# White Paper

## *Long Zoom Lens*

## *For*

## *4K Super 35mm*

## *Digital Cameras*

December 29th, 2017

# Contents

## Abstract

*The world of television production is beginning to adopt 4K Super 35mm (S35) image capture for a widening range of program genres that seek both the unique imaging properties of that large image format and the protection of their program assets in a world anticipating future 4K services. Documentary and natural history production in particular are transitioning to this form of production. The nature of their shooting demands long zoom lenses. In their traditional world of 2/3-inch digital HDTV cameras, they have a broad choice in portable lenses – with zoom ranges as high as 40:1. In the world of Super 35mm the longest zoom lens is limited to 12:1 offering a telephoto of 400mm. Canon was requested to consider a significantly longer focal range lens while severely curtailing its size and weight. Extensive computer simulation explored countless combinations of optical and optomechanical systems in a quest to help ensure that operational requests and full 4K performance could be met. The final lens design is anticipated to have applications beyond entertainment production, including a variety of security systems.*

# 1.0 INTRODUCTION

The traditional television world has long been centered on the much smaller 2/3-inch image format size – and here the diverse needs of television production have propelled vigorous competitive developments in long zoom lenses – both box field lenses and portable EFP lenses. 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 long zoom HDTV lenses specifically designed to support a wide range of field productions (EFP). 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.

Considering the multifaceted nature of field production Canon elected to develop two EFP lenses – the wide angle HJ40x10B and a companion telephoto HJ40x14B.


**Figure 1** *The original 2/3-inch HDTV 40x long zoom EFP lens – the HJ40x10B*

These portable 40:1 zoom EFP 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.

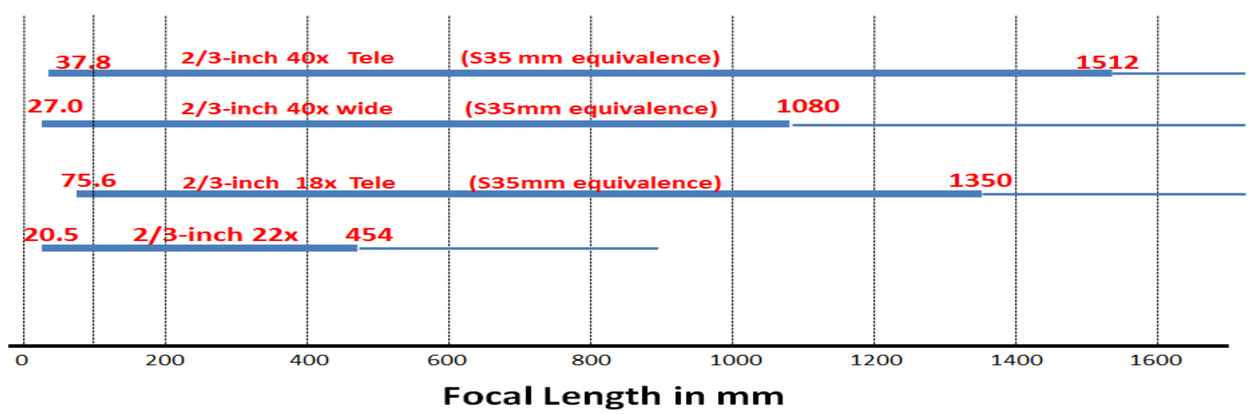



**Figure 2** *Showing Some Canon 2/3-inch EFP lenses and their Super 35mm equivalent Focal Ranges*

## 2.0 SUPER 35mm ZOOM LENSES – AND THEIR FOCAL RANGE LIMITATIONS

Through many decades the global motion picture film industry presided over most of the optical innovations in Super 35mm (S35) lens design. Larger image formats also emerged and are still used today for some premium theatrical motion pictures. But, S35 remains center stage. Sets of prime lenses, covering a broad range of focal lengths, remain the preferred imaging tool for directors and cinematographers, and they are readily available from numerous prominent optical manufacturers. S35 zoom lenses were also developed, but because of size and weight considerations they were of modest focal ranges.

While 2/3-inch lenses and cameras remained widely deployed for documentary and natural history production, the creative merits of the larger Super 35mm image format was gaining increasing appeal to many genres of television production. Competitiveness, in turn, spurred brisk new development activities in a new generation of S35 lenses [3]. In this new era, the zoom lens is growing in popularity. The more recent adoption by the broadcast television industry of the S35 single image sensor camera for a variety of program genres has added impetus to both lens and camera design.

In particular, there has been a rising appeal from television producers for long telephoto S35 lenses having 4K optical performance – for a variety of documentary productions. About six years ago, Canon engaged in discussions with some producers of wildlife production who voiced their frustration with the focal range limitations of available S35mm zoom lenses


**Figure 3** *Early experiments using the Canon 4K S35mm 10:1 Cine Zoom quickly confirmed the need for a greater focal range for wildlife production.* Picture courtesy of: Cinematographer Susan Gibson.

More recently, there has been a growing spectrum of requests for portable longer zoom S35mm cine lenses from sports broadcasters, producers specializing in concerts, and from large houses of worship – all of whom seek the cinematic look of the larger image format.

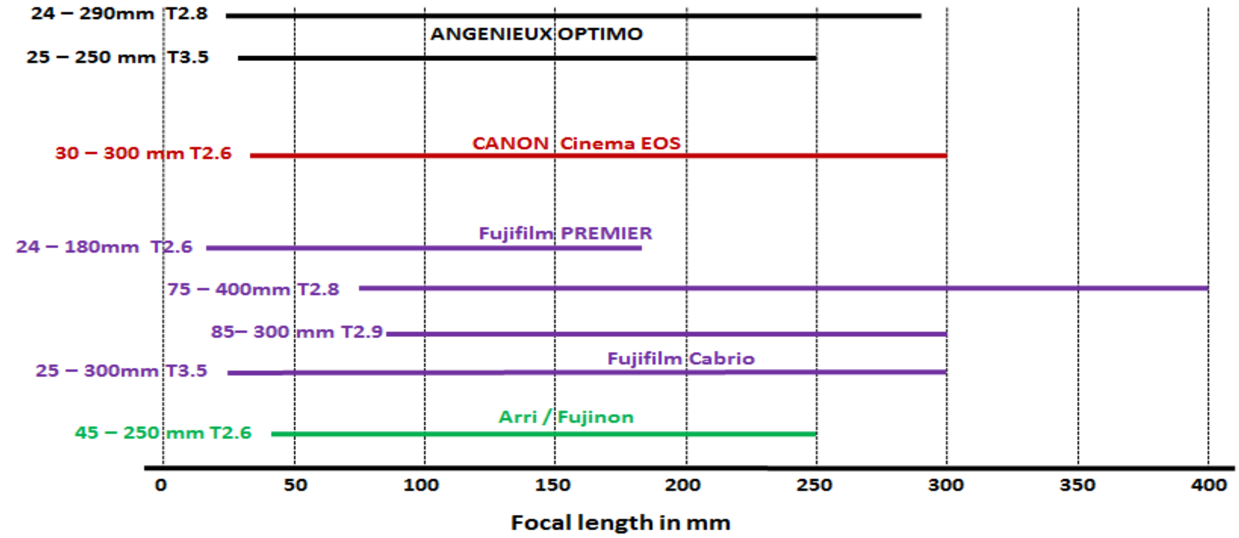



**Figure 4** *Showing the focal range limitations of contemporary Super 35mm long zoom lenses from prominent manufacturers*

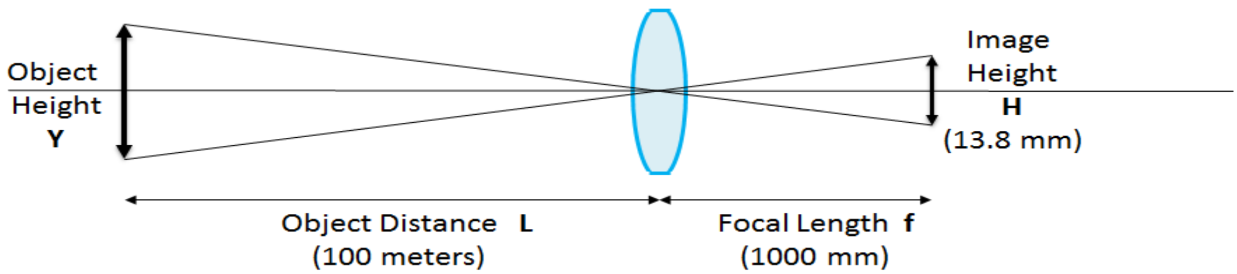
## 3.0 PRIMARY OPERATIONAL DESIGN TARGETS

A broad consensus among the natural history producers was a desire to fully frame a subject of 50 to 60 inches high (1.3 – 1.5 meters) – this encompasses many wild animals – from a distance of 100 meters (approximately 330 feet).

**Figure 5** *Wildlife producers seek the capability to frame wild animals from a considerable shooting distance*

At the same time most also urged a reasonable wide angle setting that could offer capture of wide vistas when shooting for a natural history production.

A simple calculation as shown in Figure 4 shows that a 1000mm focal length is required to fully frame an object height of 55 inches.




$$\text{Focal Length } \mathbf{f} = \mathbf{H \times L / Y}$$

$$= 13.8\text{mm} \times 100{,}000\text{mm} / 55 \times 25.4$$

$$= 1000 \text{ mm}$$

**Figure 6** Calculation of focal length required to image a 55-inch high object from 100 meters

There was general agreement among many of the world's cinematographers that a 50mm wide angle setting would support framing of panoramic vistas. Many also requested a focal range extender (popular in high-end broadcast lenses – but unheard of in the S35 cine domain).

Following a number of discussions with a variety of wildlife producers, it was finally agreed that the following would constitute the core design targets for the operational specifications of this new lens.

- Fully frame a 55-inch object height at an object distance of 100 meters (330 feet)
- 20x Zoom range – from 50mm wide to 1000mm telephoto
- Built-in 1.5x range extender – extends focal range from 75mm to 1500mm
- Ease of Focusing
- Integral high speed Digital Servo Drive Unit – for control of zoom, iris, and focus

## 4.0 PRIMARY OPTICAL DESIGN TARGETS

- Full 4K optical performance maintained over total Focal Range (up to 1500mm)
- Tight control of aberrations over wide range of Object Distances
- Precise zoom tracking
- Minimized focus breathing

A 4K imaging system is defined by the photosite sampling lattice of the associated camera image sensor. The 4K production format has been standardized by SMPTE as ST 2048-1:2011 [2] and defines a digital sampling structure of 4096 (H) x 2160 (V). The television 4K UHD has a slightly smaller structure of 3840 (H) x 2160 (V). As shown in Figure 7 the Nyquist frequency for this system is 2160 television lines per picture height (TVL/ph) or 1080 Line Pairs/ph. The associated optical Nyquist is generally cited as line pairs per millimeter (LP/mm) – and for the Super 35mm image format size this becomes 1080 LP / 13.8 mm = **80 LP/mm** *(rounded up from the more precise 78.2 LP/mm shown below).*

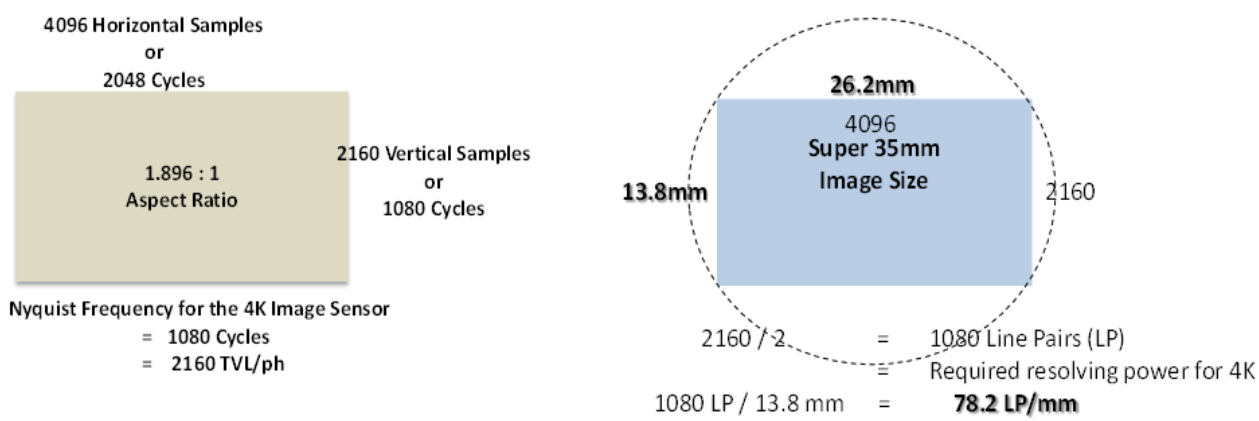



**Figure 7** Relating optical Nyquist frequency with that of a 4K image sensor

The left of Figure 8 shows the MTF of a generic 4K lens at picture center. The lens-camera MTF at picture center is the convolution of the lens MTF with that of the electronic MTF of the associated 4K camera – shown on the right of Figure 8. Decades of cinematography experience have shown that the perceived image sharpness on a large screen (theatrical cinema or home display – at normal viewing distances – is more influenced by the height of the MTV curve at half Nyquist than at Nyquist [4] [5].

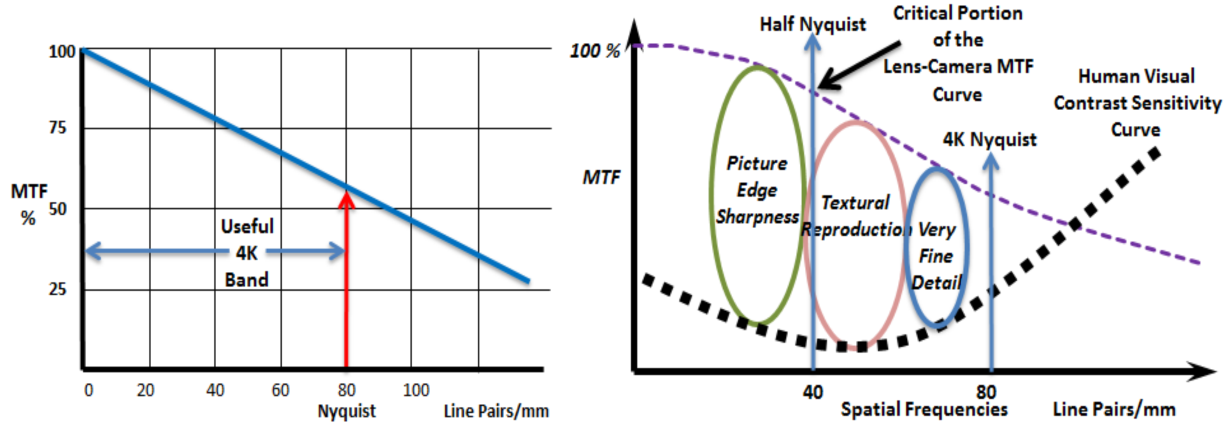



**Figure 8** On the left is a generic 4K lens MTF characteristic at picture center and on the right is the associated lens-camera generic center MTF characteristic

The significant challenge to 4K lens design is achieving as high an MTF as possible in the 40 LP/ph region and then maintaining that MTF to the degree possible across the image plane [3]. Canon defines two zones to specify the MTF level across the image plane – they are shown in Figure 9. Equally important is minimizing variations in MTF as the focal length is changed – a particular challenge for a 20:1 zoom range.

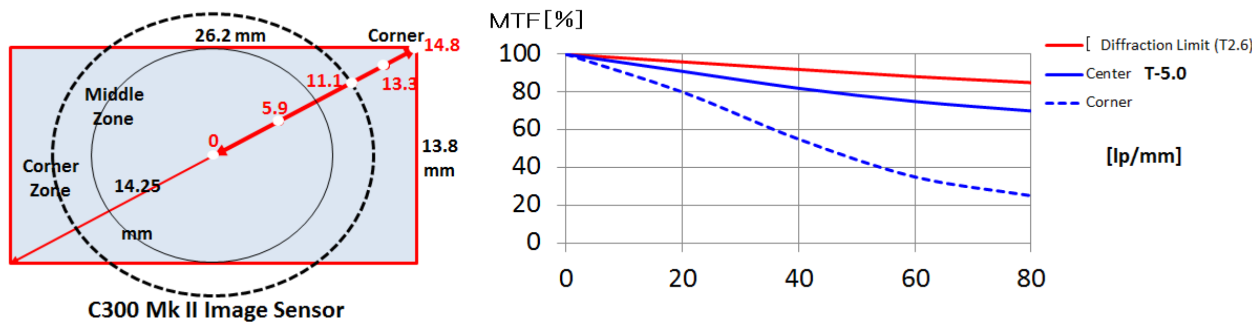



**Figure 9** *The two zones within the active image plane that Canon uses to define MTF performance and the computer simulation of the anticipated MTF*

## 5.0 THE PHYSICAL CHALLENGE

Those consulted in specifying the sought-for ultra-telephoto S35mm lens were adamant in their imposed limitations on size and weight. The nature of their shooting operations mandates easy transportability of their lens-camera systems. In today's digital world that squarely places the onus on the lens rather than the camera. A consensus on no more than 15 lbs. weight and an overall length no greater than 16 inches emerged from extensive consultations with major producers of documentary and natural history programming. A measure of the challenge posed by these constraints is evident from an examination of available contemporary "long" zoom Super 35mm lenses in wide use today – shown in Table 1.

**Table 1**

| | Contemporary 4K Cine Long-Zoom Lenses | | | |
|---|---|---|---|---|
| Focal Length | 24-290mm | 24-180mm | 75-400mm | 45-250mm |
| **Zoom Ratio** | **12x** | **7.5x** | **5.3x** | **5.6x** |
| T No. | T2.8 | T2.6 | T2.8 | T2.6 |
| MOD | 1.22m | 1.24m | 2m | 1.2m |
| **Length (inches)** | **18.6** | **15.95** | **17.5** | **14.6** |
| Front Diameter | 162mm | 136mm | 136mm | 134mm |
| **Weight** | **27.7 lbs** | **19.6 lbs** | **19.6 lbs** | **16.5 lbs** |

The Super 35mm image format size inherently dictates larger glass elements than the popular 2/3-inch lenses used in HDTV production. 4K performance over the total focal range requires larger elements. High optical sensitivity and curtailment of F-stop drop (ramping) calls for large front glass elements. The desire to severely control monochromatic and chromatic aberrations in order to achieve that 4K optical performance argues for more glass elements (higher number of elements offer more degrees of design freedom to combat these multiple aberrations).

Old established design conflicts – long wrestled with by those developing portable high performance zoom lenses – were, at the outset, central to the initial planning. The primary quest was the achievement of the desired overall 4K optical performance in a long telephoto lens within the end user requested constraints of lens size and weight.

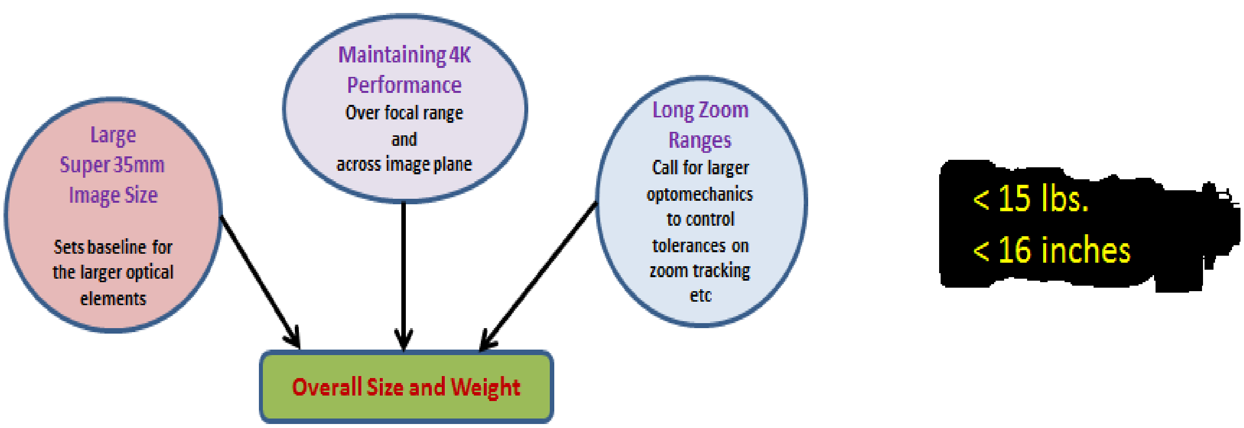



**Figure 10** *Primary determinants of size and weight of a 4K Super 35mm zoom lens*

The severe restrictions on size and weight were to launch the most challenging lens development project in Canon's history.

### 5.1 Challenging Relationship between Lens Zoom Ratio and Object Image Size

To illustrate the degree of the physical challenge it is interesting to consider initial thinking within Canon some years ago when our first long zoom Super35mm cine lens was being contemplated. The well-known 2/3-inch HDTV lens – the HJ22x7.6B – was offered to Canon as a model for a possible S35 lens. Computer simulation showed that such a lens – retaining the F-1.8 (or T-2.0) maximum aperture would have a size shown in the center of Figure 11 below. It simply was not practical. Canon's ultimate decision was to develop the 10:1 zoom cine zoom lens – the S35mm CN-E30 – 300 mm having a maximum relative aperture of T-2.95. This lens offered a pragmatic balance between size and operational capabilities.

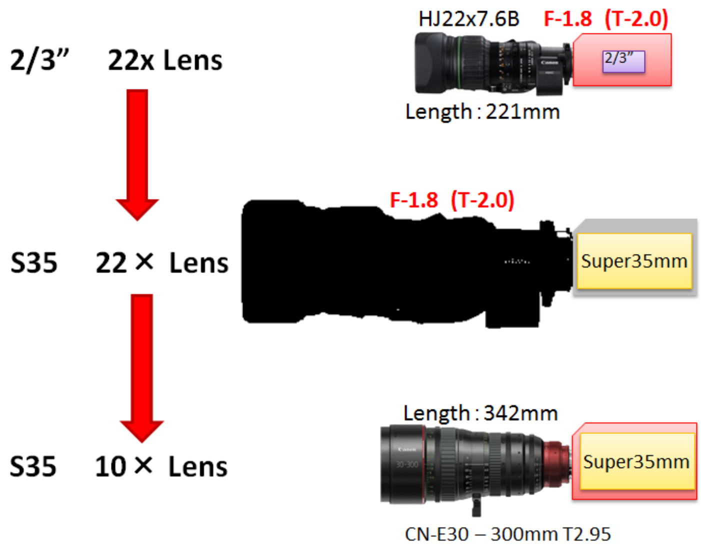



**Figure 11** *Illustrating the challenge of producing a long-zoom S35mm cine lens*

In the early planning phase of the requested long-zoom S35mm 4K lens, the model initially suggested by many was the famous 2/3-inch HDTV 40:1 zoom range lens – the HJ40x14B. Extrapolating that lens to a S35mm lens having the same maximum aperture of T-3.0 would require a lens of the size shown in Figure 12. This would not come close to meeting the requested physical size and weight.

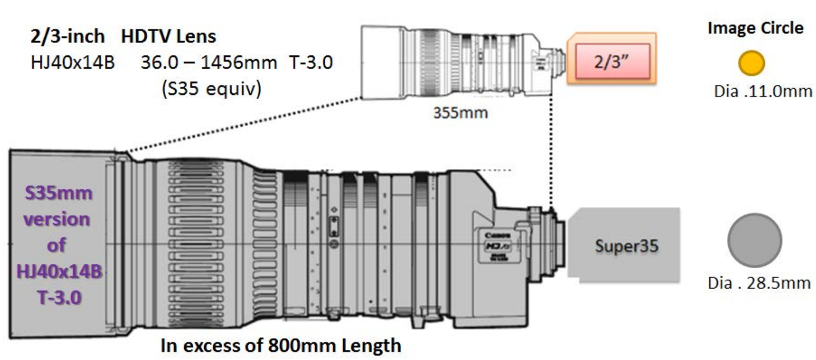



**Figure 12** *The dramatic increase in physical dimensions of a S35mm lens with a 40:1 zoom range*

## 6.0 THE IMPOSSIBLE LENS – THE CANON CN20x50

At InterBee 2014 Canon formally introduced the CN20x50 Super 35mm 4K lens having a zoom ratio of 20:1. Against all odds, the remarkable design team produced the world's first truly telephoto S35mm zoom lens. It incorporates a built-in 1.5x range extended – another world's first. What really commands attention is the fact that it met the physical size and weight challenges. Indeed, it did more than meet them – weighing in at 14.5 lbs. and achieving a length of 15.9 inches. When re-reviewing Table 1 above, it becomes apparent that a breakthrough design had been achieved.


**Figure 13** *The CN20x50 Telephoto S35mm 4K Zoom Lens*

The importance of the short length of the lens can be gleaned from Figure 14 which shows the easy reach for the camera operator to manually focus the lens.

**Figure 14** *Easy manual focusing is facilitated by the short length of the CN20x50 lens*

## 7.0 NEW OPTICAL DESIGN INNOVATIONS

The optical and optomechanical design teams were closely united in a series of detailed design reviews that progressively explored all 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 – and each time an issue arose, they delved deeply into the causes of the problems and how to resolve them.

The optical team explored new glass materials, optimum number of elements, element shapes, element groupings, use of aspheric elements, while the optomechanical team explored new materials (for weight and ruggedness), mounting strategies for the lens elements that would 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. Flexibilities in thinking unconstrained by existing conventions became central to the project. Ultimately a core optical design emerged that embodied five core areas of new optical innovations – see Figure 15.

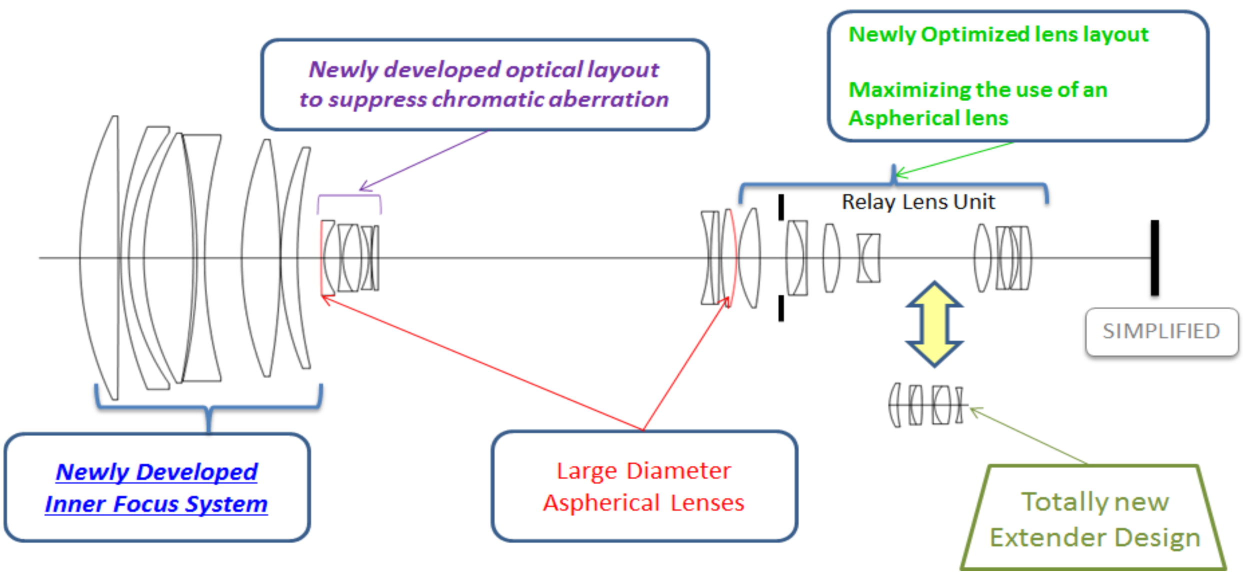



**Figure 15** *Identifying areas of design innovations within the overall zoom lens optical system*

### 7.1 Use of a Range of Contemporary Glass Materials

Optical designers have today a wide choice in glass materials that have been developed by major global manufacturers over many decades. Each have their own optical and physical characteristics that allow combinations to exercise degrees of control over many aspects of the broad band of wavelengths required for cinematography. In grappling with the unique optical challenges of a 4K long zoom lens a departure from typical glass materials used in high-end broadcast HDTV lenses was necessitated. This is indicated in Figure 16.

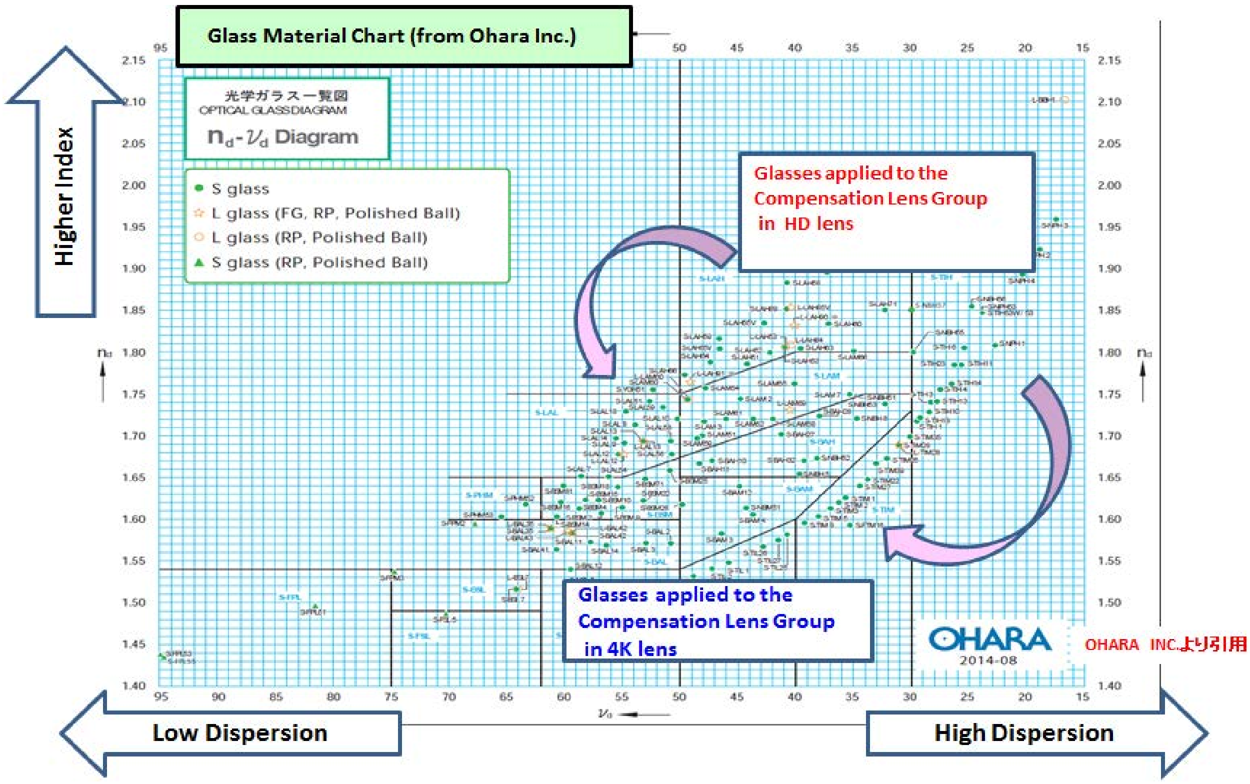



**Figure 16** *Glass materials traditionally selected in contemporary HDTV lenses are generally in the upper regions of the chart and quite different materials from the lower regions were selected for the zooming variator in the new 4K zoom lens*

## 7.2 New Inner Focus System Design

The inner focus system 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. Focus rotation angle, focus breathing characteristics, chromatic aberration behavior on wide angle settings, are all associated with this optical subsystem. Lens size and weight are heavily proportional to decisions made in the overall design of this system.

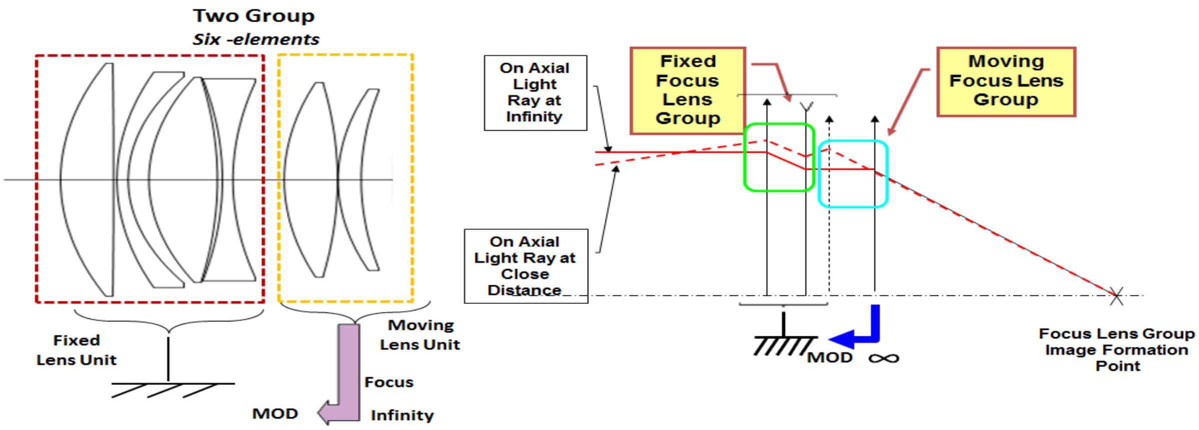



**Figure 17** *A newly developed Inner Fixed Focus Group minimized focus breathing*

Recent high performance 4K cinematography lens designs employed both 3-group and 4-group inner focus systems as described in reference [1]. As part of the weight reduction strategy the new long zoom lens uses a novel 2-group system using only 6-elements as shown in Figure 17. The diameter of the front focusing lens group was restricted to 136mm.

### 7.3 Challenge of Focusing 4K imagery in Shallow Depth of Field

Especially in wildlife shooting, the camera operator is often challenged to maintain focus on animals that are continually moving. 4K resolution combined with the shallower depth of field of the larger Super 35mm image format escalates this challenge. Cinematography lenses traditionally incorporate very wide rotation angles for the Focus control ring – often 300 degrees or more to alleviate the task of focusing. However, in the case of this long zoom lens – where servo drive of both zoom and focus are considered a high priority – the speed of both of those controls can be important under certain shooting conditions. That called for a compromise in the focus rotation angle. This was finally optimized at 180 degree rotation.


**Figure 18** *Focus rotation angle is 180 degrees to aid manual focusing* and achieve high speed servo drive

A second design consideration with respect to facilitating achievement of precision focus was an optical strategy entailing utilization of a subtle degree of spherical aberration to broaden the MTF characteristic [7].

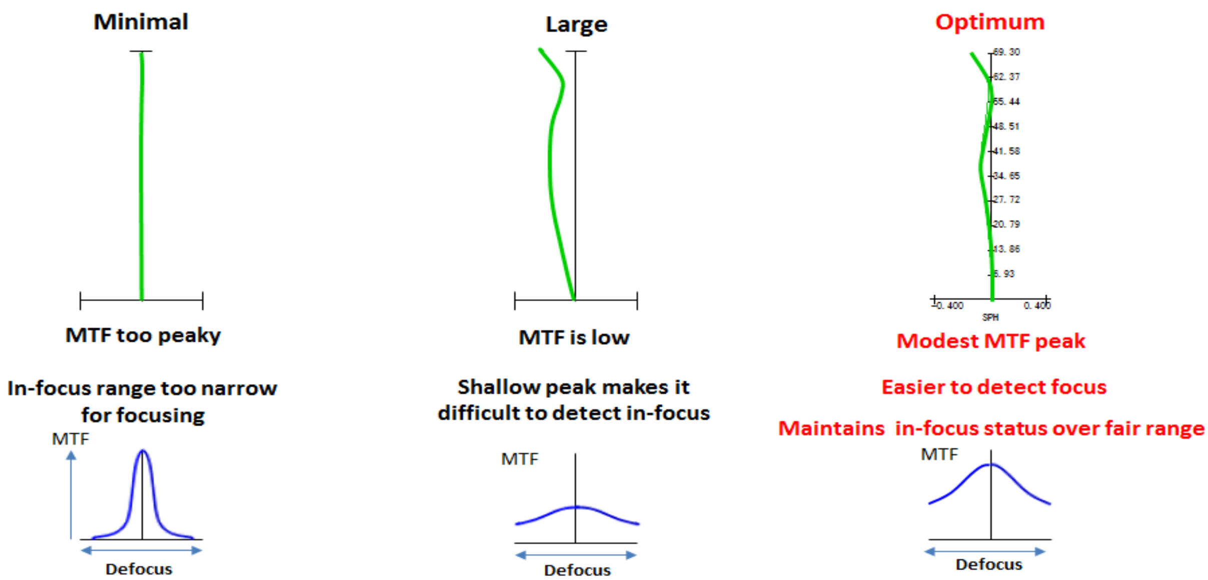


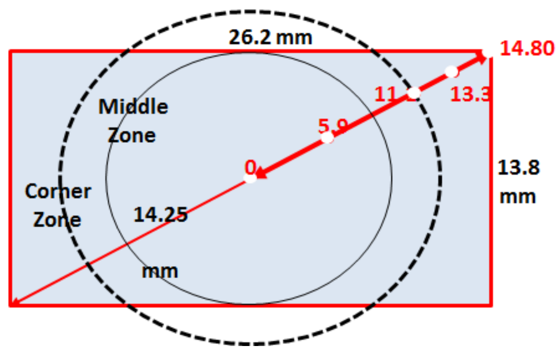

**Figure 19** *Simplistic outline of a design strategy to introduce a precisely controlled amount of spherical aberration into the lens to modify the MTF behavior in a manner that broadened the defocus characteristic*

## 7.4 Control over Optical Aberrations

The core science of lens design lies in controlling the degree of the multiple optical aberrations within the system to specific tolerance levels (there are five monochromatic and two chromatic aberrations inherent to each and every glass element) [6]. Modern computer simulation techniques have been greatly empowered by extended computing capabilities, ever-advancing software design tools, and the accumulated experiences of the optical and optomechanical designers. Among the strategies deployed in simulation is the use of small light pencils or bundles – having a prescribed number of light rays – that are passed through the entire optical system and then closely examined at the output reference plane. The spatial disposition of the individual light rays will portray the imprimatur of the various optical aberrations encountered. Single wavelength pencils will expose monochromatic aberrations and wide spectrum light bundles can explore the chromatic aberrations. The ensuing design process is a hugely iterative cycle of testing numerous optical strategies (glass materials and their respective sizes, shapes, groupings, group combinations) while the computer examines the hundreds of millions of optical parameter variables across the entire image surface. The ultimate goal is to elevate the multiple performance parameters that collectively produce a high performance 4K output image – over the total focal range – while simultaneously curtailing the aggregate of the optical aberrations that conspire to impair those performance parameters.

### 7.5 Example of Computer Simulation Results for CN20x50

Figure 20 shows the computer simulated results (final design stage) for four of the optical aberrations at one specific lens setting – full 1000mm telephoto and with a standard scene object distance – across the image height (defined as the distance in mm from picture center to the picture corner as shown below).



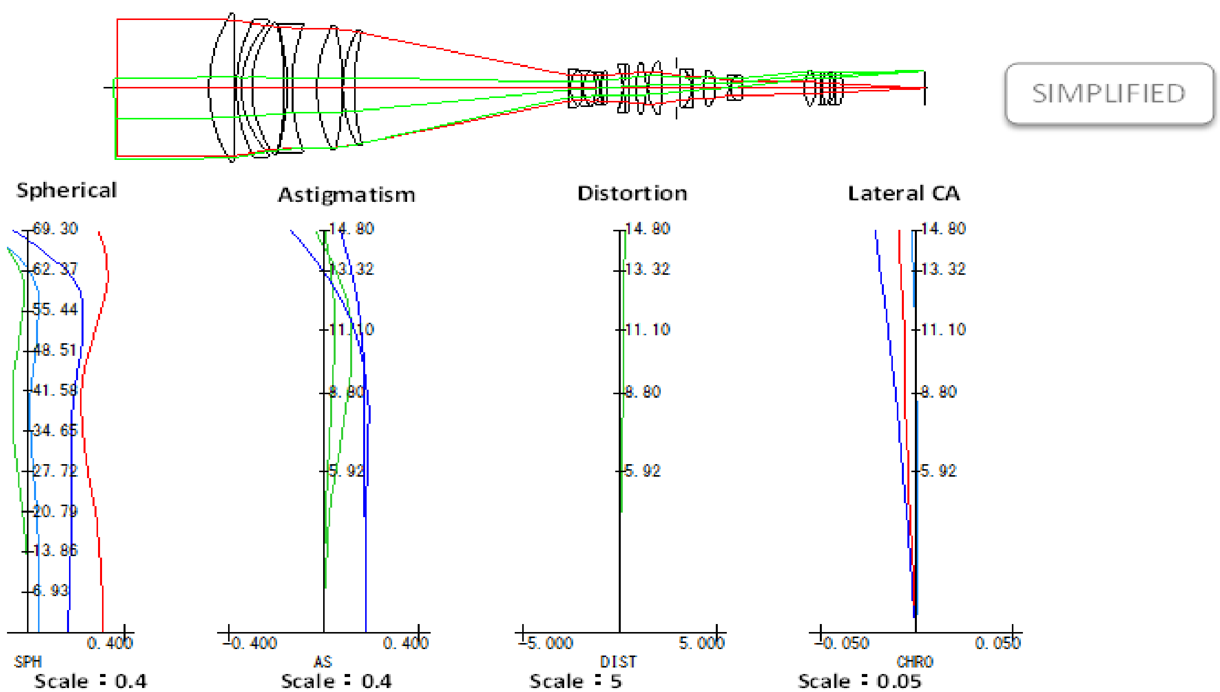




**Figure 20** Showing the computer simulation of the final level of four optical aberrations – the spherical aberration being assessed at four wavelengths from 656nm to 436nm and the astigmatism at two wavelengths (both meridional and sagittal).

# OPTICAL SENSITIVITY

## 8.1 Maximum Relative Aperture

The image brightness delivered by a lens is defined by the F-Number which is the ratio of the lens focal length and its effective aperture diameter. That effective aperture is the diameter of the lens entrance pupil. In turn, the diameter of the lens input focusing group becomes the primary determinant of the maximum relative aperture of the lens. Because the CN20x50 lens is part of the Cinema EOS Cine Servo family its maximum relative aperture is specified in photometric terms as a T-Number – and that specification is T-5.0 (Appendix 1).

Recognizing that this S35mm lens will be particularly appealing to those producing television documentaries and wildlife programming, it is helpful to know the equivalent maximum relative aperture as an F-Number. The following calculation is made:

$$\text{F-Number} = [\text{ T-Number} \times \sqrt{\text{Transmission \%}}\ ] \ / \ 10$$

If we assume the lens transmission is 81% then

$$\begin{aligned} \text{F-Number} &= [\,5.0 \times \sqrt{81}\,] \ / \ 10 \\ &= 5.0 \times 9 \ / \ 10 \\ &= 4.5 \end{aligned}$$

While the optical speed of the lens is somewhat restricted it needs to be seen in context with the electronic sensitivity of most contemporary digital Super 35mm cameras, whose nominal sensitivities are typically close to T-11.0 (measured at 2000 Lux, 3200 degree incident light on an 89.9% white chart) – see Table 2. This means that the camera (Canon C300 Mk II is the typical cine camera) will deliver full 100% Luma Level with a scene illumination of only 400 Lux when the lens is wide open at T-5.0.

## Table 2

| Light | Illumination (Lux) | Lens Aperture | ISO Setting | ND Filter |
|---|---|---|---|---|
| | 132,000 | | | 6-stop |
| BRIGHT SUN | 100,000 | | | |
| | 64,000 | | | |
| HAZY SUN | 50,000 | | | |
| | 32,000 | | | 4-stops |
| BRIGHT CLOUDY | 25,000 | | | |
| | 16,000 | | | |
| | 10,000 | | | |
| DULL CLOUDY | 8,000 | | | 2-stop |
| | 4,000 | T-16.0 | | |
| Camera → | 2,000 | T-11.0 | | Clear |
| | 1,000 | T-8.0 | | |
| VERY DULL DAY | 500 | T-5.6 | | |
| | 400 | T-5.0 | ISO 850 | |
| SUNSET | 250 | | ISO 1,600 | |
| DUSK | 125 | | ISO 3,200 | |
| | 62.5 | | ISO 6,400 | |
| | 31.25 | | ISO 12,800 | |
| TWILIGHT | 15.125 | | ISO 25,600 | |

## 8.2 Ramping Characteristic

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 – that is, the brightness delivered by the lens starts to fall-off. Paradoxically, this behavior is often termed the undesirable lens "F-Drop". It is more generally referred to as the Ramping characteristic of a given lens.

The CN20x50 is specified to have a sensitivity of T-5.0 (or F-4.5) over the lower focal range. If this was to be maintained out to the 1000mm telephoto extremity the diameter $E_N$ of the entrance pupil at 1000 mm would need to be

$$\begin{aligned} \text{Diameter } E_N &= \text{Focal length} \;/\; \text{F-Number} \\ &= 1000\text{ mm} \;/\; \text{F-4.5} \\ &= 222\text{ mm} \end{aligned}$$

This diameter in the input optical focusing group (almost 9-inches) would require a very large lens that could not possibly meet the desired size and weight requirements (the input focusing group constitutes approximately 70/80% of the overall glass weight of a zoom lens).

All of the computer simulation entailed in the overall design of this lens constrained the diameter of the lens front port at 136mm. The diameter of the optical focusing group is slightly less than this – at 124mm. This diameter defines the maximum size of the entrance pupil – from which the maximum focal length at which that F-4.5 maximum relative aperture can be sustained is calculated as follows:

$$F = f / E_N$$

From which

$$\begin{aligned} \text{Focal Length } f &= F \times E_N \\ &= 4.5 \times 124 \\ &= 558\text{ mm} \end{aligned}$$

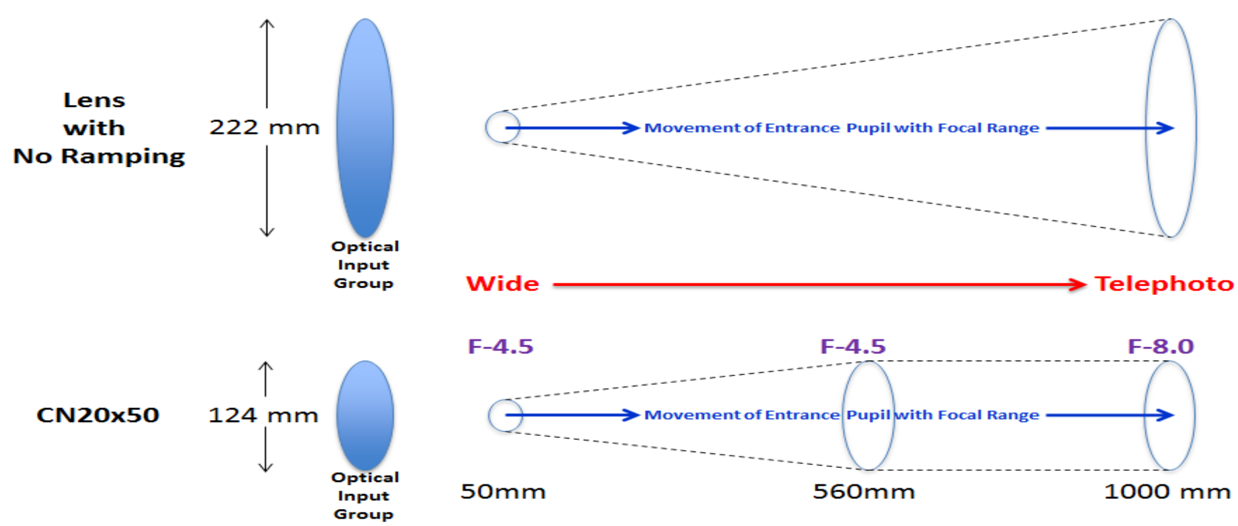



**Figure 21** *Illustrating the very large lens that is required to maintain F-4.5 maximum aperture of the entire focal range compared to the pragmatic design of the CN20x50*

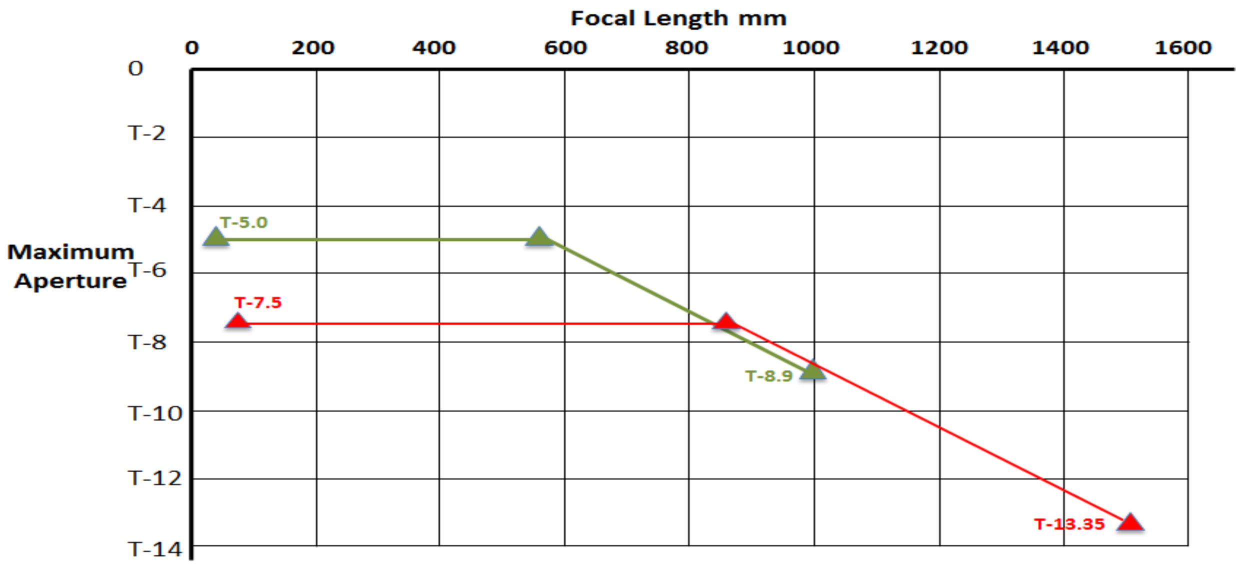



**Figure 22** *Showing the ramping characteristic in green – while the red curve shows the alteration when the 1.5x extender is switched in*

The CN20x50 maintains the F-4.5 maximum relative aperture over the focal range of 50 to 560 mm before it starts to ramp down to F-8.0 (T-8.9) at 1000 mm. To put this in perspective Figure 23 shows the CN20x50 characteristic compared to well-established popular long zoom S35mm lenses.

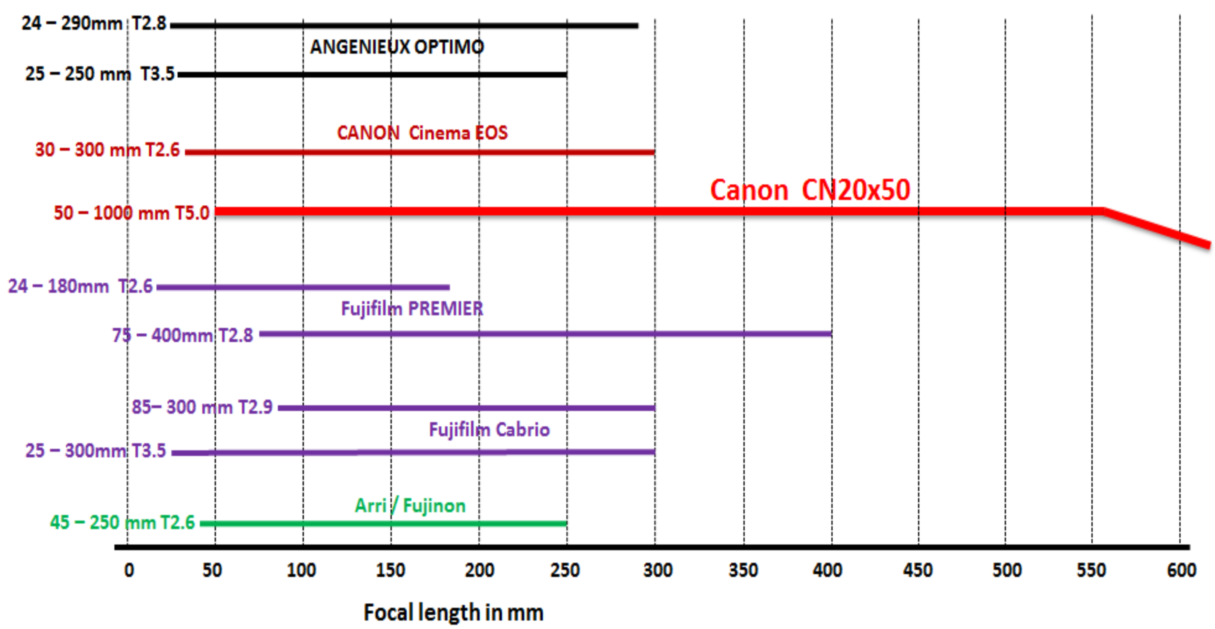



**Figure 23** *Comparing the constant aperture portion of the CN20x50 maximum relative aperture characteristic with established long zoom S35mm lenses*

## 9.0 CHALLENGE OF THE FOCAL RANGE EXTENDER

Broadcast television lenses have long embodied optical range extenders to provide a sometimes vital focal range extension for those many challenging shooting situations. In the realm of cinematography Super 35mm zoom lenses have never adopted this expediency. However, with the rapidly rising penetration of this larger imaging format into an increasing number of television production genres it was inevitable that the need would arise – and it did. The technical challenges of the extender in the larger format are considerable. Besides implementing the desired increase in focal length it also elevates the lens T-number.

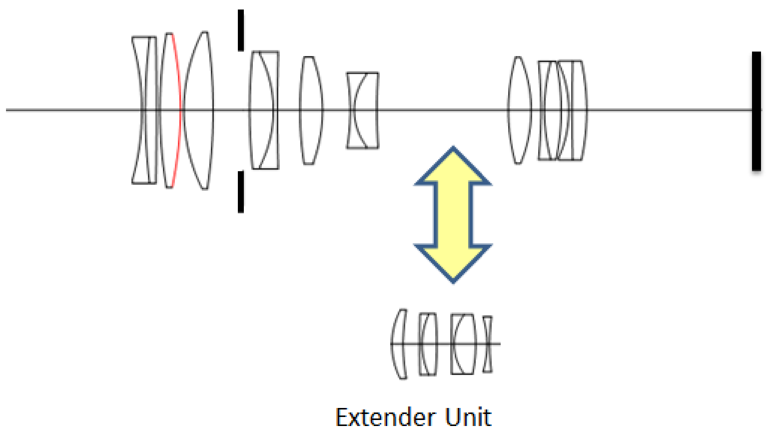



**Figure 24** *The 1.5x extender unit in the CN20x50 lens represents a radically new optical design*

Most challenging is the physical fact that the extender enlarges the negative effects of aberrations by a factor proportional to the square of the extender's zoom ratio (here 1.5 squared or 2.25x). This called for particular attention to the design of the range extender – where its optical performance had to exceed that of 4K in order to minimize its impact on the overall 4K performance of the lens when switched in and out.


**Figure 25** *Showing the manual switch to actuate the 1.5x range extender*

An innovative new approach was taken to the design of the optical group that constituted the extender. The degree of success of that design is indicated by the two sets of computer simulated optical aberrations shown in Figure 26.

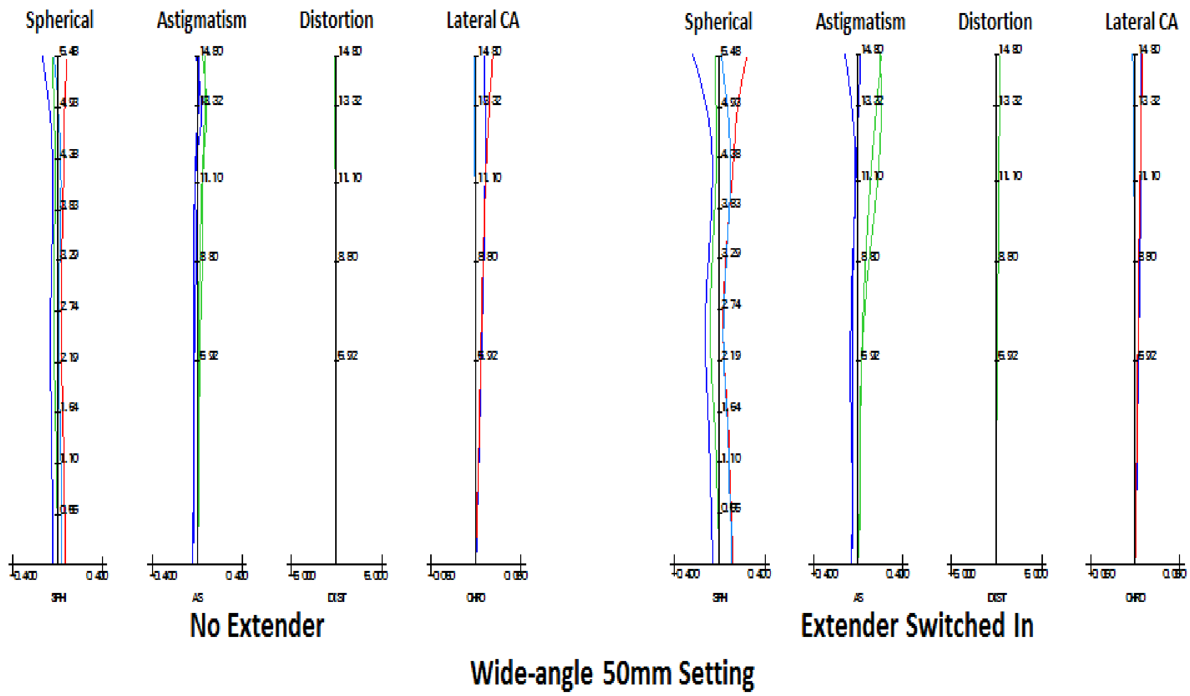



**Figure 26** *Showing computer simulation of the remarkably tight control over optical aberrations for the two conditions of extender switched in and out*

## 10.0 OPTOMECHANICAL INNOVATIONS

Maintaining the durability required for broadcast applications within all forms of environmental conditions was one of the hurdles to achieving compactness and lightness and demanded flexible design thinking unconstrained by existing conventions. On the optomechanical front, component parts were fashioned from materials that provided a balance between weight and durability, and a great deal of trial and error was necessitated using advanced simulation technology to find ways of reducing the weight while ensuring the dependability necessary for the intended applications. The traditional 300 degree rotation angle for focus control preferred by cinematographers was reduced to 180 degrees. Innovative new techniques for lens element mounting were devised to counter the effects of anticipated large environmental temperature changes. The lens is offered with the PL-mount or the Canon EF-mount.


**Figure 27** *Showing the optomechanical design of the lens and the integral digital servo drive unit*

A critical part of the overall design was the digital servo drive system to support precision control of the lens focus, zoom, and iris. Due to the large 180 degree rotation angle of the lens (to support both manual focusing ease and servo drive speed), the focus drive speed was increased to help ensure the same degree of usability in broadcast applications.

The drive unit can operate the zoom over its 20:1 range in 1.5 sec – or do a slow zoom in 180 seconds.

## 11.0 PERSPECTIVE

In cinematography there often arises a desire to alter perspective within a scene. As an illustration -- on the left in Figure 28, the subject has been framed at the wide 50 mm setting which reproduces the background as both wide and far away. On the right of Figure 28 the subject was re-reframed with the focal length set to full telephoto of 1000 mm and now the background is both defocused and appears much closer.

**Figure 28** *Showing the use of lens focal length to introduce possible creative adjustments to perspective*

## SUMMARY

An important step forward in high performance S35 long zoom lens design has been reached. 4K optical performance combined with a 20:1 zoom range has been achieved in a portable lens that promises new creative options for cinematography and for television production.

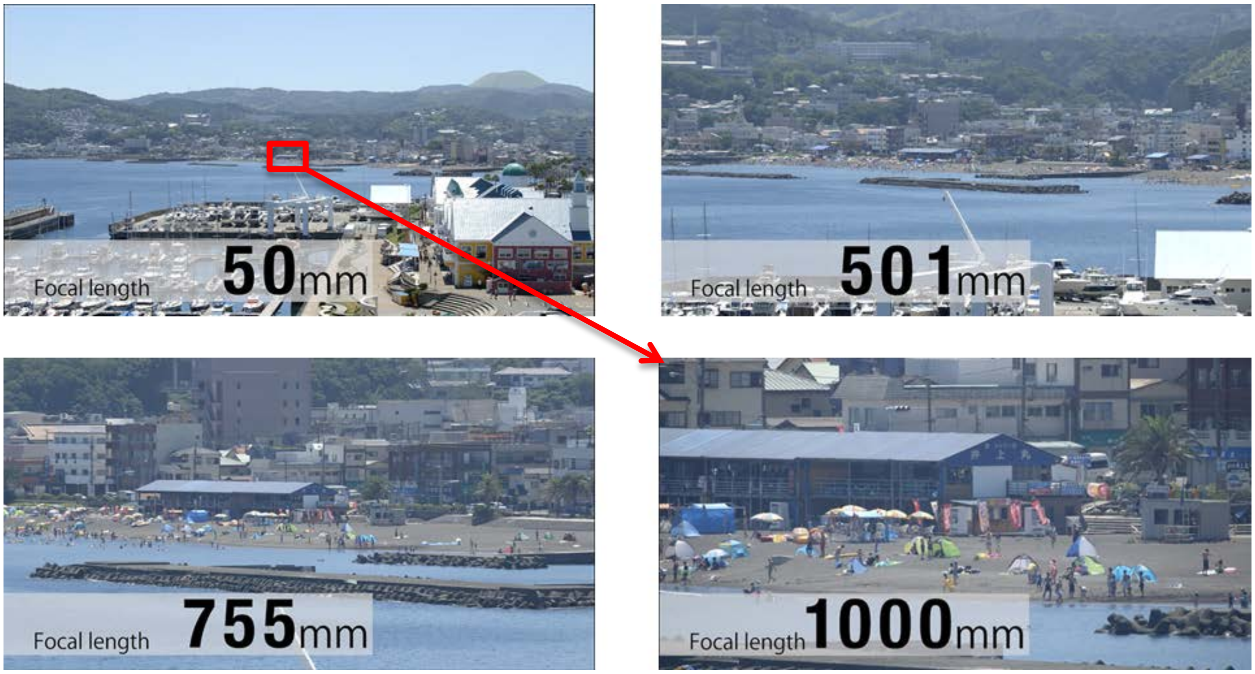



**Figure 29** *Showing actual images from the CN20x50 at four different focal lengths*

**Figure 30** *While physically sizeable – the new CN20x50 does facilitate easy shoulder mounting*

During the past two years the CN20x50 has been used on numerous international wildlife and documentary productions. Many commented on the short length facilitating comfortable focusing.


**Figure 31** *The CN20x50 on location in Africa in early 2016*


**Figure 32** *The new telephoto S35 lens on a high-speed 4K digital camera*

**APPENDIX 1**

**Table 3 Lens Operational Specifications**

<table>
<tr><th colspan="2"></th><th>CN20x50 IAS H/E1</th><th>CN20x50 IAS H/P1</th></tr>
<tr><td colspan="2">Mount</td><td>EF</td><td>PL</td></tr>
<tr><td colspan="2">Zoom Ratio</td><td colspan="2">20x</td></tr>
<tr><td colspan="2">Focal Length<br>(with Extender)</td><td colspan="2">50-1000mm<br>75-1500mm (1.5x)</td></tr>
<tr><td colspan="2">Maximum Aperture</td><td colspan="2">T5.0 at 50-560mm<br>T8.9 at 1000mm<br>T7.5 at 75-840mm<br>T13.35 at 1500mm (1.5x)</td></tr>
<tr><td colspan="2">Iris Blade</td><td colspan="2">11</td></tr>
<tr><td rowspan="2">Angle of View</td><td>Aspect ratio 1.78:1<br>Dimensions 24.6x13.8mm</td><td colspan="2">27.6° x 15.7°<br>1.4° x 0.8°<br>18.6° x 10.5°<br>0.9° x 0.5° (1.5x)</td></tr>
<tr><td>Aspect ratio 1.9:1<br>Dimensions 26.2x13.8mm</td><td colspan="2">29.4° x 15.7°<br>1.5° x 0.8°<br>19.8° x 10.5°<br>1.0° x 0.5° (1.5x)</td></tr>
<tr><td colspan="2">M.O.D ( from Image Plane )</td><td colspan="2">3.5m / 11.5'</td></tr>
<tr><td rowspan="2">Object Dimensions at M.O.D.</td><td>1.78:1<br>24.6x13.8mm</td><td colspan="2">139.3 x 78.1cm at 50mm<br>7.3 x 4.1cm at 1000mm<br>92.9 x 52.1cm at 75mm<br>4.9 x 2.7cm at 1500mm (1.5x)</td></tr>
<tr><td>1.9:1<br>26.2x13.8mm</td><td colspan="2">148.3 x 78.1cm at 50mm<br>7.8 x 4.1cm at 1000mm<br>98.9 x 52.1cm at 75mm<br>5.2 x 2.7cm at 1500mm (1.5x)</td></tr>
<tr><td colspan="2">Front Diameter</td><td colspan="2">Φ136mm</td></tr>
<tr><td colspan="2">Approx. Size (WxHxL)</td><td>175 x 170.6 x 413.2mm</td><td>175 x 170.6 x 405.2mm</td></tr>
<tr><td colspan="2">Approx. Mass</td><td colspan="2">6.6kg</td></tr>
<tr><td colspan="2">Pitch of Focus/Zoom/Iris Gear</td><td colspan="2">Focus:0.8/0.5 Zoom:0.5 Iris:0.5</td></tr>
</table>

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