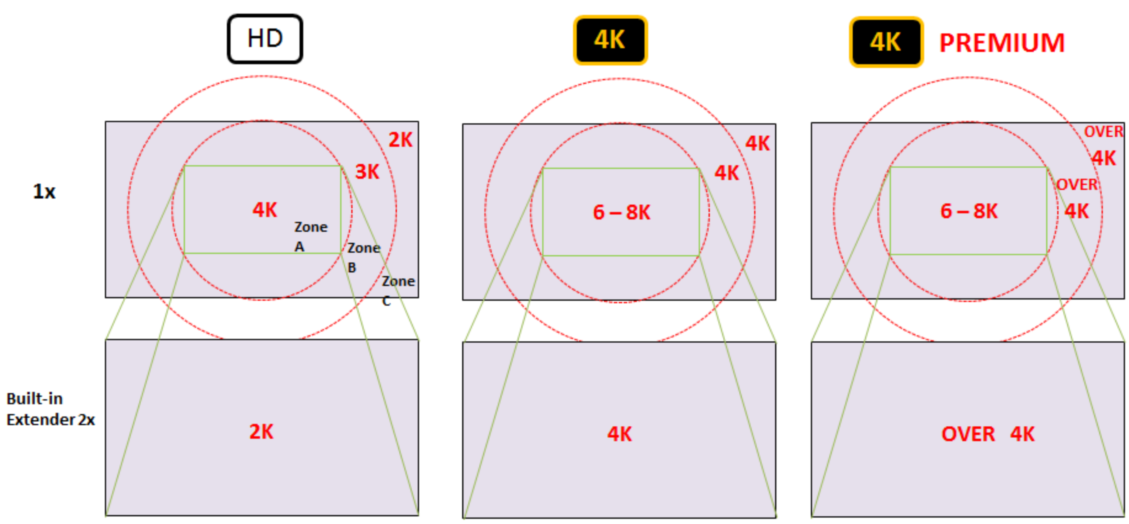
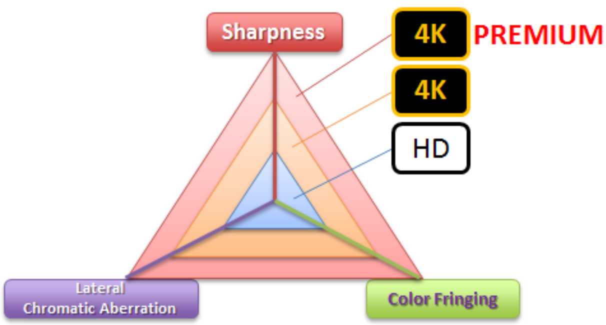



**Figure 10** *Illustrating the significance of the 4K PREMIUM lens from the viewpoint of spatial optical resolution across the 16:9 UHD image plane – when compared to 4K and to HD lenses*

## 6.3 Further Discussion on the 4K PREMIUM UHD Lens

State of the art computer simulation techniques were mobilized to optimize three critically important optical parameters shown in Figure 11 that bear upon achieving these criteria. In the computer simulation it was found that each of these core parameters could be taken to an even higher performance level by incorporation of some additional design strategies – but they would entail higher costs. Canon judged it important to offer a choice to the marketplace and this gave birth to the PREMIUM lens – the UJ86x9.3B long-zoom field lens and the new studio lens UJ27x6.5B.

A unique new zoom/focus system was also a central part of the PREMIUM design.




| Picture Performance Attributes | UJ86x9.3B 4K PREMIUM | UJ90x9 4K |
|---|---|---|
| Sensitivity | Very High(F1.7) | High(F2.4) |
| Image Sharpness (In Picture Center) | Exceptionally High | Very High |
| Image Sharpness (In Picture Corner) | Very High | High |
| Black Reproduction | Superb | Excellent |
| Contrast Ratio | Exceptionally High | Very High |
| Chromatic Aberration | Invisible | Tightly Controlled |
| Monochromatic Aberrations | Invisible | Tightly Controlled |

**Figure 11** *A simplistic overview of the critical optical design parameters that separate the overall optical performance of HD, 4K, and 4K PREMIUM*

Figure 12 further elaborates on the basic differences in MTF between the 4K and the 4K PREMIUM lens. The enhanced MTF of the PREMIUM lens will directly benefit a 4K camera, an HD camera, and a downconversion from a related 4K video to HDTV.

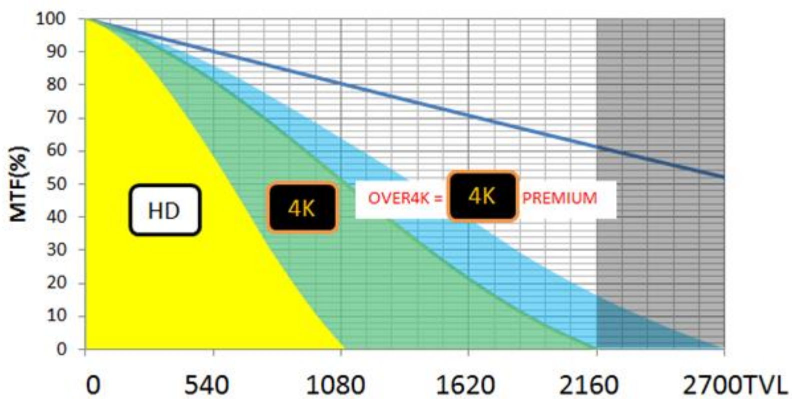



**Figure 12** *Showing that the 4K PREMIUM Lens has a higher MTF than the 4K lens – indicated in blue*

An additional design priority for the 2/3-inch long zoom lens was to achieve a lowering of the MTF drop over the entire focal range of the zoom lens. Figure 13 simplistically conveys the nature of the MTF variations with both focal length changes and across the image plane. The design goal is to flatten those curves to the degree possible while also minimizing the separation between the wide angle curve and the telephoto curve.

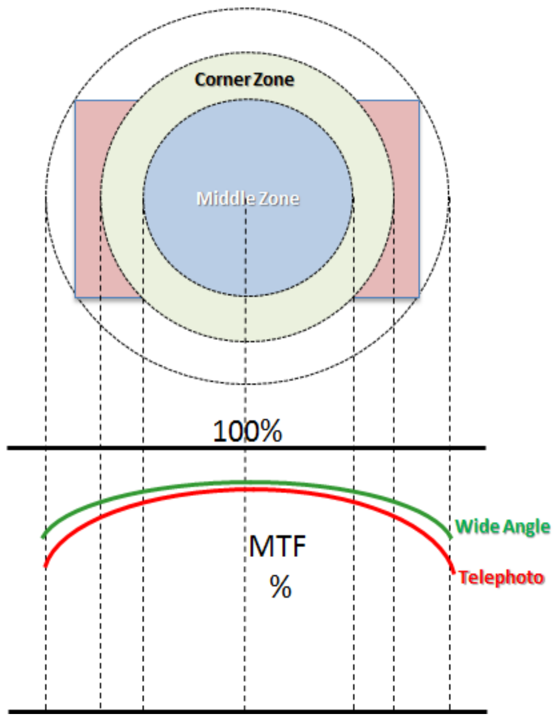



**Figure 13** *Showing the hypothetical MTF characteristics of a 4K lens as a function of both the two spatial zones and the total focal range*

## 7.0 Optical Design Strategies to Meet the 4K MTF Goals

Powerful new computer simulation techniques supported detailed examination of the potential contribution of new glass materials, judicious deployment of large aspheric lens elements, possibilities offered by new lens element groupings, and choices in new exotic multilayer optical coatings – all combined to achieving the extraordinarily high optical performance for 4K UHD imaging. This deep scrutiny enabled the identification of two performance levels for 4K UHD that supported the additional introduction of the higher performing 4K PREMIUM lens systems.

Achieving tighter control over the falloff in MTF across the image plane largely relied on a redesign that used large aperture aspherical lens elements and deployment of Fluorite and Hi-UD glass elements.

Leveling the variations in MTF across the focal range was achieved by an innovative redesign of the variator and compensator groupings that constitute the zoom controlling elements.

A significant redesign of the input floating focus system was a major contributor to tightening the control in MTF variations as the subject distance from the lens front varied.

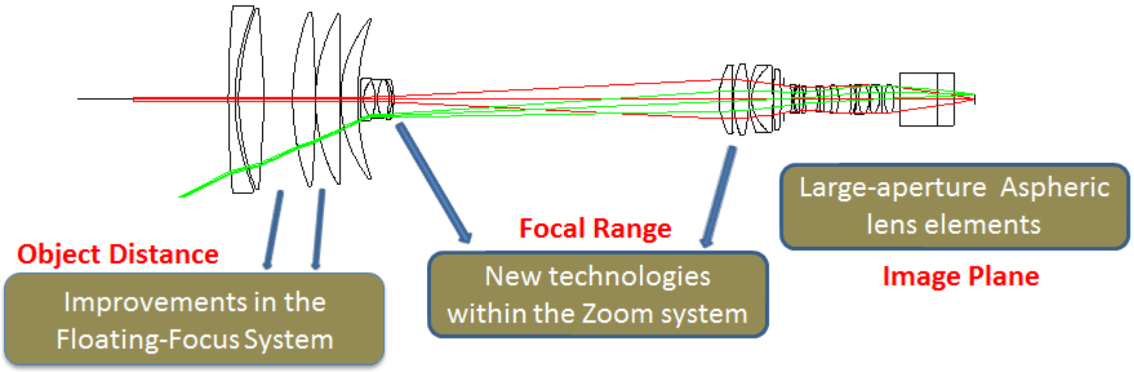



**Figure 14** *Highlighting the central new design strategies that underlie the full 4K performance*

Critical to achieving the final 4K performance of the lens system are the incredibly tight tolerances required for each and every lens element – entailing new superfine machining and polishing techniques – as well as refinements to final optical system assembly techniques. A great deal of expertise had been perfected in these areas during Canon's recent years of developments on 8K UHD lenses.

## 8.0 2/3-inch 4K UHD Lens-Camera – Limitation to Depth of Field

The nature of optics is that it is impossible to form an infinitely small image point. At best, a tiny image circle is formed. As that circle grows in size the image becomes less sharp. Optical engineers speak about a "minimum circle of confusion" to help define the degree of sharpness of a given lens. They also refer to a "permissible circle of confusion" to describe the fact that our human visual system can tolerate a certain degree of increase in that circle before we become aware of the degradation in image sharpness.

When a lens is adjusted to sharply focus on a chosen subject within a scene the degree of sharpness of that subject will lower if the subject moves forward or backward with respect to the lens. Over a certain distance the degree of this defocusing is subjectively almost imperceptible – but at some point it does become noticeable. Depth of field is bounded by two zones: *Near Limit* and *Far Limit*, where *Near* is the closest distance (to the camera) that subjects appear to be sharp and *Far* is the shortest distance beyond which subjects appear out-of-focus – Figure 15.

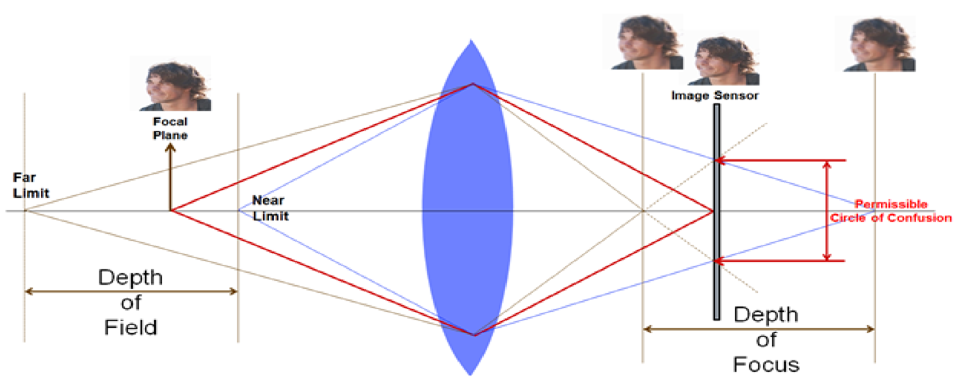



**Figure 15** *A simplistic rendering of the geometrical determinants of the permissible circle of confusion – the drawing has been exaggerated to better expose the geometry entailed*

The depth of field of a lens is affected by its focal length and aperture settings, and also by the distance of the subject from the lens front. Figure 16 shows a simplistic comparison between the optical depths of field for a Super 35mm image format size compared to that of a 2/3-inch image size. If the two lenses are side by side and *are set to identically frame a given subject* then the Super 35mm will exhibit a shallower depth of field as shown. *This is primarily a consequence of the shorter focal length of the 2/3-image format* necessary to attain the same image framing as the Super 35mm lens.

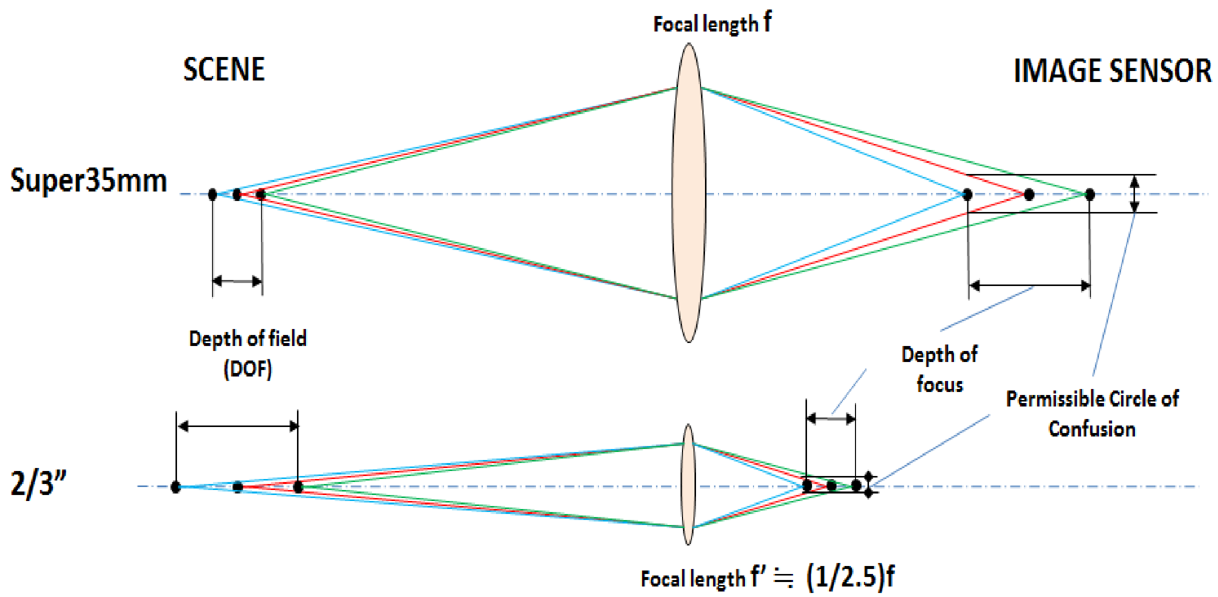



**Figure 16** *Showing the shorter depth of field of a large image format lens when the two lenses are side by side and separately adjusted to identically frame a given subject*

While the phenomenon of depth of field is primarily the unique optical behavior of all lenses – it must be understood that the lens and the image sensor of the associated camera do form an intimately intertwined imaging system. This is especially true when assessing the depth of field of a lens-camera system. It can best be understood by recognizing that it is the image sensor that gets the first look at the image being projected out of the lens – and the sampling lattice of that image sensor determines the effective diameter of the circle of confusion. The smallest size of a circle of confusion is approximately determined by the spacing of two scanning lines.

For a 2/3-inch HDTV lens this becomes the vertical dimension divided by the number of vertical scan lines:

5.4 mm / 1080 lines = 0.005 mm

If that 2/-3-inch camera is a 4K UHD rather than an HDTV camera – then the smallest circle of confusion becomes:

5.4mm / 2160 lines = 0.0025 mm

The smaller the permissible circle of confusion the more shallow will be the depth of field of that lens camera system. The comparison is outlined in Figure 17.

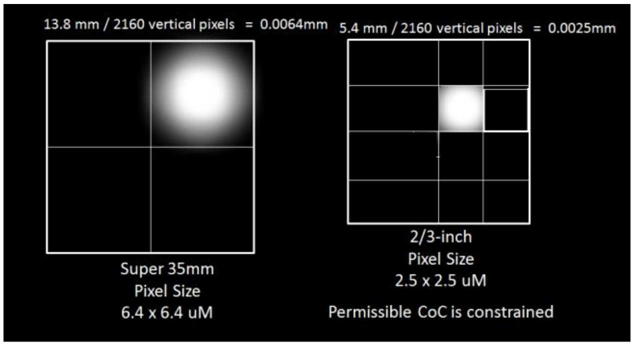



**Figure 17** *The constraint imposed upon the lens-camera circle of confusion by the smaller photosite of the 2/3-inch image sensor compared to the Super 35mm image sensor*

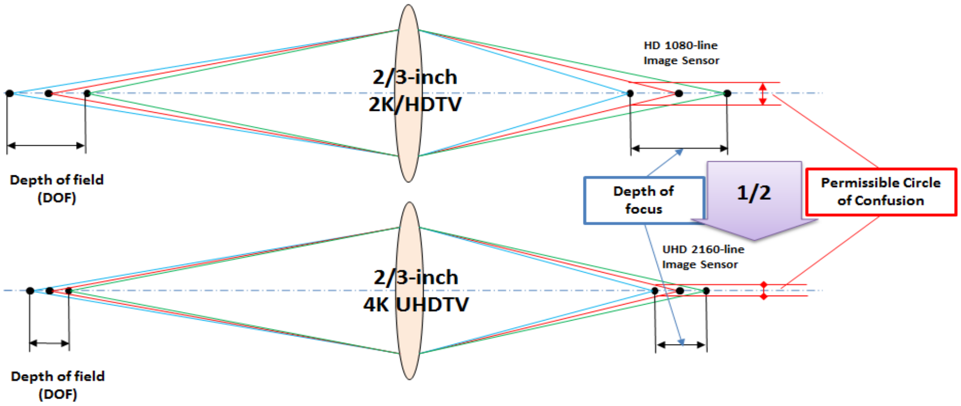



**Figure 18** *Showing that the 2/3-inch 4K UHD lens-camera system has a permissible circle of confusion that is approximately half that of the 2/3-inch 2K HD camera*

This fundamental linkage between the lens and the image sensor can be mathematically calculated and it shows that the 2/3-inch lens camera for 4K UHD will exhibit a depth of field closer to that of the Super 35mm 4K UHD lens-camera system than to a 2/3-inch HD lens-camera system – as shown in Figure 19. It is worthy of note to point out that this behavior also was manifest in the transition from SD to HD.

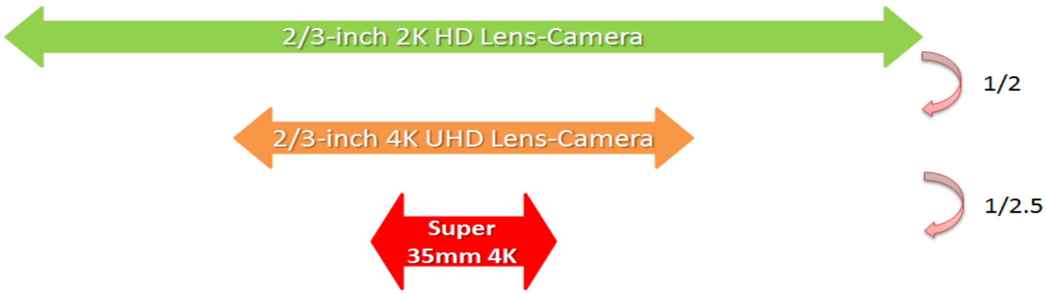



**Figure 19** *The 2/3-inch 4K UHD Lens-Camera imaging system will exhibit a depth of field behavior closer to that of the Super 35mm 4K UHD camera than it is to the 2K HDTV system*

## 9.0 2/3-inch 4K UHD Lens-Camera – Restriction on Range of Aperture Settings

Just as in the case of depth of field, some intractable optical physics come into play with respect to lens aperture settings. Diffraction is a fundamental optical phenomenon that is inherent to all lenses that use a lens iris. Reference [1] is a useful tutorial on the details of lens diffraction – an optical behavior that imposes a restriction on lens sharpness as a function of the actual settings of the lens iris. Figure 20 depicts the actual behavior for a 2/3-inch lens. These curves apply to all lenses of that image format size – regardless of model or of manufacturer.

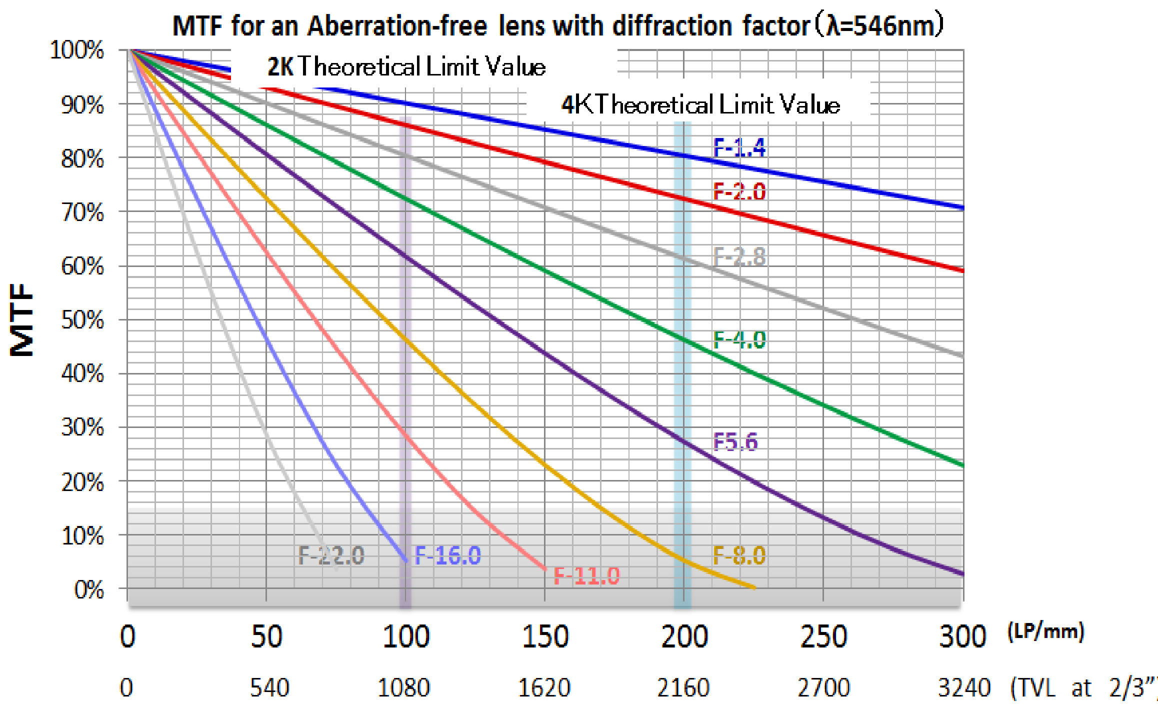



**Figure 20** *Showing how the optical phenomenon of diffraction progressively lowers the MTF of a lens as the aperture is stopped down*

Over the HDTV passband – from 0 to 100 LP/mm – the progressive loss in MTF as the lens aperture is stopped down might appear severe. Yet few camera operators notice the loss in sharpness because the human visual system is quite adaptive in terms of the perceived sharpness of real world images. Otto H. Schade Snr. [2] brilliantly explained this by pointing out that a distinction must be made between Picture Sharpness and Resolving Power when assessing image resolution. His work demonstrated that the square of the area under the MTF curve -- when normalized – aligned with human perception of image sharpness – see Figure 21.

Understanding this rather technical phenomenon is helped when real world image content is related to the Lens-Camera MTF characteristic as shown in Figure 22. The distant viewing associated with television and cinema dictates that we are more stimulated by edge transitions and textural content than we are by very fine low level details. Accordingly, a high MTF in the mid-band is more perceptive.

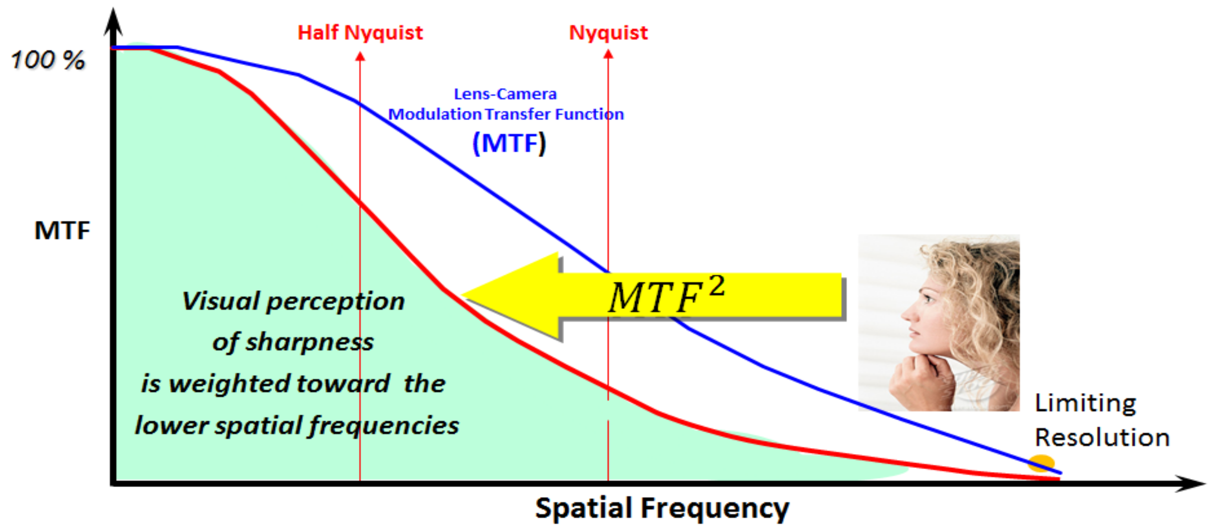



**Figure 21** *Subjective image sharpness is proportional to the area under the Lens-Camera $MTF^2$ curve*

The green shaded area represents the square of the area under the original Lens-Camera MTF curve. The key take away is that the human visual system's perception of picture sharpness is stimulated more by spatial details within the lower portion of the system passband. This can be related to real world images which typically are made up of edge transitions, textures, and various levels of coarse and fine details as shown in Figure 22.

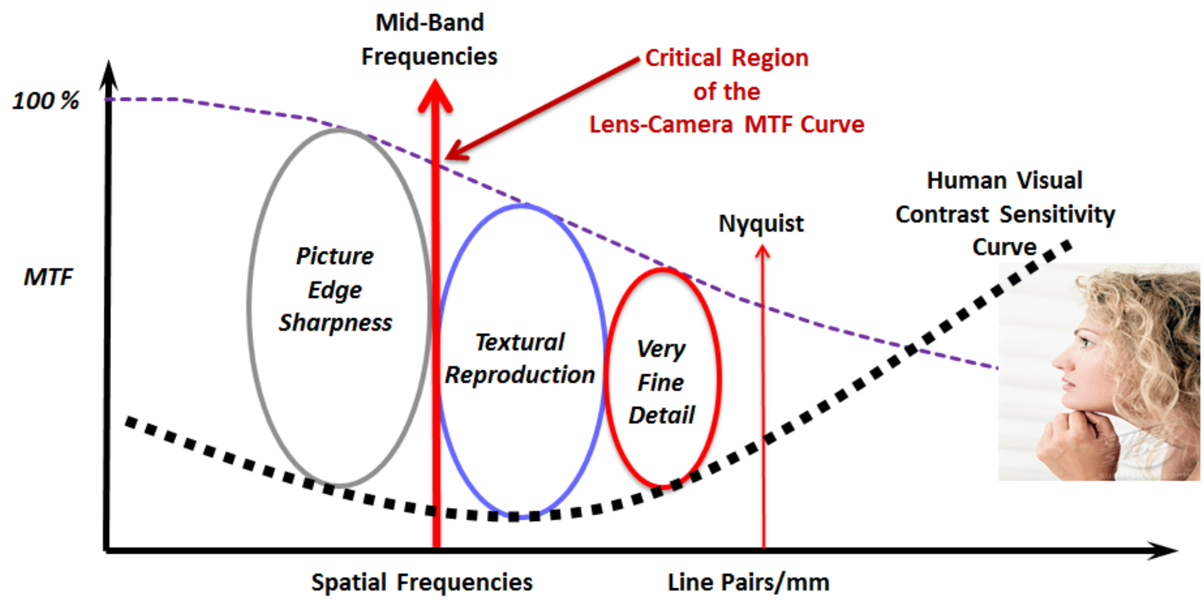



**Figure 22** *In terms of perceived image sharpness the human visual system is more stimulated by the height of the MTF curve in the vicinity of the Half-Nyquist spatial frequency than at the Nyquist frequency*

With that as background the important region of an HDTV lens is centered in the vicinity of the half-Nyquist frequency region – around 50 LP/mm (the Nyquist band-edge is 100 LP/mm) [3]. The diffraction curves show that at F-16.0 there is still about 50% MTF at that 50 LP/mm region. Even with the lens closed down to F-22.0 there still remains almost 30% MTF to which our visual system will still respond. But, a recommended operational range would be wide open to F-16.0

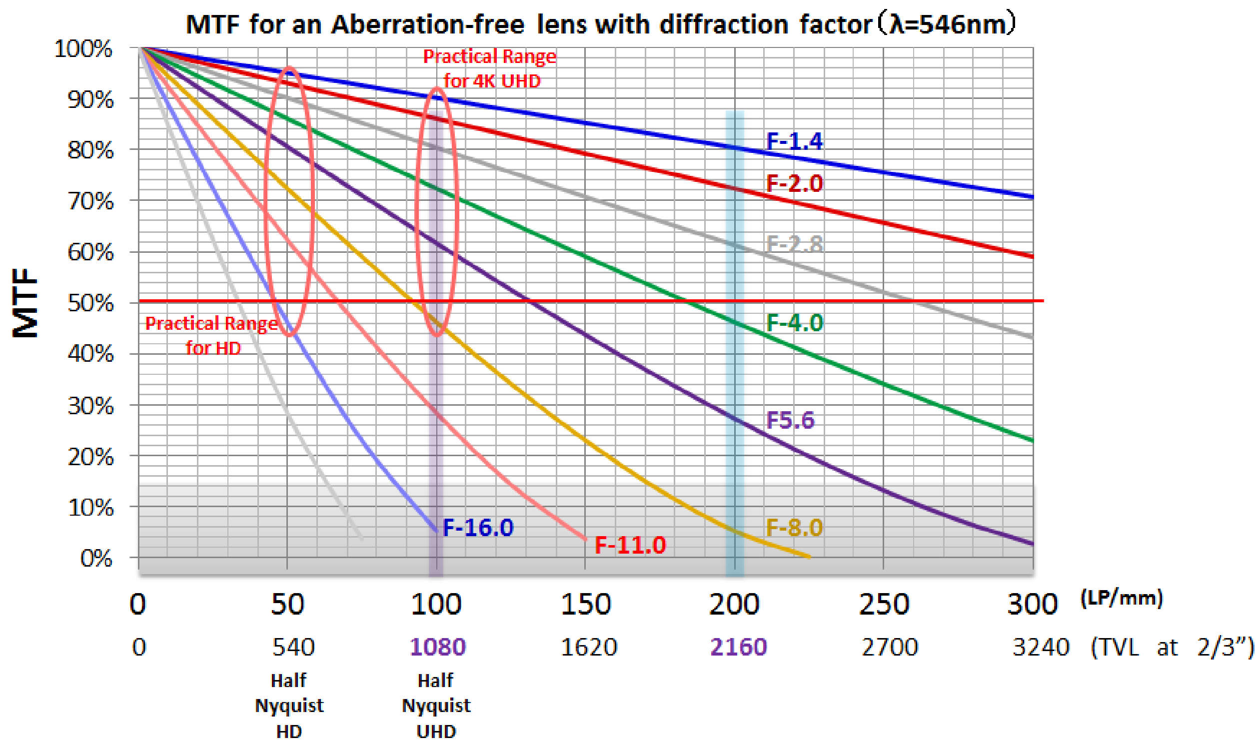



**Figure 23** *Showing the effective range of lens aperture settings for the 2/3-inch lens-camera systems for HDTV and UHDTV*

When that same 2/3-inch lens is coupled to a 4K UHD camera the passband is extended to 200 LP/mm (the UHD Nyquist spatial frequency). The curves in Figure 23 show that the central region for 4K UHD is now around 100 LP/mm and that a lens aperture setting of F-8.0 becomes the equivalent limitation. An F-11.0 setting will still deliver 30% MTF. However, the practical operational range of lens aperture for quality 4K UHD is from wide open to F-8.0.

This restriction can be accommodated with some readjustments of the various ND filters that are always a major sensitometric controller in top end field cameras intended for sports coverage under a wide range of scene illuminances. The good news is that the new 4K UHD cameras have exceptional sensitivity which will greatly help these operational re-adjustments.

## REFERENCES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[2] Otto.H.Schade, Snr. "Image Quality: A Comparison of Photographic and Television Systems" Reprinted SMPTE J., 100: 567 – 595, June 1987

[3] Brian Caldwell, Wilfried Bittner, Winston Ip, and Dan Sasaki. "High-Performance Optics for a New 70mm Digital Cine Format" *J. SMPTE, Page 49 – 54, March 2013*