White Paper

New Generation

2/3-Inch 4K UHD

Long-Zoom EFP Lenses

CJ45ex9.7B

CJ45ex13.6B

December 5th, 2017

New Generation 2/3-inch 4K UHD Long Zoom EFP Lenses

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Abstract

Five years ago Grass Valley triggered the entry of the established 2/3-inch image format into the newly emerging broadcast television world of 4K UHD with their introduction of a studio/field camera system. Within a year most of the major broadcast television camera manufacturers were showing prototypes of 2/3-inch 4K UHD camera systems and camcorders. The major lens manufacturers quickly flanked these developments with a new generation of 2/3-inch 4K UHD Lenses.

Canon introduced our first such lens in 2014 and have steadily rolled out a range of long zoom field, studio, and portable 4K UHD lenses culminating in the current family illustrated below [1]. Television sports coverage was the initial driver behind these 4K UHD lens-camera systems. Studio soon followed.

2/3-INCH 4K UHD Lenses		
Television Production **4K UHD** (3840 x 2160) and **HD** (1920 x 1080)		
Television Outside Broadcast	**Television Studio**	**Mobile Production**
• Sports • Live Events • House of Worship	• Episodic • Drama • Game Show • Performance Reality	• Sports • Live events • Documentary • News Magazine
 4K PREMIUM **UJ86x9.3B**	 4K PREMIUM **UJ27x6.5B**	 **CJ12ex4.3B** **CJ20ex7.8B**
UJ90x9B 		
Long Zoom Field Lens	**Studio**	**Wide angle Portable**

More recently, with the rapidly growing interest in 4K UHD electronic field production (EFP), there emerged a broadening request for 2/3-inch portable long-zoom 4K UHD lenses. Natural history programming in 4K UHD has grown briskly, as have many forms of documentaries, as well as 4K UHD television coverage of concerts, major events, and expanding coverage of most sporting events. This White Paper will describe two new portable 4K UHD 2/3-inch EFP lenses – each having a zoom range of 45:1 – specifically designed to address this extensive range of program genres.

The special challenge posed by the high imaging demands of 4K UHD will be described. Central to this was grappling with the fundamental physical conflicts in achieving the requisite extended focal range, optical sensitivity, highest 4K performance – while still producing a size and weight expected by those who deploy such lens-camera systems. The new optical design strategies to meet these challenges will be outlined. The paper will separately review the use of these lenses – and the overall performance – when coupled to Super 35mm cameras using available optical B4 to PL adaptors.

The performance of the integral new digital drive unit for control of zoom, focus, and iris is reviewed, as is the built-in image stabilization system. Digital system interfaces are described.

1.0 Introduction

The arrival of a 2/3-inch HDTV camcorder in 1997 thrust this small image format center stage as manufacturers struggled to make HDTV production equipment more compact and lightweight (all early HDTV cameras and lenses were of larger formats – with one-inch being the most popular). Initial television industry skepticism that the small 2/3-inch image format could support lenses and cameras capable of credible origination of 1080-line HDTV spawned vigorous international competitive initiatives. Within a few years the industry saw 2/3-inch studio, field, and portable HDTV cameras and lenses emerge from most of the major global manufacturers – accompanied by an increasing proliferation of HD camcorders. Successive generations saw progressive performance improvements.

Now a new era of 4K UHD has arrived. Paralleling this is a veritable explosion in video content and distribution over many platforms. Both large format Super 35mm and small 2/3-inch image format lens cameras are in high demand. Having met the initial thrust of 4K UHD into worldwide sports coverage with large box field lenses, Canon more recently turned its focus to extending the capabilities of portable field production. To grasp the challenges posed to developing portable long zoom 2/3-inch lenses for 4K UHD it is helpful to first benchmark the pioneering development of such extended focal range lenses for HDTV.

2.0 Legacy of HDTV Portable Long Zoom EFP Lens

In anticipation of the impact HDTV would likely have on many program genres – but most especially on documentary and natural history production – Canon in 2001 introduced two portable 2/3-inch HDTV lenses specifically designed to support a wide range of field productions. Long focal range was the top priority. Easy portability was an accompanying passionate plea given the nature of the numerous in-field productions in hostile environments. Some of the user requirements that were posed at that time are summarized in Table 1.

TABLE 1 Early User Requirements for HDTV Portable Long Zoom Lenses

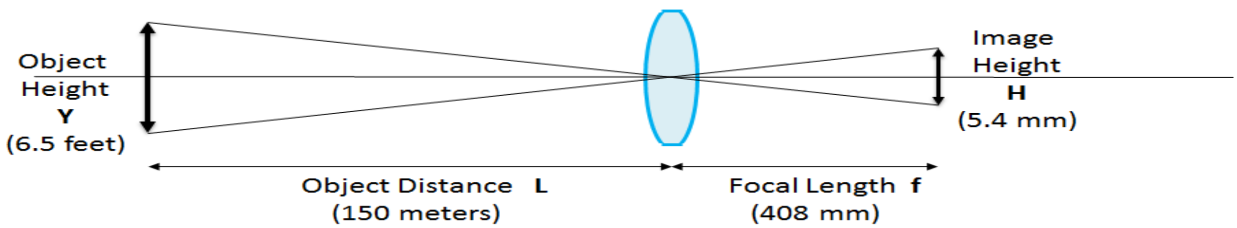
Operational

- Fully frame a tall human at an object distance of 150 meters (500 feet approx.)
- Built-in 2.0 x range extender
- Weight no greater than 15 lbs.
- Ease of Focusing
- Integral high speed Servo Drive system
- Compatibility with industry accessories

Performance

- Full HDTV optical performance over total focal range
- Tight control of aberrations over total focal range
- Precise zoom tracking

The operational requirement specified in Table 1 translated into a lens capable of a focal range of approximately 400 mm as shown by the calculation in Figure 1. This assumes the 5.4 mm height of the 2/3-inch image format and a human of 6 ½ feet in height.



Focal Length $f = H \times L / Y$

$= 5.4\text{ mm} \times 150{,}000\text{ mm} / (78 \times 25.4\text{ mm})$

$= 408\text{ mm}$

Figure 1 *A simple optical calculation establishes the requisite maximum focal range of the desired lens*

Considering the many variations of the specification in Table 1 that were prevalent back around year 2000, Canon elected to develop two EFP lenses – the wide angle HJ40x10B and a companion telephoto HJ40x14B.

Figure 2 *The original 2/3-inch HDTV 40x long zoom EFP lens – the HJ40x10B*

These 40:1 zoom lenses were deemed remarkable achievements for that time because of their relative compactness (being only 14 inches in length) and modest weight of 12 lbs. More than 15 years later they continue to be in demand. A sense of the compactness of such a portable long focal range lens is indicated in Figure 3.

Figure 3 *The HJ40x lens remains very popular in documentary and wildlife program origination*

3.0 Priorities of EFP HDTV Imaging

The priorities of these HDTV EFP lenses separated into their challenging ***Operational*** expectations and the anticipation of very high HDTV optical ***Performance***.

3.1 Operational

The basic operational specifications for these two HDTV lenses are shown in Table 2.

Table 2 Operational Specifications for the HJ40 x Long Zoom 2/3-inch EFP Lenses

	HJ40x10B		HJ40x14B	
Zoom Ratio	40x		40x	
Built-in Extender	1.0x	2.0x	1.0x	2.0x
Focal Length	10 – 400 mm	20 – 800 mm	14 – 560 mm	28 – 1120 mm
Angular Field of View (Degrees)	51.3 x 30.2 10 mm) 1.4 x 0.8 (400 mm)	27.0 x 15.4 (20 mm) 0.7 x 0.4 (400mm)	37.8 x 21.8 (14 mm) 1.0 x 0.6 (560 mm)	29.4 x 11.0 (28 mm) 0.5 x 0.3 (1120 mm)
Minimum Object Distance	2.8 m (10 mm with Macro)		2.8 m (10 mm with Macro)	
Object Dimension at MOD	248.4 x 139.7 cm (10mm) 6.2 x 3.5 cm (400 mm)	124.2 x 69.9 cm (20 mm) 3.1 x 1.8cm (800 mm)	177.1 x 99.5 cm (14 mm) 4.5 x 2.5 cm (560 mm)	88.6 x 49.8 cm (28 mm) 2.3 x 1.3 cm (1120 mm)

3.2 Optical

For high quality HDTV imaging there were three critically important optical design priorities when these two lenses were under development:

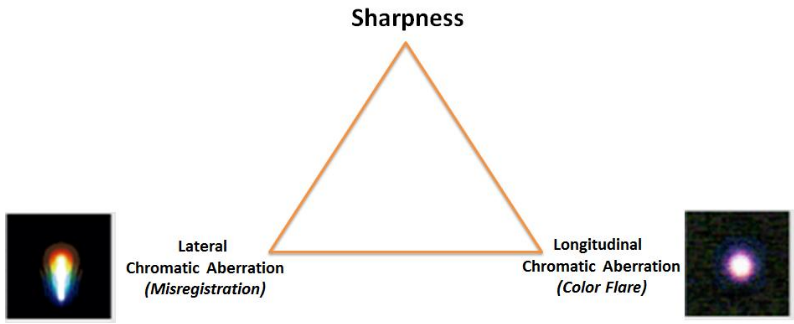


Figure 4 *Summarizing the most critical optical performance parameters to ensure high quality HDTV*

Sharpness is inherent to HDTV. The resolution of the system is defined by the lattice sampling of the camera image sensor. But the visual sharpness is directly linked to the contrast of the high spatial detail within any given scene. This bears directly on the lens Modulation Transfer Function (MTF) convoluted with the MTF of the camera. Lateral chromatic aberration causes color misregistration on high contrast edges within the imagery – especially toward picture extremities. Longitudinal chromatic aberration causes color fringing on any speculars with this imagery. Compared to the SDTV era the significantly higher resolution in the HDTV image sensor could render such aberrations more visible.

4.0 EFP Acquisition in the New Era of 4K UHD

Twenty years after HDTV began the transition from SDTV a radically new era in television imaging is now underway. 4K UHD has become a practical reality in terms of all of the related core technologies. Anticipating that the transition to a new 4K UHD television era will echo the protracted march of HDTV program production, Canon assigned a priority to developing long-zoom portable lenses that meet full 4K UHD optical performance. Like their HDTV predecessors – there are two such lenses – one wide angle (***CJ45ex9.3B***) and one telephoto (***CJ45ex13.6B***). The significance of the design achievement will become apparent in the following sections.

5.0 New Priorities

Based upon marketplace requests over the years, there are four additional and significant challenges to the design of these lenses compared to the processor HJ40x HDTV lenses:

1. Extension in focal range beyond 40x
2. Extension in wide angle of view
3. Elevation of optical performance to the high levels 4K
4. Increase in the speed of the servo zoom, focus, and iris

However, the biggest design challenge of all was to incorporate all of these enhancements *while maintaining the same size and weight* as the earlier HD lenses – a particularly widely heard plea from many invested in field production.

5.1 Basic Operational Specifications:

The two new lenses are shown in Figure 5.

Figure 5 *The 2/3-inch 4K UHD EFP Portable lenses – CJ45ex9.7B left and CJ45ex13.6B right*

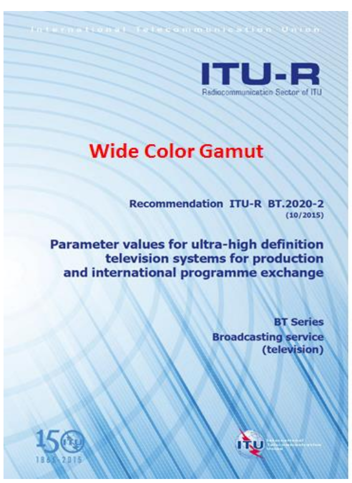
Figure 6 *Showing the mechanical switch that engages the 2.0x range extender*

Table 3 Basic Operational Specifications of the two 4K UHD EFP Lenses

	CJ45ex9.7B		CJ45ex13.6B	
Zoom Ratio	45x		45x	
Built-in Extender	1.0x	2.0x	1.0x	2.0x
Focal Length	9.7 – 437 mm	19.4 – 874 mm	13.6 – 612 mm	27.2 – 1224 mm
Angular Field of View (Degrees)	52.7 x 31.1 (9.7 mm) 1.26 x 0.71 (437 mm)	27.8 x 15.8 (19.4 mm) 0.63 x 0.35 (874 mm)	38.9 x 22.5 (13.6 mm) 0.90 x 0.51 (612 mm)	20.0 x 11.3 (27.2 mm) 0.45 x 0.25 (1224 mm)
Minimum Object Distance	2.8 m (10 mm with Macro)		2.8 m (10 mm with Macro)	
Object Dimension at MOD	254.3 x 143.0 cm (9.7 mm) 5. 8 x 3.3 cm (437 mm)	127.2 x 71.5 cm (19.4 mm) 2.9 x 1.7 cm (874 mm)	182.9 x 102.9 cm (13.6 mm) 4.2 x 2.4 cm (612 mm)	91.5 x 51.5 cm (27.2 mm) 2.1 x 1.2 cm (1224 mm)

5.2 Overall Optical Performance

It is important to note that this new era in television entails two other dramatic enhancements to image quality – in addition to the fourfold increase in resolution. They are High Dynamic Range (HDR) and Wide Color Gamut (WCG). The new era of 4K UHD saw a significant international standardization activity within the International Telecommunication Union (ITU). From their work two important standards recently emerged. The first was ITU Rec BT.2020 [2] that specified all of the formats entailed in UHD as well as a much wider color gamut (WCG) than that of HDTV. A second standard ITU Rec BT.2100 [3] specified all parameters relating to the second major image enhancement of High Dynamic Range (HDR). These standards guided many aspects of the optical design of these two new EFP portable lenses.



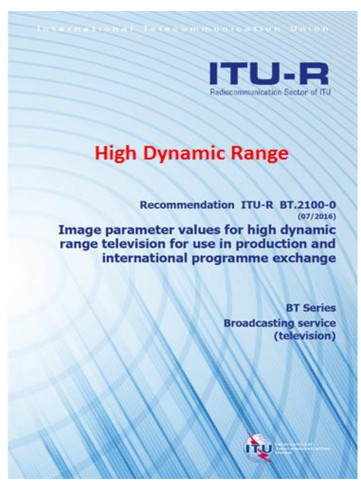


Figure 7 *Showing the two key ITU standards for UHD Wide Color Gamut and HDR*

These standards imposed additional challenges to the design of the new 4K UHD lenses. The lens applies the first performance footprint on the image within any lens-camera acquisition system. For 4K UHD motion imaging the image sensor deploys four times more spatial samples than HDTV. That elevates the challenge of minimizing chromatic aberrations as the sensor can now "see" even small degrees of this. HDR and WCG further enhance the visibility of these aberrations – placing an even higher onus on suppressing them to where they become subjectively invisible.

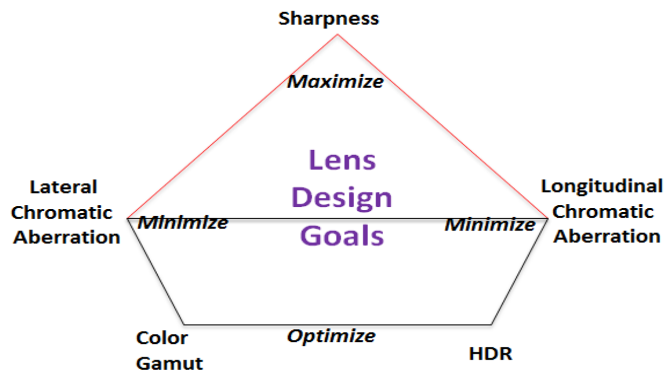


Figure 8 *The critical image performance parameters required for high quality 4K UHD lenses*

5.3 Picture Sharpness

It is important to understand the significance of picture sharpness as it relates to 4K UHD resolution in a small 2/3-inch image format size. The determinant is the resolution of the 2/3-inch image sensor and this is calculated in the left of Figure 9. This, in turn, prescribes the number of line pairs that the lens must be capable of transmitting to the image sensor. The sharpness of the resultant lens-camera 4K image is closely related to the height of the MTF curve across the total bandwidth [4]. Figure 9 shows an approximation of the MTF behavior in the earlier HJ40x lens and that of the new 4K lens at picture center.

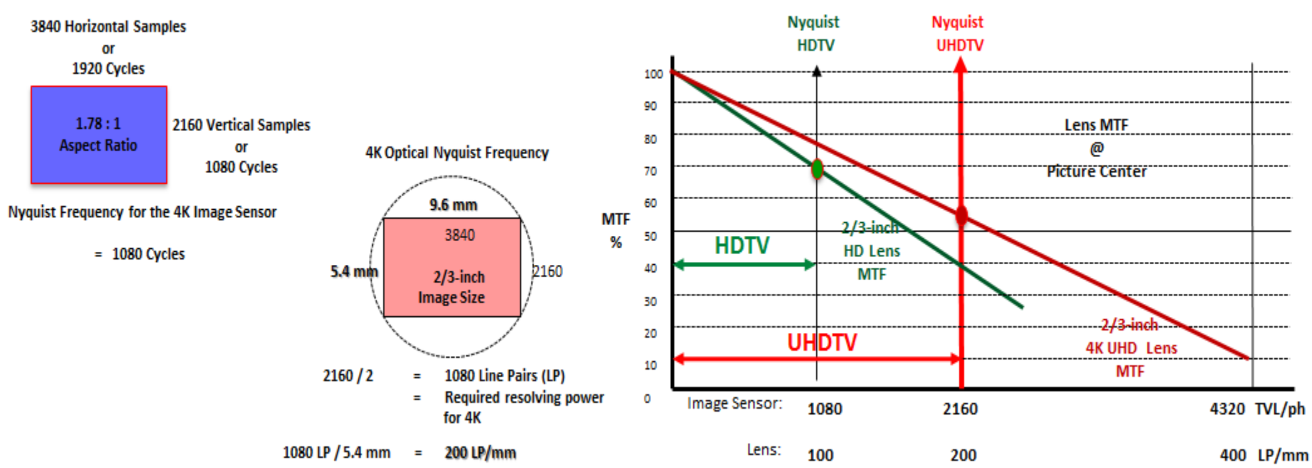


Figure 9 *Showing the resolution requirements for 4K UHD on the left and the associated lens MTF on the right which is the ultimate determinant of picture sharpness*

6.0 Special Challenge of HDR and WCG

As illustrated in Figure 10 the disposition of the dynamic range of the camera image sensor defines a number of regions within the overall light transmission through the lens.

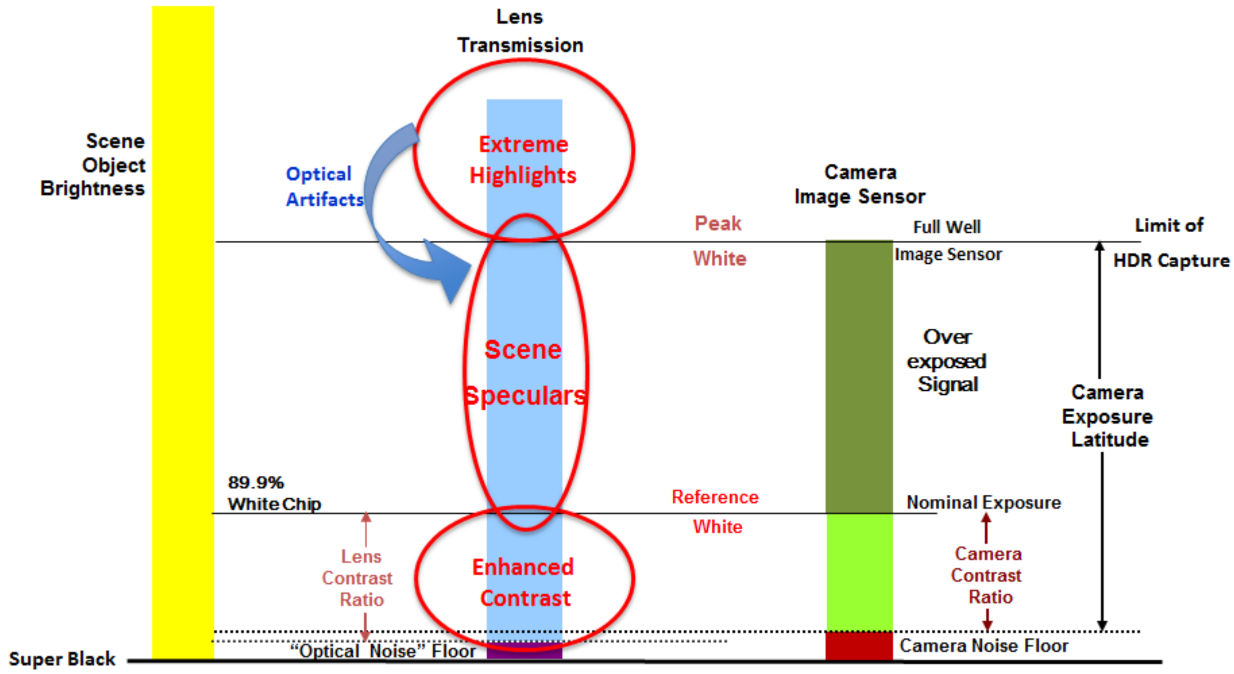


Figure 10 *Simplistic outline of the HDR significance to various levels of the lens optical transmission*

The optical performance of the lenses must accommodate the special demands of HDR in terms of the following:

1. **Deep Black Reproduction** – This defines the degree that the lens-camera system can reproduce detail in deeply shadowed areas of a scene. This required new advanced optical coatings as well as sophisticated mechanical design strategies within the lens barrel to help curtail unwanted reflections that can contaminate black reproduction

2. **Excellent** Contrast – to help ensure reproduction of subtle tonal gradations and textures over the nominally exposed signal levels (from black to 100% reference white) that are considered central to 4K imaging

3. **Clean Reproduction of Specular Highlight** – which capitalize on the extended dynamic range of the contemporary image sensors and constitute an important aspect of HDR imaging

4. **Management of intense highlights** – such as those caused by direct sun reflecting off cars and windows and car headlights at night can stimulate unwanted optical artifacts that can contaminate the desired HDR reproduction

7.0 Wide Color Gamut

The color gamut of a camera is determined when the three spectral sensitivities of the image sensor(s) are processed to convert them to a three dimensional color space. That processing traditionally entails a 3 x 3 linear matrix – prior to application of the camera OETF transform. The spectral responses of the trichromatic RGB camera overlap to various degrees (design choice of the camera manufacturers). The spectral response of the lens obviously modifies those of the camera. The spectral response of the new lenses was refined to accommodate the wider color gamut specified in the ITU-R BT.2020-2 standard. An important linkage exists between HDR and WCG in the reproduction of color [5].

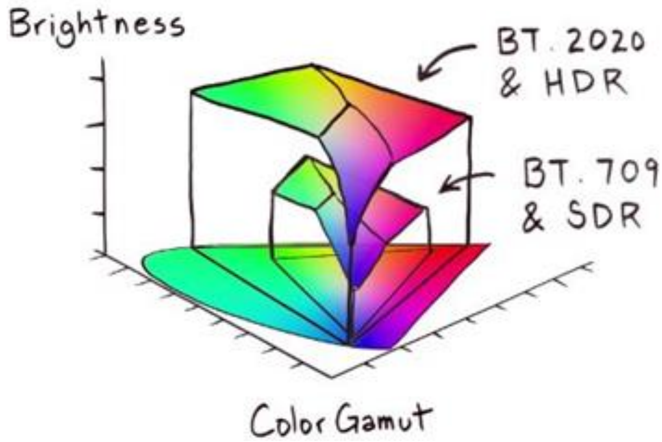


Figure 11 *HDR elevates the level of Luma and this, in turn elevates the color volume*

Both color and intensity bear directly upon the appearance of color [6]. However, not all colors are available at high intensities (blue being the principle example). Despite this, the higher intensities of HDR accordingly can enhance the subjective richness of many colors – this is described as an increase in their color volume.

7.1 Minimization of Chromatic Aberrations

Having four times more spatial resolution than HDTV the 4K UHD image sensors are capable of "seeing" much smaller chromatic aberrations than the HDTV sensor. Considering this doubling of both horizontal and vertical resolution, it is imperative that the lens mobilize design strategies to help minimize these aberrations.

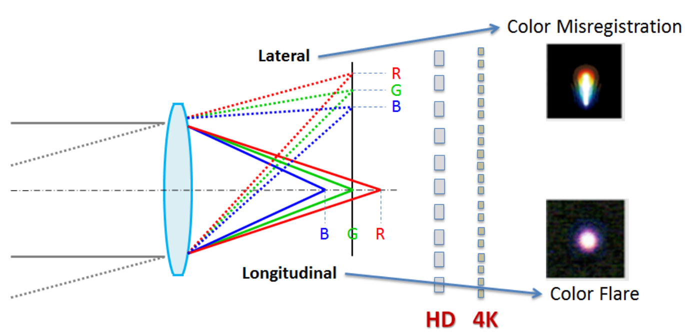


Figure 12 *The two chromatic aberrations and their increased visibility to a 4K image sensor*

In optical design a common strategy entails the use of more elements which offer additional degrees of freedom to optically compensate for the aberrations as the light rays traverse the system. However, lens size and weight constraints act as implacable opposition to over-utilizing the number of elements. Accordingly other strategies were harnessed in this new lens design. Ultimately, this led to a radical new optical system design compared to that of the earlier HDTV long zoom lenses.

8.0 Totally New Optical System

As a consequence of the elevation of the overall optical performance requirements – and ever cognizant of the size and weight restrictions – a total redesign of the optical system was undertaken. This entailed the all-important input floating focusing optical group and the separate optical subgroups involved in the lens zooming system. The optical and optomechanical design teams were closely united in a series of detailed design reviews that progressively explored possible options to reconciling an overall design. The design teams and the manufacturing/assembly department regularly met face-to-face for discussions on practicalities of manufacturing, assembly, and alignment. The optical team explored latest glass materials, optimum number of elements, element shapes, element groupings, use of aspheric elements, while the optomechanical team explored optimal structures (for weight and fast servo speed), mounting strategies for the lens elements that could withstand extreme environmental conditions envisaged for this lens, and operational aspects of controlling zoom, iris, and focus according to the dictates of the production world. Ultimately a central optical design emerged that embodied two core areas of new optical innovations:

- New Input Floating Focusing Group
- New Multigroup Zooming System

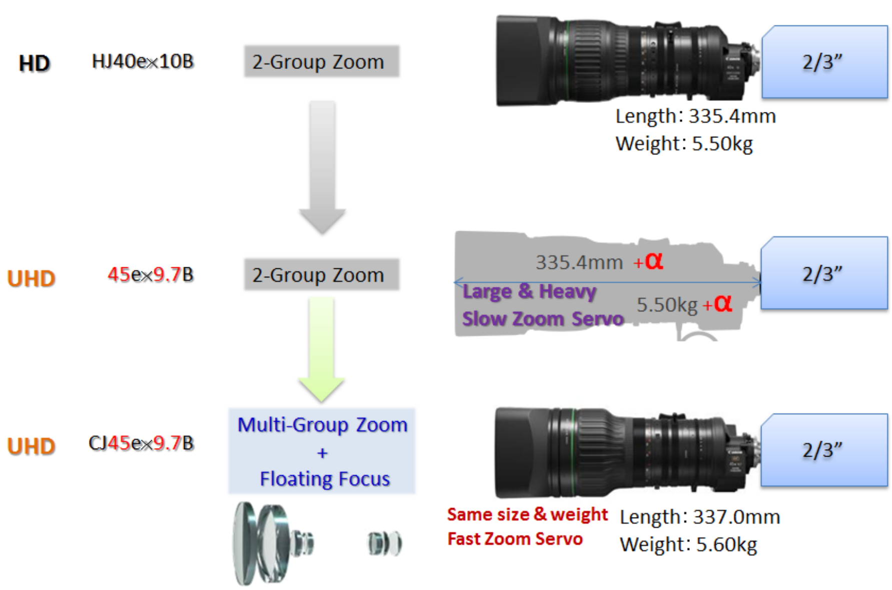


Figure 13 *Total re-design of the optical subsystems for Focus and Zoom were critical to matching the size and weight of the new 4K UHD lenses to the former HDTV long zoom lenses*

8.1 New Input Focusing Group

The focus optical subsystem entails high responsibility for numerous optical performance parameters and operational considerations. The lens maximum relative aperture is largely determined by this lens input optical grouping. In addition, focus rotation angle, focus breathing characteristics, chromatic aberration behavior on wide angle settings, are all associated with this optical subsystem. Overall lens size and weight are heavily proportional to decisions made in the overall design of this system. Central to the design is curtailing the size and weight of the rear moving lens system. To help ensure UHD optical performance focus fluctuations must be suppressed – and this was accomplished by using two separate moving groups as indicated in blue in Figure 14. While their diameter still tended to be large this dual system helped minimize the separate group trajectories during a focusing operation.

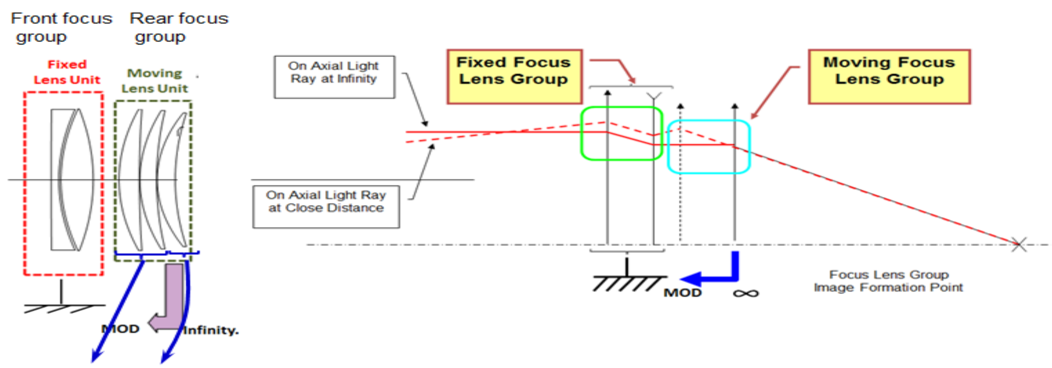


Figure 14 *A newly developed Floating Focus Group helped to minimize focus breathing and helped to ensure UHD optical performance*

8.2 Multigroup Zooming system

The earlier generation ENG or EFP zoom lenses utilized a traditional dual group zooming system comprising the Variator optical group and the Compensator optical group as typified in Figure 15. Zooming action entails the differential movement of these two optical subsystems as shown below.

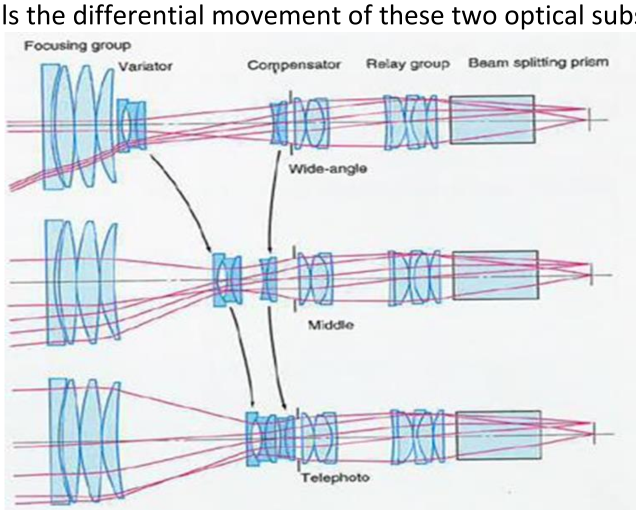


Figure 15 *Two optical groups that implement the zooming action in the ENG or EFP zoom lenses*

Within this two-group zoom system the Variator has the longest trajectory. The zoom torque associated with a given lens group that must be overcome by the drive unit is determined by the mass of that group times its zoom stroke distance. The mass of a given lens element is proportional to its diameter cubed – as outlined in Figure 16. If the diameter of a lens element is reduced to 80% its mass is approximately halved.

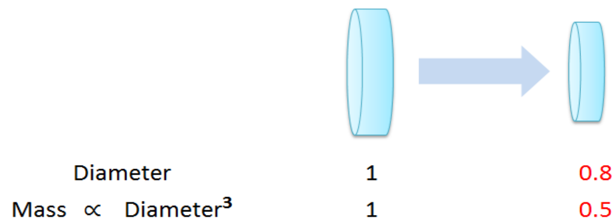


Figure 16 *Showing the critical relationship between the mass of a lens element and its diameter*

In seeking longer focal ranges for these new lenses the challenges in achieving the requisite zooming speeds while also achieving UHD performance were escalated. This called for a radical new design approach to the zooming optical subsystems. The central goals were to achieve greater control over multiple lens aberrations to help ensure full 4K performance while at the same time expediting an increase in the speed of the zooming action (when the digital drive unit is set to maximum zoom speed).

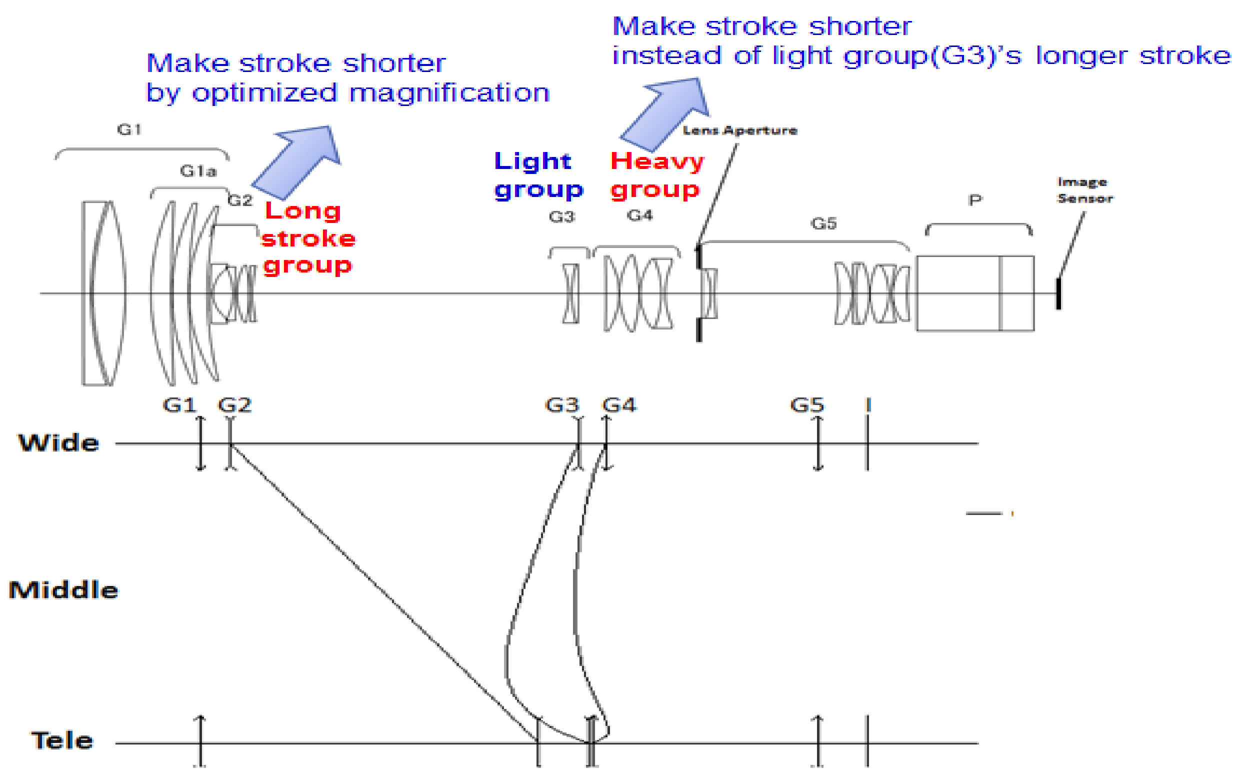


Figure 17 *Principles of the new Multigroup optical system – conveying the approximate relative motion of the three optical subsystems across the total focal range*

A sense of the relative motion of these three lens subgroups over the total zoom range of the lens is illustrated in Figure 17. This proved possible with group G2 and G3 – but group G4 of necessity (issues relating to aberration correction) is a somewhat larger group. Thus, it was important to reduce the weight and stroke distance of the G2 group (having the largest stroke) while also reducing the stroke distance of the G4 group (having the largest weight).

9.0 Central Design Challenge – High Sensitivity and Low Weight

The goal to achieve as high an optical sensitivity as possible directly conflicts with the equally important goal of curtailing the size and weight of the overall lens. The maximum relative aperture of a given lens at a given focal length is defined by the F-number – or relative aperture – which, in turn, is defined by:

$$F\text{-}number = f \,/\, E_N$$

Where f is the focal length

E_N is the diameter of the entrance pupil

The entrance pupil of a lens is the virtual image of the aperture that is formed by the lens elements in front of the diaphragm, and it is located within the overall optical system where light paths cross before being focused onto the camera's image sensor. That location is dependent upon the complexities of the optical subgroups within any given lens system – as shown hypothetically in Figure 18.

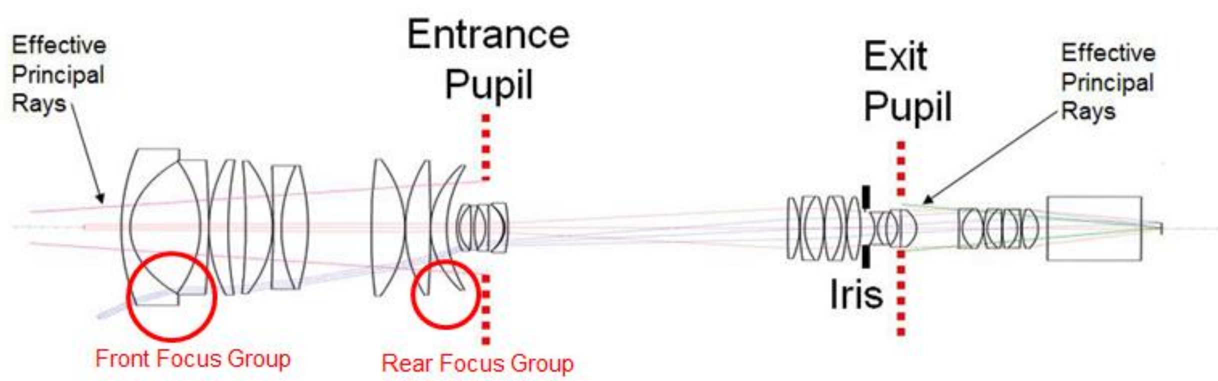


Figure 18 *Conceptual showing of the Entrance and Exit Pupils of a complex multi-element lens system. Within any given lens their respective locations necessitate complex computations*

The entrance pupil is defined as the image of the aperture stop as seen from an axial point on the object through those lens elements which precede the aperture diaphragm. The entrance pupil of a zoom lens changes in diameter as the focal length is changed. Zooming toward the telephoto end will gradually enlarge the diameter of the entrance pupil and cause its location to move further back along the optical axis. When its diameter increases to equal the diameter of the input optical focusing group it can increase no more and accordingly, the effective F-number increases. Paradoxically, this behavior is often termed the "F-Drop". It is more generally referred to as the Ramping characteristic of a given lens.

A great deal of careful analysis of the new lenses was undertaken to help ensure a high optical sensitivity as well as a practical overall size and weight. An advantage of using the Multigroup zooming system is that the diameter of the optical input port can be reduced to a degree – it was ultimately set at 127 mm – which is large for a portable lens – but still carefully curtailed to strike an optimum compromise between optical sensitivity and overall size and weight. The diameter of the floating focus lens elements is slightly smaller than the 127 mm port because of lens element mounting details. The final compromise is illustrated by Figure 19 which illustrates the size and weight achieved for the two lenses, and by Figure 20 which shows the behavior of the maximum relative apertures of the two lenses.

Figure 19 *Showing the size and weight of the two 4K UHD EFP lenses*

The overall size and weight are fractionally larger than the earlier generation HJ40x HDTV lenses. Assuming a desired maximum relative aperture of F-2.0 for the CJ45ex9.7B lens then the 127 mm diameter does ultimately pose a limit on the entrance pupil. The diameter of the input focusing group is actually 112mm. This diameter defines the maximum focal length at which that F-2.0 can be sustained.

$$F = f / E_N$$

From which

$$\text{Focal Length } f = F \times E_N$$
$$= 2 \times 112$$
$$= 224 \text{ mm}$$

In the case of the more telephoto CJ45ex13.6B the maximum relative aperture is F-2.8 and again the calculation becomes 2.8 x 112 = 312mm. Based upon this optical behavior, Figure 20 shows the range of constant relative maximum aperture for the two new CJ45ex9.7B and CJ45ex13.6B lenses.

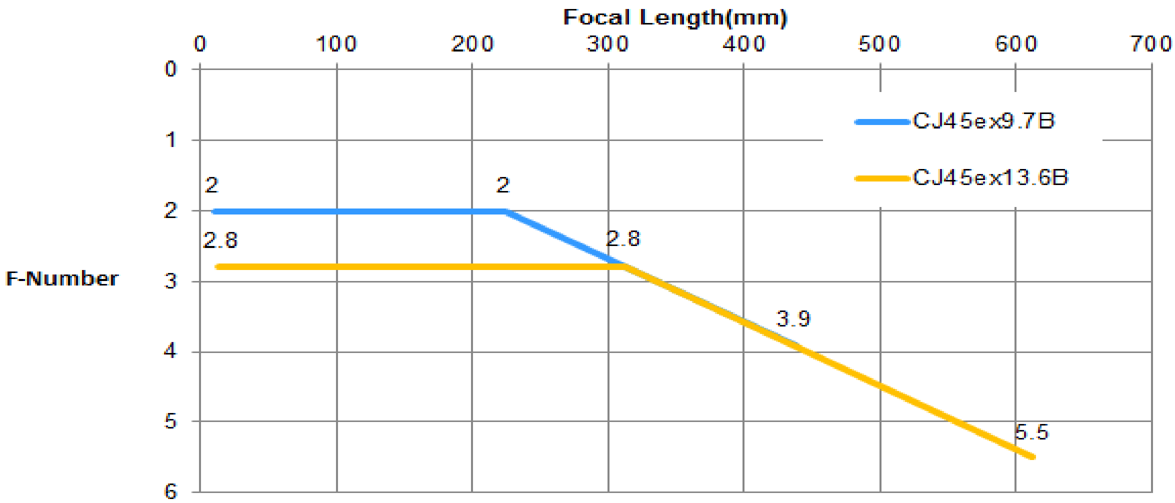


Figure 20 *Showing the Maximum Relative Aperture and the associated Ramping characteristics of the two new UHD EFP lenses*

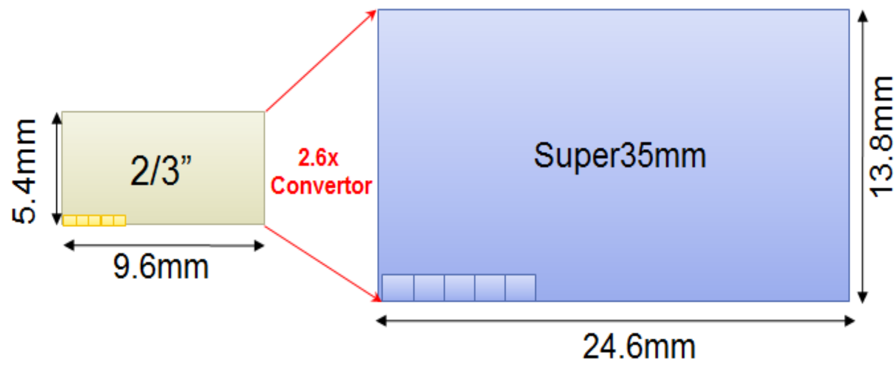
10.0 2/3-inch Long Zoom Lens with Super 35mm Cameras

The deployment of large format single sensor cameras for high profile events – including sporting events, concerts, and also in megachurches – has increased in popularity in recent years. However, Super 35mm zoom lenses have traditionally been severely curtailed in their focal ranges (although some advances are being made in that respect [7]). Accordingly, 2/3-inch long zoom lenses – using B4 to S35 optical (one example is shown in Figure 21) – are being deployed on Super 35mm camera systems.

Figure 21 *Showing one typical example of a 2/3-inch lens and an optical adaptor to Super* 35mm

It is anticipated that the new CJ45ex9.3B/13.6B lenses will be especially appealing to situations that seek a more compact lens-camera system for these applications. The implications of using the optical adaptor (having an effective image diameter conversion of 2.6x) are shown in Table 1.

TABLE 4 Converting the 2/3-image from the CJ45ex lenses to a Super 35mm 4K UHD Image Sensor



	2/3"UHD		Super35 UHD
Image Size	9.6mmx5.4mm	2.6x	24.6mmx13.8mm
Effective Pixels	3840×2160	1.0x	3840×2160
Effective Pixel Size	2.5µm×2.5µm	2.6x	6.4µm×6.4µm
Relative Aberration	1	2.6x	2.6
Focal Length	9.7-437mm 13.6-612mm	2.6x	25.2 - 1136mm 35.4 - 1591mm
F-Number	2.0-3.9 2.8-5.5	2.6x	5.2 - 10.1 7.3 - 14.3

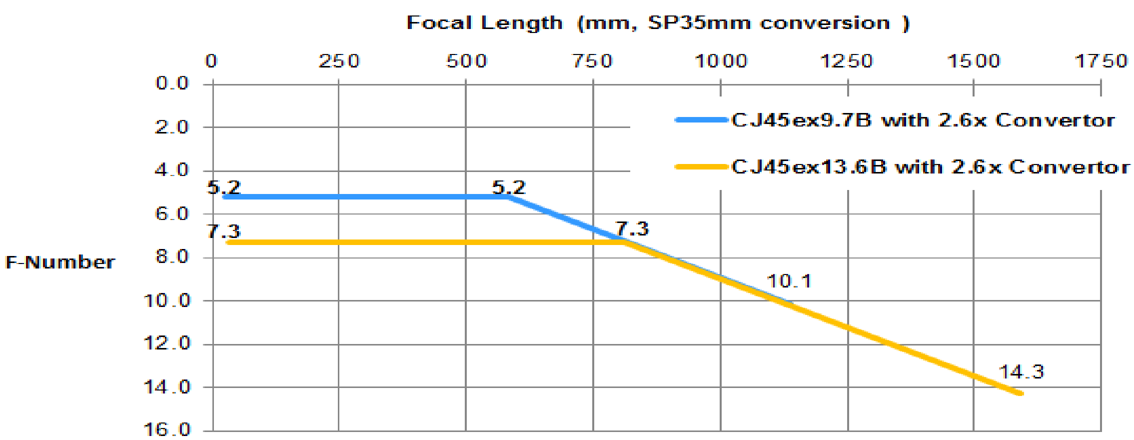


Figure 22 *Effective Focal Ranges of the two lenses when used with a B4 to S35mm adaptor*

11.0 Digital Servo Unit

The digital servo unit employs 16-bit encoders to ensure high positional accuracy. The use of absolute value encoders removes any need for initialization upon power switch-on. This empowers positioning detection at the moment of power-on as well as immediate enablement of aberration correction action between the lens and camera.

Figure 23 *Two views of the digital servo unit – on the left is shown the associated display unit and on the right the integral servo zoom controls are shown*

Selection, execution, and adjustments related to a variety of operational functions are easily performed using the servo unit's on-board information display. Detailed data on the residual lens aberrations that support the ITU-R BT.2020 standard are stored in memory within the drive unit and are sent over the serial link to the camera – many of which today incorporate digital aberration correction systems using that data.

Figure 24 *Close-up of the digital drive unit showing the physical engagement with the zoom, iris, and focus control rings and also showing the zoom control on the unit itself*

The drive speeds that were finally achieved (compared to the HDTV HJ40 lenses) are shown in Figure 25. The maximum zoom speed over the total 45x focal range was reduced to a mere 1.2 seconds. The slowest zoom speed can be set to 300 seconds for the total focal range. The focus rotation angle was increased to 180 degrees (from 110 degrees in the HJ40x lenses) in the new CJ45x lenses to help facilitate better control when focusing 4K imagery. The servo drive unit can drive the focus control over that full range in 1.8 seconds.

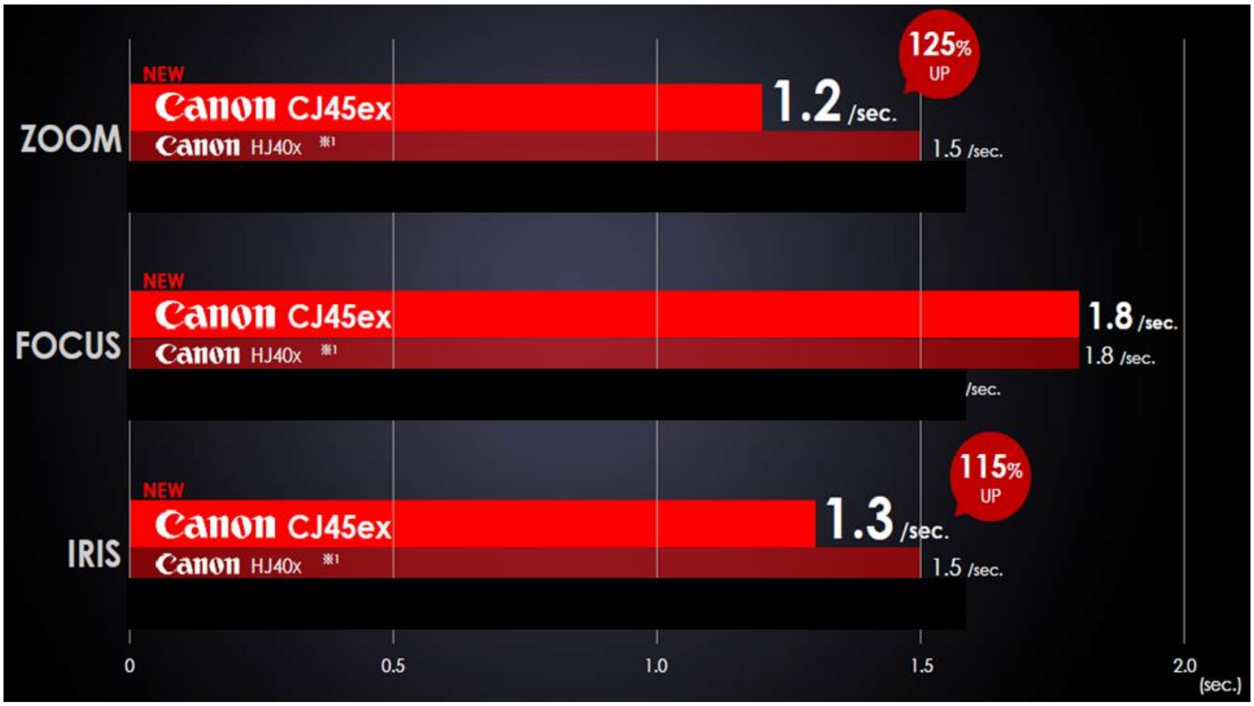


Figure 25 *Outlines the speed performance of the digital drive unit for zoom, focus, and iris compared to those of the HDTV long zoom lens*

12.0 Image Stabilization

These lenses use built-in image stabilization – a newly designed system compared to that in the original generation HJ40x lenses. As shown below the improvement is significant in the all-important higher vibration frequency range (that is typically stimulated when shooting within helicopters, boats, and motor vehicles). Stabilization mode settings are enabled from the digital information display in the digital servo drive unit

Figure 26 *Shows the relative degree of control over a range of vibration frequencies known to stimulate image instabilities in long zoom lenses*

13.0 System Interfaces

Three standard 20-pin connectors ensure the capability of a 16-bit virtual output while zoom and focus controllers are engaged via the other two connectors.

Figure 27 *Showing the three 20-pin system interfaces integral to the digital drive unit.*

Figure 28 *Remote 1 and 3 connectors are used for the standard broadcast zoom and focus controllers while Remote 2 delivers the digital data for virtual operations*

14.0 Summary

Electronic field production manifests itself within a wide range of program production genres. In the still thriving realm of HDTV television production the 2/3-inch image format continues to play a major role – most especially in sports production – but also in natural history and documentary, broadcast newsgathering, special event coverage, concerts, award shows, large house of worship productions, news magazine shows, and others. At times, many of these productions require a long focal length. It is for this reason, after more than fifteen years, the Canon HJ40x10B and HJ40x14B portable lenses remain in considerable demand.

Now, however, the era of 4K UHD has arrived. While UHD delivery services are presently modest on a global scale (and still quite limited here in the USA) the march is indisputably underway. As testament to this – while 4K Super 35mm lenses and cameras now proliferate in theatrical motion picture production and high-end television episodic productions the world's professional manufacturers have raced to produce 2/3-inch based 4K UHD lenses and cameras in response to rising enquiries and test projects from broadcasters and cable and satellite operations. As this White Paper has shown, Canon has been quite proactive in developing an ever-broadening range of 2/3-inch 4K UHD lenses. The arrival of two long focal range lenses greatly strengthens the 4K UHD optical portfolio.

While large format single sensor cameras have sparked a new form of creativity within many of these productions (both HDTV and 4K UHD) because of the different cinematic look that they can impart, they can still be hampered by the limited focal ranges of Super 35mm zoom lenses. Various high quality optical adaptors (typically B4 to PL) have appeared in the global marketplace that will couple a 2/3-inch long focal length lens to any one of the many Super 35mm cameras now widely available. The new lenses offer impressive focal ranges under such circumstances – CJ45ex9.3B (25.2 – 1136 mm) and the CJ45ex13.6B (35.4 – 1591 mm).

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