Canon

WHITE PAPER

Focus Demand & Zoom Controllers

AUGMENTED CREATIVE CONTROL

Innovations in Focus Demand and Zoom Demand Controllers for 4K UHD Long Zoom Field Lenses

Written by
Larry Thorpe, Senior Fellow, Canon USA

For more info:

pro.usa.canon.com

New Innovations in Broadcast Television 4K UHD Imaging

1.0 Introduction

Canon has entered a golden age in broadcast television lenses. On the BCTV front, the transition to 4K UHD production has recently been picking up in the U.S – although distribution is still a derived HDTV format. In the short space of three years Canon Inc has rolled out no less than eleven portable 4K UHD lenses, five long zoom 4K UHD box field lenses, one studio 4K UHD box lens, and a family of Cinema EOS Sumire prime lenses.

Important experiences were gained with the many productions undertaken with our first generation of 4K UHD field lenses – the UJ90x9B and the UJ86x9.3B. While the competition appeared to scoop Canon in mid-2016 with a 4K UHD lens having both an extended telephoto and a wide-angle capability – the optical performance was found by many customers to fall short of 4K expectations. However, this did spur the optical team in Canon Inc to go all out on a second-generation 4K UHD long zoom lens development.

2.0 A Major Breakthrough in Long Zoom Field Lens Design

The UJ122x8.2B and UJ111x8.3B represented a major leap forward in the design of long zoom telephoto lenses – simultaneously introducing significant advances on the both operational side and on the performance specifications:

1. Simultaneously extending focal range at the Wide (8.2mm) and at the Telephoto (1000mm) extremes (122x zoom ratio)
2. Overcoming barriers to sustaining 4K MTF at image extremities
3. Improving optical HDR and WCG performance over our first generation 4K field lenses
4. Significantly improving the built-in image stabilization system compared to prior generations
5. Finally eliminating the troublesome “drift” that can accompany sudden cessation of a Pan or Tilt when IS system is engaged
6. Virtual elimination of lens Ramping and Peripheral Illumination – the ARIA system (a collaboration with Sony)

The degree of success of these products can be measured by the enthusiastic response of all of the professional directors and professional camera operators who have evaluated these lenses, and, of course, by the highly encouraging briskness of their sales around the world.

In parallel with the development of these remarkable new lenses, the BCTV design group was also developing important advances on the operational side of long zoom field lenses. Extensive experiences with the first generation 4K UHD zoom lenses had revealed the challenges posed to camera operators to maintain razor sharp focus when working with viewfinders that are still largely based on HD resolution.

3.0 Challenges of Live Broadcast Television Camera Operation

Especially on live broadcasts of major events – where a production director who (instructs all camera operators via highly sophisticated intercom systems) choreographs dozens of camera feeds – the operational pressures can be considerable. As shown in Figure 1 – the camera operator can, at any moment, be simultaneously actuating one or all of the four primary lens-camera operations listed.

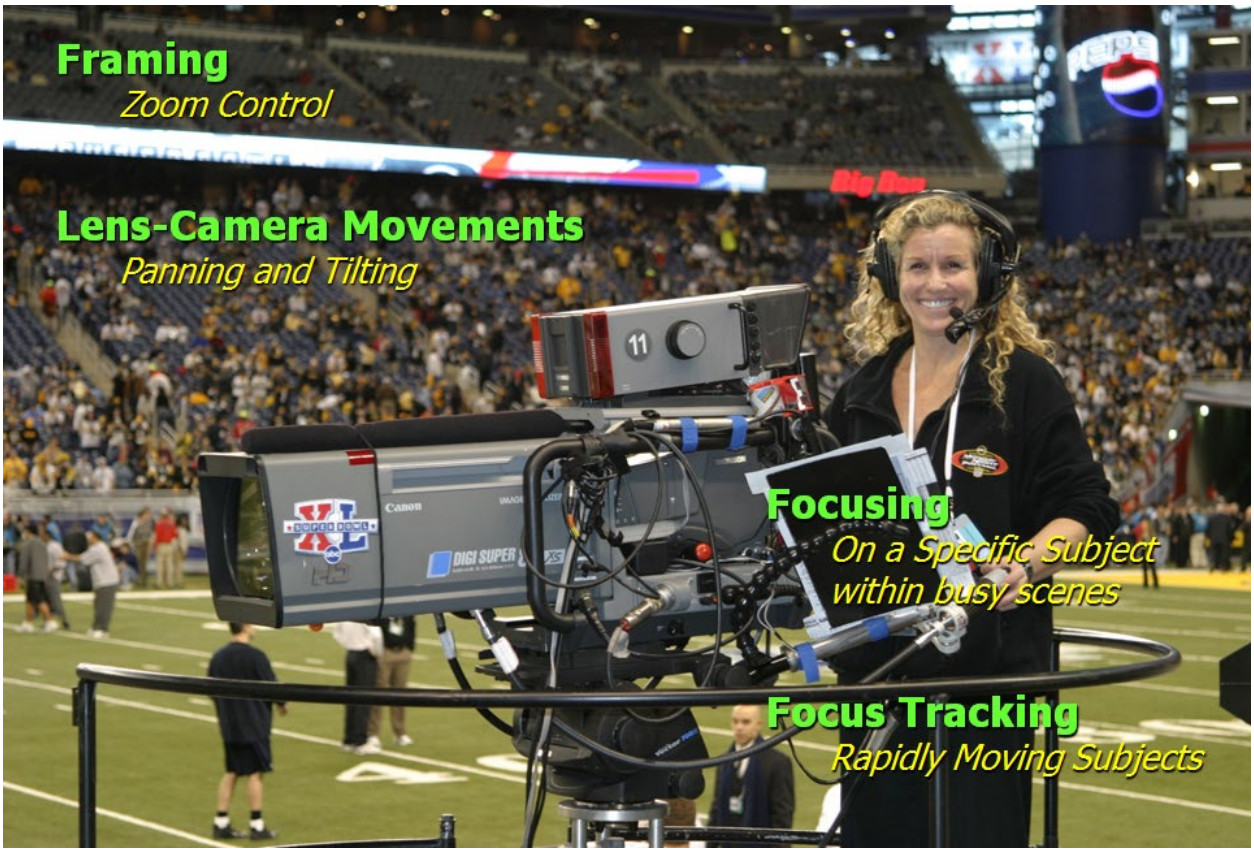

Figure 1 *Broadcast (OB) television coverage of live sporting or stage events is highly taxing on operators*

Broadcast television camera operational practices vary considerably around the world. They have evolved over seventy years of ever-increasing sophistication in major productions. The skilled camera operator has developed highly refined tactile engagement with the quite sensitive lens and camera controls in their hands. These practices have evolved in a number of directions. This is why Canon has developed different families of controllers – recognizing that all operational practices are equally valid. There are the many who have comfortably marched with progressive advances in the digital zoom and focus controllers that have been developed over the years. There are others prefer the Full Manual controllers. In addition, there are those who believe firmly in the Semi Servo control configuration. The following section highlights the salient differences between Full Servo and Semi Servo.

4.0 Focus Demand and Zoom Demand Controllers for Field Lenses

To better understand the new developments in broadcast lens controllers to be described in this paper it will be helpful to review the two primary broadcast television camera operating practices here in the U.S. today. First, the Full Servo system:

Figure 2 *The Full Servo lens control system comprises digital servo control of booth Zoom and Focus as shown*

The digital servo systems within the lens for Focus and Zoom are 16-bit precision – which allows for extremely fine control of both. In addition, the digital nature of the controller allows for great flexibilities in operational speeds as well as various pre-set adjustments such as Shuttle Shot (back and forth zooming between any two selected positions) and Frame Preset (saving and recalling preset Frame positions). The popular alternative to the Full Servo is the Semi Servo system illustrate din Figure 3:

Figure 3 *The Semi Servo control system comprise mechanical control of Focus and digital servo control of Zoom*

There is great skill and artistry entailed in broadcast television operation of live events like sports and stage shows. Many operators prefer the tactile interface offered by a mechanical control of Focus – shown in Figure 3 – and over time, they effectively master the maintenance of precision focus when shooting fast-paced sporting events.

5.0 Innovative Development in Controlling 4K UHD Long Zoom Field Lenses

Today, large format lens-camera systems have been adopted in many broadcast television productions and producers, directors, and camera operators have now become both attached to, and skilled in, the cinematic imagery and practices supported by these systems. In particular, the "rack focus" is much used in movie and episodic television dramas. This entails a subtle change in depth of field that reveals some new detail (can be an item or another human subject) in a scene – by careful manual operation of the lens focus control. Operational implementation involves changing the focus of the lens during a continuous shot – and this can be small or large changes of focus. If the focus is shallow, then the technique becomes more noticeable. It does demand precision control over focus accuracy.

Very wide rotation angles – typically 270 degrees or greater (from MOD to Infinity focus extremes) – has long been established in the cine lenses (both primes and zooms) used in the motion picture film world. The Canon family of cine prime lenses have a 300-degree rotation angle as shown in Figure 4. This greatly facilitates achieving a precision focus on a subject within a scene, while also ensuring sharp focus of moving subjects in that scene by slowly rotating the focus ring and "following" the subject.

Figure 4 Canon cine prime lens typifies the wide rotation angle of the focus control

Given the special demands of maintaining sharp focus in 4K UHD 2/3-inch cameras – and with 8K UHD cameras already looming – Canon believed that another level of both Zoom Demand and Focus Demand controllers would be a welcome addition to the existing family of broadcast controllers. These would offer heightened degrees of control over both zooming and focusing operations – in particular, bringing to the small 2/3-inch image format broadcast lens operational capabilities that emulate long established capabilities in the precision focusing operation of the larger format cinema lenses.

6.0 The New Focus Demand – FDJ-G01

What defines the new Focus Demand is:

1. Empowered internal digital controls and algorithms
2. Addition of a Display that easily guides selection of a wide range of functions without actuation of many switches. It also provides information about settings at a glance

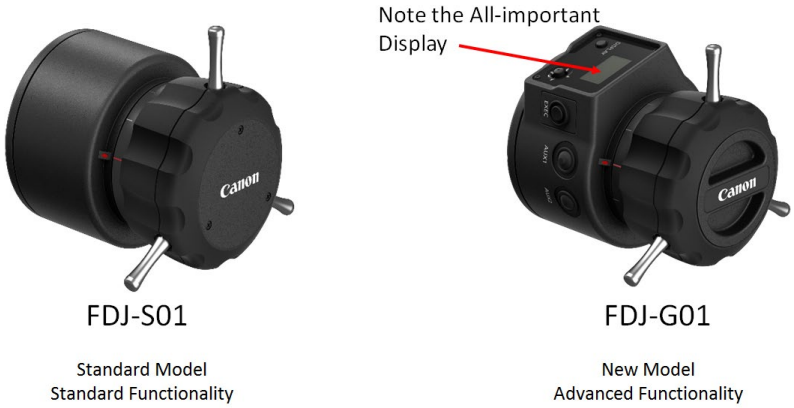

Figure 5 *Showing the new Focus Demand on the right (with display and control buttons)*

7.0 New Zoom Demand – ZDJ-G01

What defines the new Zoom Demand is:

1. Empowered digital control and algorithms
2. Addition of a Display

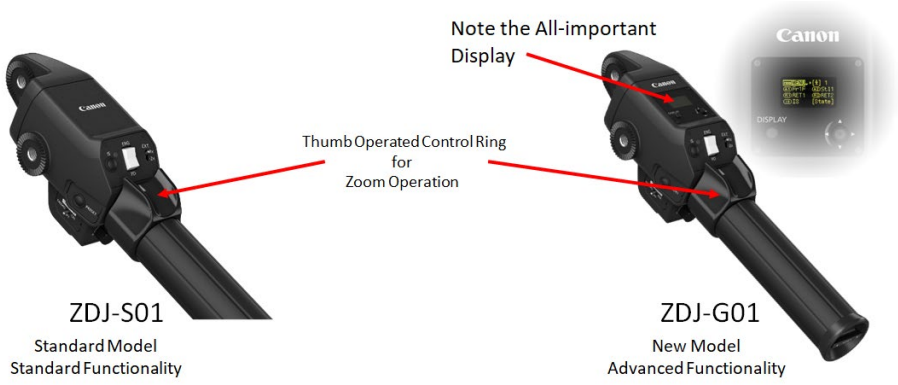

Figure 6 Showing the new Zoom Demand on the right (with display and control buttons)

8.0 Challenge of Focus Control in Long Zoom Field Lenses – Sports Coverage

The small 2/3-inch image format is often linked to deep depth of fields, and hence some degree of latitude in controlling the lens focus. However, this can be extremely variable depending upon the actual shooting environment and associated lens settings. Daytime or nighttime scene illumination and lens aperture setting, subject distance from the lens, focal length setting – all collectively contribute to very wide ranges of depth of field – especially in sports coverage.

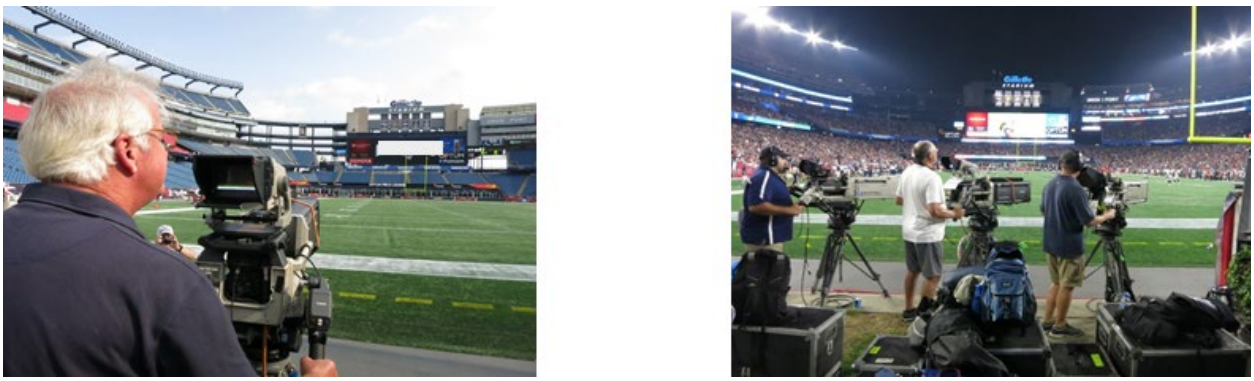

Figure 7 *Sports coverage encompasses a wide range of shooting environments*

Table 1 illustrates real world examples of three very different environments in HDTV sports coverage. It will be noted that the depth of field can vary widely depending on the three lens variables described.

TABLE 1 Three Long Lens Shooting Situations that show the variability of depth of field

Long Zoom Field Lens	Focal Length	Lens Aperture	Object distance	Rear Depth of Field	Front Depth of Field
86:1 zoom Daylight (Using 2x extender)	1600 mm	F11	1500 feet	30.6 feet	28.9 feet
100:1 zoom Nighttime	250 mm	F4	150 feet	4.5 feet	4.2 feet
75:1 zoom Nighttime under stadium lights (using 2x extender)	1400 mm	F7.2	500 feet	2.81 feet	2.78 feet

For a 4K UHD lens-camera system based on the small 2/3-inch image format size the depth of field restrictions become more severe and the challenge to achieving sharp focus escalates.

9.0 Challenge of Focus Control in Long Zoom Field Lenses – Stage Coverage

There are mobile production companies that specialize in coverage of stage shows, concerts, and award shows— rather than sporting events. As one example, the Metropolitan Opera House in NYC is known worldwide because of the HDTV satellite transmissions of live operas to cinemas and other venues, including cruise ships. What is unique about this operatic viewing experience is the use of close-ups of the singers (not possible at the live event itself !) on large screens. In addition, the nature of stage shows – especially operas – are the wide variations in stage lighting, the number actors in a given scene, and, most important, the locations of the actors with respect to each other. In the case of the presently popular live coverage of operas, these close-ups are portrayed on larges screens in cinemas and other public venues – and consequently are very demanding in terms of the precision of focus.

Figure 8 *Opera entails many forms of illumination and carefully choreographed positioning of actors*

While most stage shows are broadcast live, they are generally preceded by rehearsals (sometime multiple) where the relative positioning of actors with respect to each other is carefully mapped out.

Figure 9 *Shooting musical groups and can entail many forms of illumination and multiple close-ups of individual* talent

4K UHD poses severe challenges to achieving razor sharp focus in a small image format like 2/3-inch. Figure 10 conveys the increasing sensitivity of the focus control – in terms of the rapid drop in sharpness with only a small movement of the focus control knob – as the resolution of the television system increases.

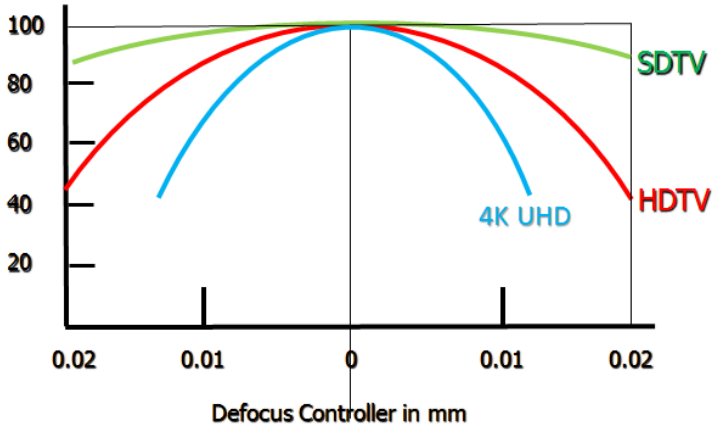

Figure 10 *The focusing challenge of increasing resolution in 2/3-inch image format lens-Camera systems*

Broadcast television live coverage of stage shows – that are distributed to movie houses and broadcast on television – entails considerable use of facial close-ups of the performers. Scene lighting can often be very low and lens apertures are opened, often producing extremely shallow depths of field.

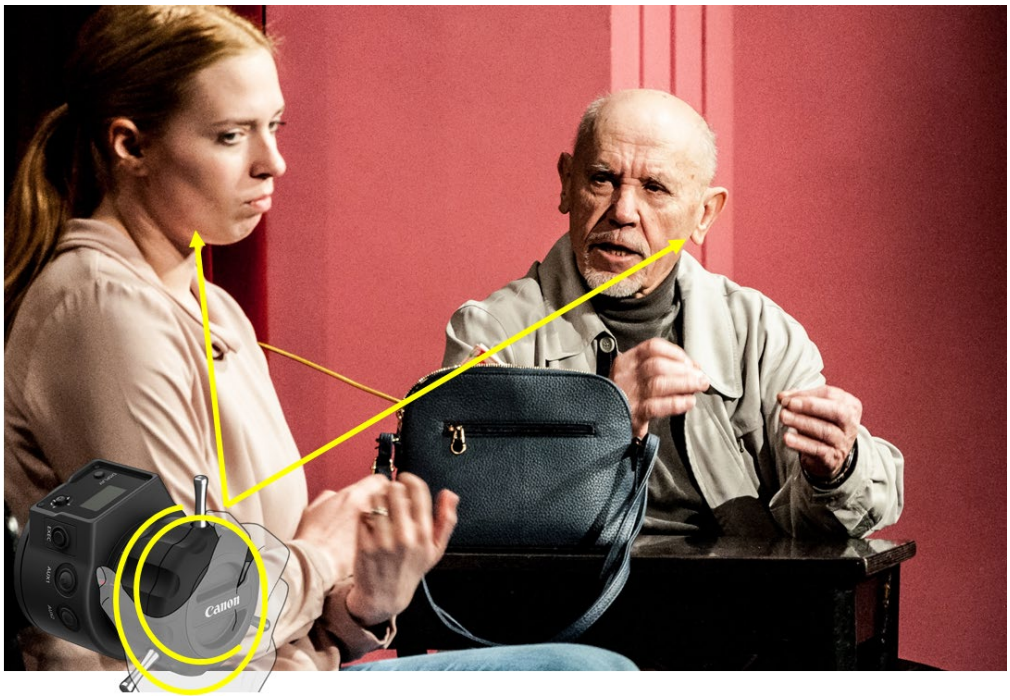

Figure 11 *Achieving razor sharp focus on close-ups of actors on stage in 4K is very challenging*

10.0 New Focus Demand – Resolving the Challenge of Focus Accuracy

Figure 8 reveals how different the new Focus Demand is compared to the standard Focus Demand. As shown, it is endowed with a number of important operational controls as shown in Figure 12.

Figure 12 *Identifying the new operational controls that are central to the new Focus Demand controller*

To understand how the new FDJ-G01 Focus Demand solves the focusing challenge when shooting 4K UHD (or 8K UHD in the future) it is helpful to start by looking at the Standard Model's total range of focus (from Minimum Object Distance to Infinity) – as shown in Figure 13.

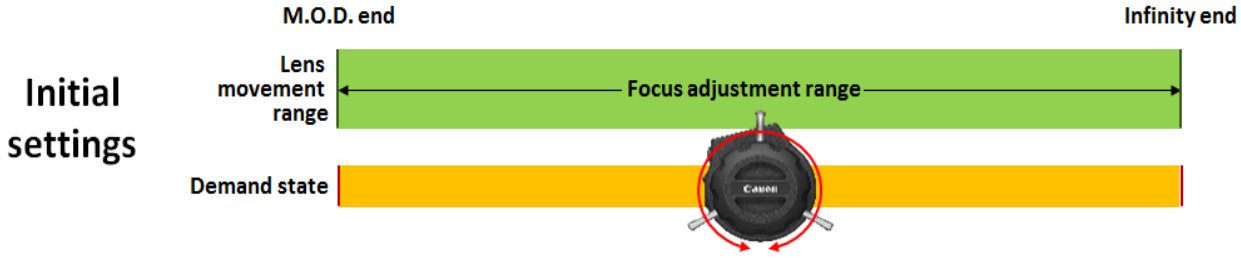

Figure 13 *The relationship between rotation of the Focus Demand controller and the actual range of focus*

It takes 2.5 turns of the Focus control knob to manually cover the total focus range. This, in itself, does apply a degree of Vernier control of focus, which works well when the lens settings favor a reasonably deep depth of field. The new mode to be described in the next section is intended for those situations where that depth of field is very shallow.

11.0 Fine Focus – Mode 1

This is a powerful new innovation in operational control of lens focus – in terms of offering the camera operator an immensely enhanced degree of fine control over the manual operation of focusing. A simple preprogramming of the Focus Demand electronically empowers it to simulate the wide rotation angle of the focus control inherent in cinematography lenses. The operator does this by programming the Focus Demand controller to implement a small range of focus with multiple manual turns of the control knob.

The value of this mode is best illustrated by consideration of a lens-camera system located within a theater and imaging an actor on the stage. The lens is zoomed to achieve the desired framing of the actor (close-up of the face or a medium shot) and the focus control is rotated to achieve an approximate focus – this defines the "center" of the focus setting. This anchors the chosen subject distance. With the aid of the built-in display and the control buttons integral to the new Focus Demand FDJ-G01 simple adjustments are now made to preset two limits around that central focusing setting – producing the "Required" focus operational range shown in Figure 14. Now, range of motion of the control knob is expanded – the 2.5 turns that previously covered the entirety of the focus range of the lens is instead dedicated to that programmed restricted range of focus. This allows a beautifully smooth and slow zeroing in on razor-sharp focus of the chosen subject.

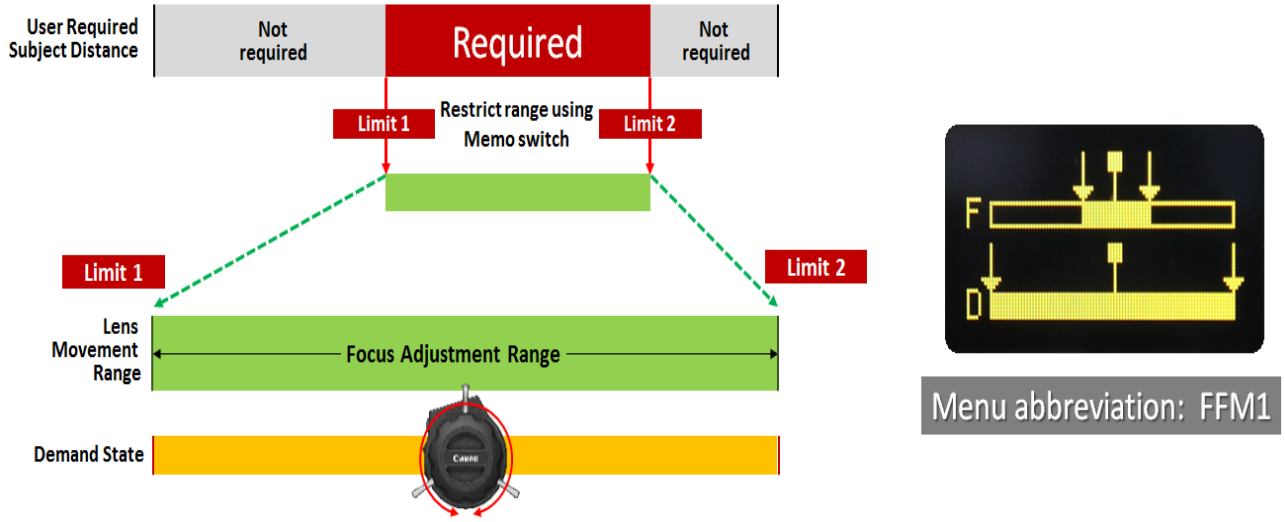

Figure 14 *Outlines the principle behind the setting of Fine Focus Mode 1*

By choosing the degree of the restricted range, the Focus Demand can achieve a highly precise 4K image sharpness – especially valuable on facial close-ups. It also supports implementation of a precision rack focus between a number of actors on a stage – this being particularly powerful when a duet is being sung in an opera. In group settings, the rack focus operation can be extended to accommodate each performer as the sing in turn. Clearly, the actuation of this mode requires rehearsal – but this is generally expected in stage shows. Figure 15 suggests a possible rack focusing operation.

Figure 15 *Multiple turns of the Focus Knob can smoothly rack focus between facial close-ups of each player*

This scenario postulates the camera operator opening by zooming in for a sharply focused close-up on the central singer – followed by a precision rack focus to the face of the lady on the left – and this followed in turn with another rack focus to the face of the singer on the right.

12.0 First Tests of FDJ-G01 Focus Demand in Stage Setting

Our first tests of this new Focus Demand – seeking creative judgement – took place in September, 2019 at a major music house in New York city working with a mobile production company who specialize in operatic coverage. Two of their most experienced camera operators participated in these tests and spent a great deal of time exploring all the capabilities.

The tests consisted of the camera operators shooting multiple actors on stage from 30 to 40 feet distance – and re-adjusting the focus on each of the actors who were spaced around the stage. Using standard Focus Demands it was clear that slight focus demand movements had significant effects on the image sharpness. Their enthusiasm for the Fine Focus Mode 1 control was high – they had never seen anything like it – and they affirmed that this is a significant breakthrough. They further explained that only two of their operators use Full Servo – all others use manual focus. They believed that the prowess of FDJ-G501 will easily convert them.

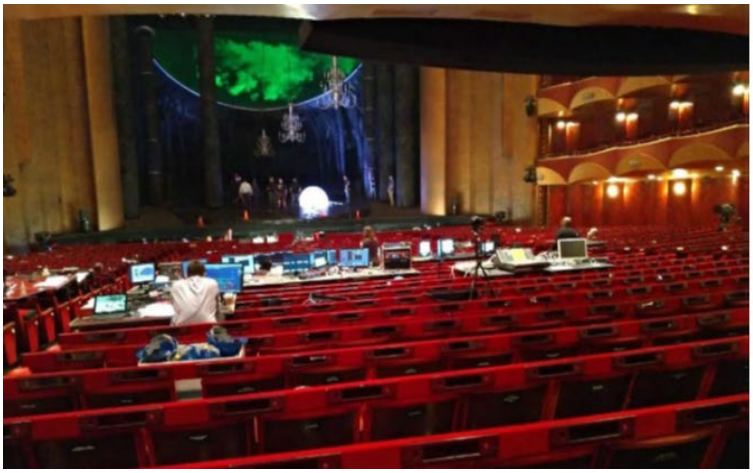

Figure 16 *Tests of the new Focus Demand FDJ-G01 controller being conducted in NYC*

13.0 Fine Focus – Mode 2

An alternative mode can be set when the focus center does not need to be set on a chosen subject at a specific object distance. The abbreviated menus that is labeled FFM2 is selected and the two limits are set about the current focus position. This function increases the precision of focusing – but it does limit the actual focus adjustment range.

14.0 Focus Range Limit

An entirely different mode of operation can also be programmed in the Focus Demand unit – that is termed Focus Range Limit. The menu selection as portrayed in the display for this mode is shown in Figure 17. In situations where focus range is fixed to some extent – some forms of stage shows – the focus is centered on a chosen subject and then a limited range around that focus is programmed. Now a limited rotation of the focus knob will provide the focus range required to address any limited movements of the subject.

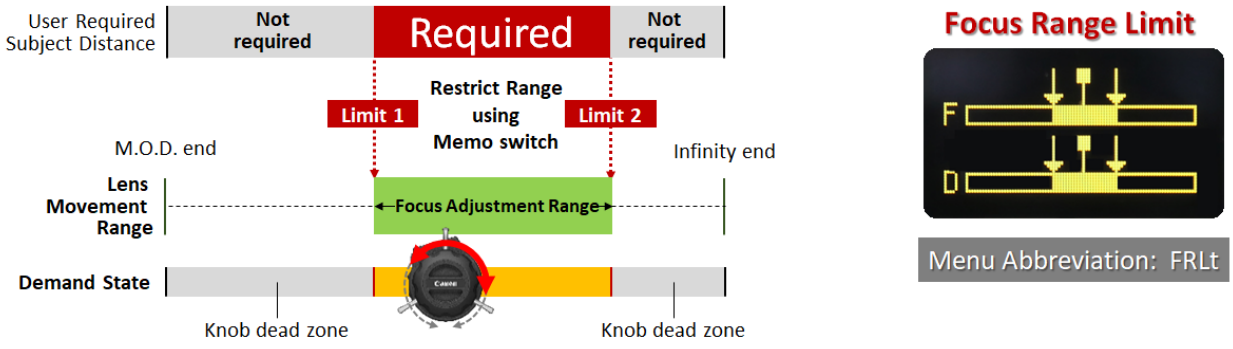

Figure 17 *Note the limited operational range of the focus knob that has been programmed in the Focus Demand*

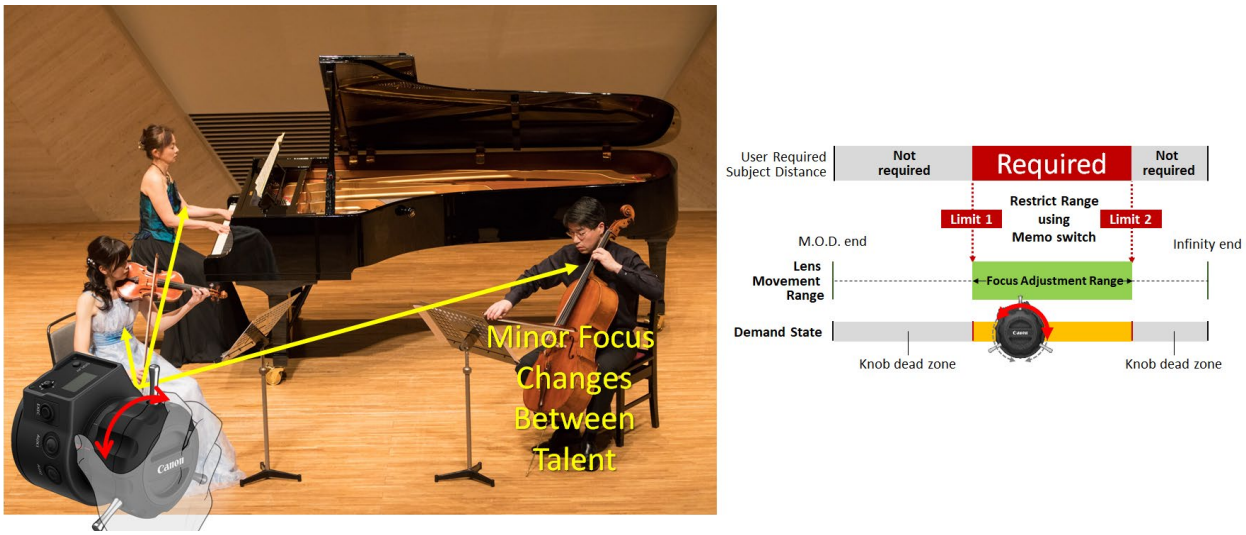

Figure 18 *Focus Range Limit – when the lens-camera is far from the talent the manual control movement can be minimized*

15.0 Control Range Limit

In a sense, this mode is the opposite of the Fine Focus Mode 1. This sets dead zones in the demand movement range and enables greater focus movement with smaller rotation angle with the focus adjustment range kept as-is. This is ideal for alternating focusing, such as at a tennis rally – where the active focus range has been preset to allow rapid refocusing on each player with a minimum rotation of the focus knob – as illustrated in Figure 20.

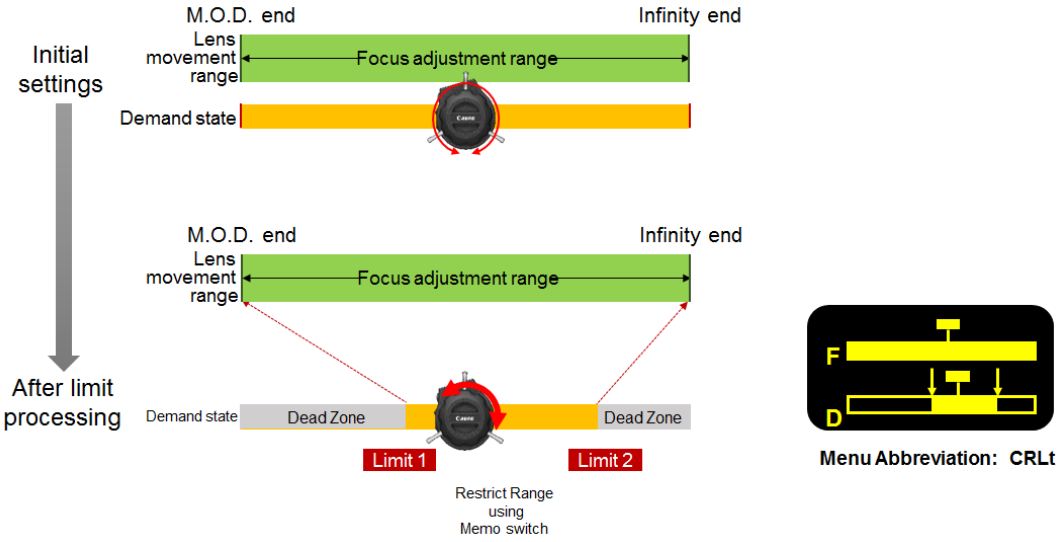

Figure 18 *Focus Demand is programmed to provide selected active focus range with minimized knob rotation*

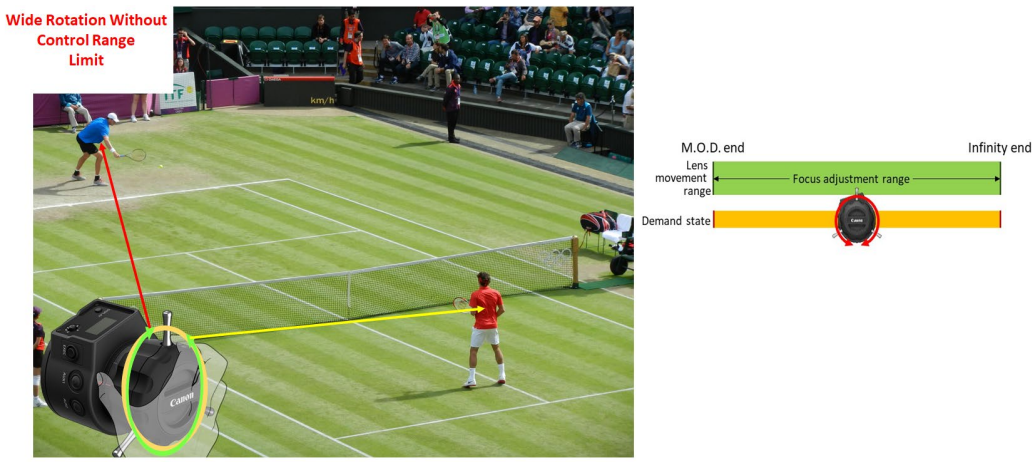

Figure 20 *Normal action of Focus knob entails a wide rotation angle to separately focus the two players*

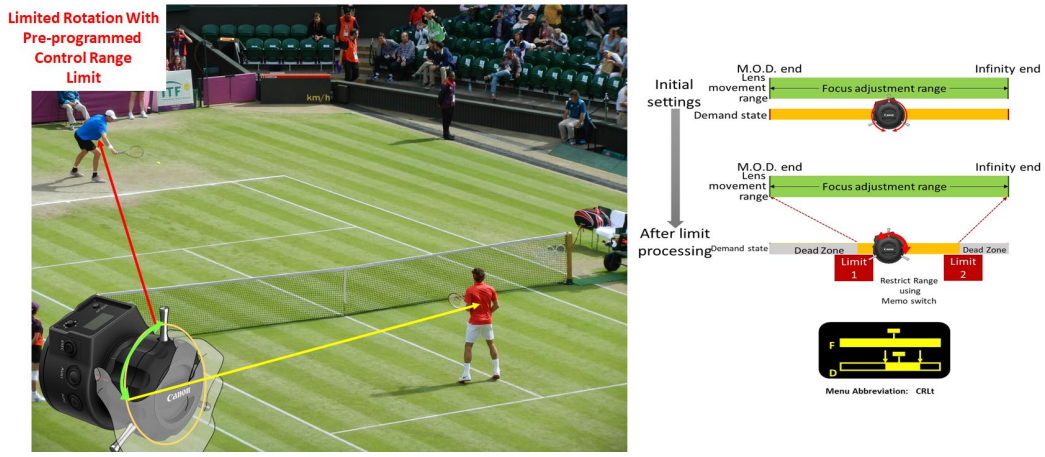

Figure 21 *Curtailment of the active Focus range that accommodates easy focus change between both players*

16.0 Focus Curves

A Focus Curve defines the position of the actual focus itself in relation to the physical position of the focus knob. The Focus Curve selector switch on the Focus Demand lets operators switch the focus position in relation to the focus knob position, between one straight line and two basic curve modes – known as the Far Mode and the Near Mode – as shown in Figure 22.

The Far Mode – associated with Infinity – is the curve in which the focus position changes very slowly the more the knob is turned toward the infinity side. This makes fine focus adjustments easy on the infinity extremity of focus. The Near Mode is the opposite of Far mode, in which focus position changes very slowly the more the focus knob is turned toward the close side. This makes fine adjustments easy on the MOD extremity of focus.

In the Standard Mode, the focus position change is in direct relation to the focus knob operation.

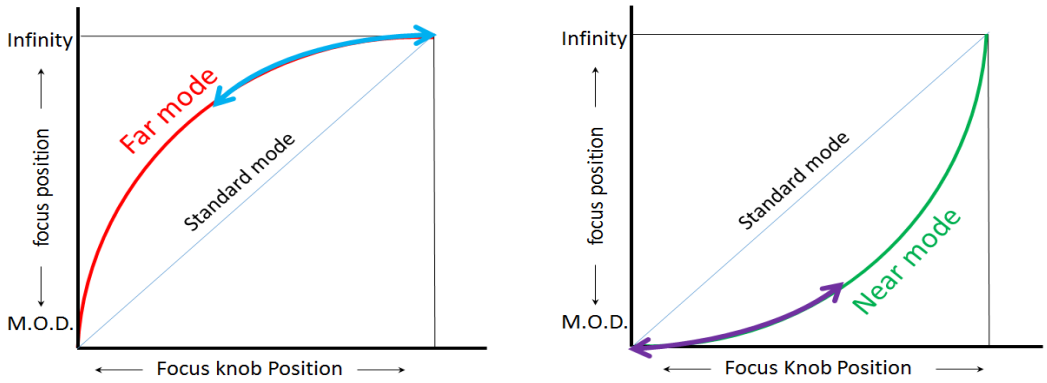

Figure 22 *In Far Mode a large rotation of focus knob produces a small change in actual focus near the infinity extremity – and the reverse is true in the Near Mode – both indicated by the colored arrows*

The Standard Focus Demand FDJ-S01 features the three types of focus curves in total – as shown in Figure 22. The new Focus Demand FDJ-G01 extends these options – allowing the camera operator to switch between nine types in Far Mode and nine types in Near Mode – facilitating a choice of an optimum focus curve for a particular shooting situation.

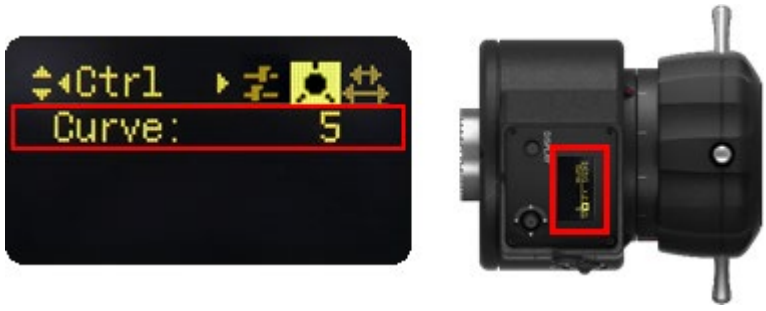

Figure 23 *The display in the focus Demand facilitates selection of the desired operational curve*

17.0 New Zoom Demand – ZDJ-G01

This new Zoom Demand controller has all of the operational functions of the standard Zoom Demand ZDJ-S01 including Frame Preset/Shuttle Shot/Speed Preset. This function moves to a prerecorded zoom position with the push of a switch. Frame Preset and Shuttle Shot each move at maximum speed, while Speed Preset moves at a prerecorded speed. Letting go of the switch in Shuttle Shot will return to the original position. Zoom Tracking allows the zoom control range to be set for both the wide angle and telephoto sides – to control zoom range required for actual shooting.

However, the new ZDJ-G01 has additional important features: user settings can be registered and operational functions can be assigned to switches from the display screen. Preset speeds can also be set, and zoom control curves can be selected. Users can also check connection status and see whether various functions are on or off.

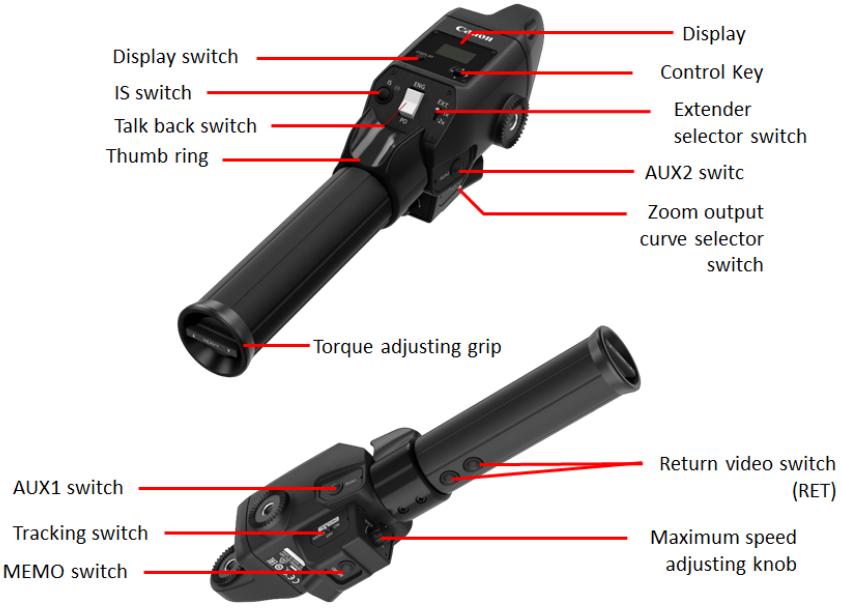

Figure 23 *The new Zoom Demand ZDJ-G01 has a display and additional control functions*

18.0 Zoom Control Curves

With Zoom Demand, the zoom speed control can be programmed to have different characteristics in relation to the control thumb ring rotation angle. These are preprogrammed control patterns within the controller that are termed the Zoom Curves.

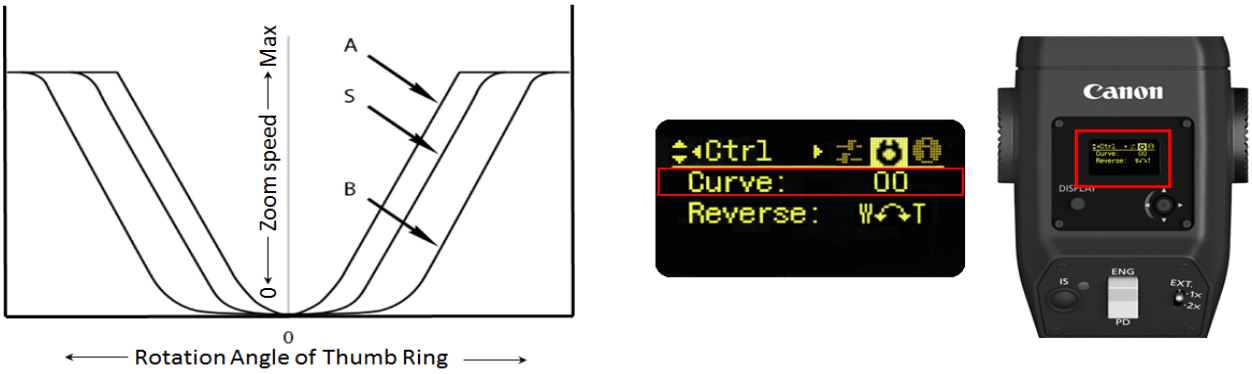

Figure 24 *There are three basic zoom control curves that can be selected on both ZDJ-S01 and the new ZDJ-G01*

For both the standard Zoom Demand ZDJ-S01 and the new Zoom Demand ZDJ-G01 these are described by the control curve set shown in Figure 24. Curve A offers a faster zoom speed with smaller thumb ring rotation angle, making it ideal for high-speed zoom operation. Curve B is the opposite of Curve A, making it useful for operation at lower zoom speeds. Curve S is midway between Curves A and B.

The standard ZDJ-S01 features three types of zoom curves in total, while the ZDJ-G01 offers a total of 19 types. From these, three types of curves can be assigned to the selector switch so users can set the optimum zoom curve for the shooting setting, which can vary greatly between studio recording, live sports, and stage shows.

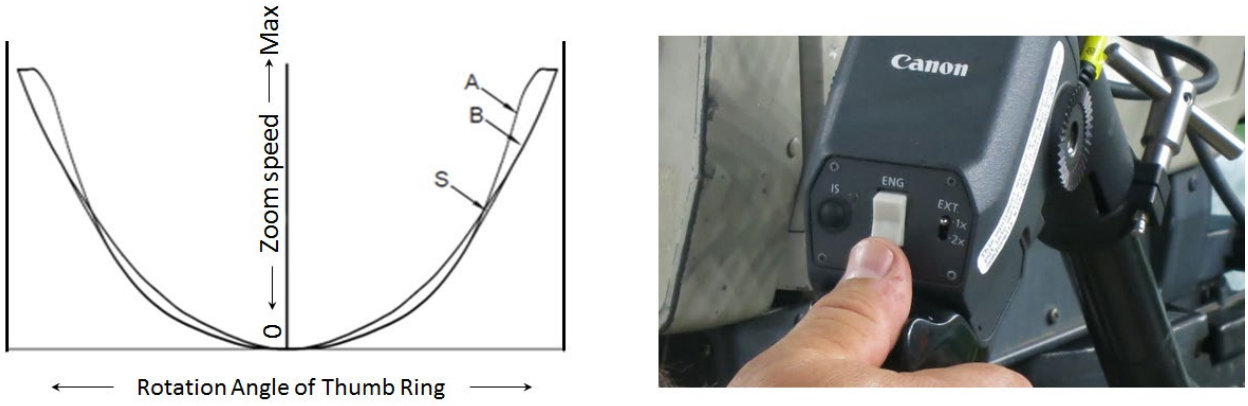

Figure 25 *Example of one set from the selectable zoom curves available with the new Zoom Demand ZDJ-G01*

The zoom curve shown in Figure 25 is ideal for fine zoom operation at medium speed. Curve A gives more priority to fine zoom operation, while Curve B places greater emphasis on trackability. Curve S is similar to A in low speed ranges, and similar to Curve B in high-speed ranges.

19.0 Summary

Canon Inc achieved a landmark advance in long zoom field lenses with their successful development of what is now a trailblazing set of 4K UHD products – the UJ122x8.2B and the UJ111x8.3B. As discussed in the white paper on these products [1] significant step forwards were made simultaneously on the operational specifications and on the optical performance specifications. At this juncture, there is no comparable product that can challenge these two long zoom field lenses.

Equally remarkable is the parallel development that was also ongoing in addressing those identified challenges in 4K UHD imaging – namely, the operational impediments to ensuring sharp focus in shooting environments that can be particularly difficult. The development of the new Focus Demand and Zoom Demand controllers are powerful flanking accessories that further propel the Canon lens system beyond any competitive offering.

REFERENCES

[1] Canon White Paper *"Second Generation 2/3-inch 4K UHD Long-Zoom Field Lenses" http://downloads.canon.com/bctv/4K_Box_Lenses_White_Paper.pdf*