



SPECIAL REPORT HDTV LENS DESIGN:

A NEW INNOVATION FOR THE STUDIO

BY LARRY THORPE AND GORDON TUBBS

The traditional studio lens has long been considered the flagship among the various lens categories in terms of measuring ultimate performance. The high-aperture optics of such lenses are the basis of how they achieve high optical sensitivity, but this requires larger glass elements, which adds weight.

The television studio lens has evolved to quite a sizeable package over the past 60 years, a consequence of an unceasing quest for wider angles of view, longer zoom ratios and ever-escalating performance aspirations.

Today, that means optimizing these lenses for HDTV, which is no mean feat. Although advances in camera and recording technologies move much more quickly than those in optics, impressive optical advances have been made during the past decade. A good example is the miniaturized HDTV studio lens for direct mounting to a portable production camera.

HDTV studio performance expectations

As the standard used to measure ultimate performance, contempo-

rary studio lenses are the most closely scrutinized in formal technical evaluations by television organizations all over the world. In terms of specific image-performance parameters, the following are generally agreed to be the key design priorities for studio lenses:

- *achievement of a maximum relative aperture* to ensure HD image capture with a high signal-to-noise in low scene illumination
- *maximization of contrast performance* by minimization of flare and veiling glare at the black extremity and ghosting and highlight-related

Physical attributes	XJ22 x 7.3 compact studio	HJ22 x 7.6B EFP portable
Optical port diameter	150mm	105mm
Overall glass length	316mm	222mm
Weight	13.4lbs	6.03lbs

Table 1. A comparison of the physical aspects of the new compact studio HD lens with a current EFP portable HD lens of equivalent focal range

optical interferences due to strong light sources

- *optimization of relative light distribution* from picture center to the outer image extremes
- *a high Modulation Transfer Function (MTF) characteristic* at picture center as well as the outer regions of the picture plane (with as even an MTF characteristic as possible across the image plane)
- *minimization of curvature of field* — one of the classic optical aberrations that contribute to corner defocusing
- *careful control of spherical and comatic aberrations* — defocusing impairments that impair MTF across the image plane
- *minimization of astigmatism* — another defocusing impairment that negatively affects MTF
- *minimization of lateral chromatic aberrations* that blur and color detail transitions (especially at the extremities of the image plane), which in turn directly impairs lens MTF
- *elimination of geometric distortion* to the degree possible, especially at the wider angles of view.

Developments in portable camera designs

Slowly and inexorably, many portable cameras have achieved the picture performance, operational flexibilities and systemization that larger studio cameras have been known for. Today, many of these portable cameras — both SDTV and HDTV — are virtually indistinguishable from the larger companion studio cameras in performance and creative flexibilities.

Only the desire for the highest performance lenses (necessitating a lens that is large in size), enhanced operational considerations and better system facilities and interfaces sustains the popularity of the large hard stu-

dio camera. To many, these are still important.

A sizeable number of end users feel that the performance of current portable cameras meets many studio needs. The use of a build-up system (called a *support cradle* by some) that can facilitate rapid reconfiguration of a portable handheld into a traditional studio system using a large box lens is operationally important for some forms of program origination. For others, the use of the build-up kit is not attractive, or it is not necessary for their needs. The lens-camera system cost remains the driving imperative. Accordingly, some have chosen to use a portable camera and portable EFP lens in the studio on the basis that it is good enough for the application.

Canon believes that there is a growing constituency — aspiring to the highest quality studio performance (for prime-time drama production and flagship news studios, for example) — seeking a better compromise. This conviction warranted an investment in developing a miniaturized full-performance studio lens intended to directly couple to all of the major HDTV and SDTV 2/3in portable

- weight approximately equal to that of contemporary portable cameras
- target full HDTV studio performance to the highest degree possible
- no compromise in operational capabilities as measured by the precision, repeatability and speed of operation of the zoom, focus and iris controls
- all contemporary interfaces (robotic, virtual studio) to be built-in
- creative digital controls that match those of high-end studio lens systems.

Physical features

The result of addressing these criteria was the new compact studio lens, which has a 20x zoom ratio and a wide-angle setting at 7.3mm.

A decision on a 150mm diameter was chosen following initial computer simulation. The preservation of full studio configuration of optical elements quickly dictated the overall length of the optical path. (See Table 1.) There is quite a striking increase in glass compared to the portable EFP lens.

This difference, however, must now be put into perspective with the physical attributes of the full-bodied studio box lens described earlier. (See Table 2.) The aesthetics of the lens design is exemplified by how it looks

Physical attributes	Large studio lens 25xs	Compact studio lens 22xs
Size	558mm x 250mm x 255mm	336mm x 165mm x 17mm
Weight	47lbs	13.4lbs

Table 2. A comparison of the size and weight of the compact studio HD lens with that of a traditional studio box lens

cameras — without the use of a complex support cradle.

Design goals for a compact studio lens

In undertaking to develop such a lens, classic design criteria for studio lenses were applied. A summary of the general design goals for the compact lens were as follows:

- significantly smaller in total volume than a traditional studio box lens (by one third the total volume of that larger lens)

when mounted on some of the contemporary portable HDTV cameras. See the photo on page 4 for an illustration of how small the XJ22 lens is compared to a typical HD studio lens.

Performance of the compact lens

The desired wide angle of view and the zoom ratio go hand in hand (in terms of a basic manageable optical design), and the lens' designers also chose that the compact studio HD lens would have a 7.3mm wide angle extremity and

Image composition	XJ22 x 7.3B
Object image format	2/3in 16:9 aspect ratio
Object image size (Presented to camera imagers)	9.59mm (H) x 5.39mm (V)
Zoom ratio	22x
Focal length range	7.3mm — 161mm
with extender	14.6mm — 322mm
Angular field of view	
At 7.3mm	66.7mm x 40.6mm
At 161mm	3.4mm x 1.9mm
With extender	
At 14.6mm	36.4mm x 21.0mm
At 322mm	1.7mm x 1.0mm

Table 3. The specific angles achieved in a compact studio HD lens

a 22x zoom ratio — both being operational parameters comfortably consistent with most studio needs. (See Table 3.) This wide of an angle of view posed technical challenges to achieving a low geometric distortion — but the lens design successfully achieved a contemporary performance level.

are particularly impressive at full wide-angle focal length.

Color reproduction

The spectral transmittance characteristic of the lens has the first cut at predetermining the overall colorimetry of the camera system. The

special challenges. (See Figure 1.) The picture center MTF is about 82 percent (compared with the 84 percent of the larger lens) at the optical reference frequency of 56 LP/mm (or approximately 600 TVL/Ph for the 1080-line system). The center-to-corner results

shape of that spectral transmittance curve (especially at the critical blue and red end of the visual spectrum) must concatenate with both the RGB spectral separation of the digital camera beam-splitting system and the spectral characteristics of its image sensors to implement the final digital camera system colorimetry. This light-transmission system must anticipate meeting the colorimetry specified in the SMPTE 274M/296M (and in the international ITU R BT 709) HDTV production standards when the camera operational controls are set to their detent position.

The subsequent creative control of the digital camera over color reproduction — to meet production aspirations — must also be taken into account. Here, the ability to digitally alter the prescribed nonlinear transfer characteristic and the color matricing from the camera video operational panel to successfully manipulate chosen colors (in brightness, hue and saturation) does anticipate as wide a color gamut as possible from the lens/beam-splitter/sensor combination. The role of the lens within this combination is sometimes underestimated.

Optical performance	Large studio lens 25xs	Compact studio lens 22xs
Max relative aperture	1:1.5 at 6.8mm to 122mm 1:2.1mm at 170mm	1:1.8 at 7.3mm to 111.5mm 1:2.6 at 161mm
MOD	0.6m	0.8m
Field of view (degrees)	70.4mm x 43.3mm 3.23mm x 1.82mm	66.7mm x 40.6mm 3.4mm x 1.9mm

Table 4. A comparison of the performance of the compact studio HD lens with that of a larger studio lens

The new compact lens was able to achieve a maximum relative aperture of 1:1.8, which holds up over a zoom ratio of almost 16:1. (See Table 4.) This will address a great deal of normal studio needs. This specification means that if the lens is used with a portable HDTV camera with an $f/10$ sensitivity specification (2000 lux of 3200-degree scene illumination), then the lens-camera system can make full 100 IRE luminance video level at maximum aperture with approximately 75 lux of scene illumination (less than 7.5ft candles).

MTF performance of the compact studio lens

The design imperative of this new compact studio HD lens still retained some constraints (in size and weight) compared to its larger traditional counterpart — and this posed some

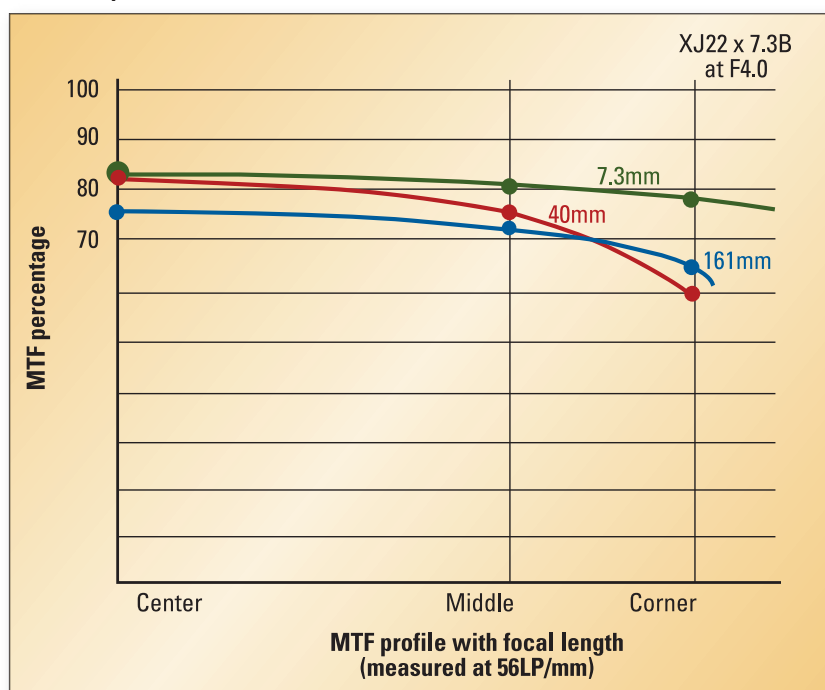


Figure 1. Shows the MTF profile across the image plane for different focal lengths of the compact studio HD lens

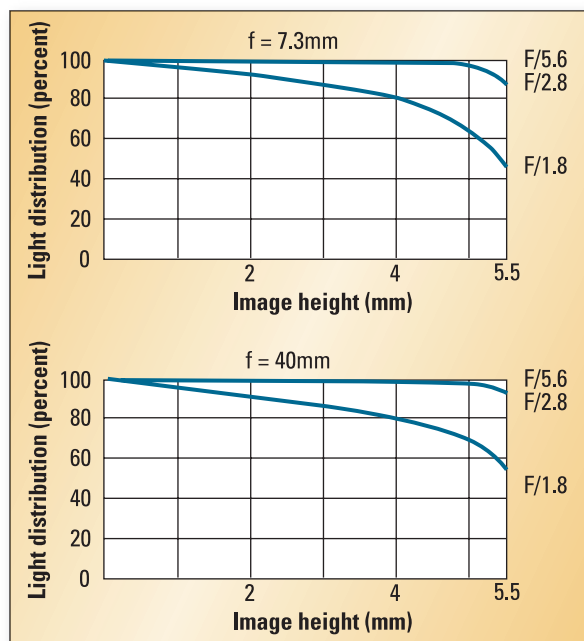


Figure 2. Shows the relative light distribution characteristic of the compact studio HD lens

The compact studio lens has a high transmission efficiency of 82 percent — a result of the fact that it uses fewer elements than a larger box lens.

Despite that efficiency difference, the larger lens is still more sensitive because its distinctly larger optics gathers more light flux.

Relative light distribution

The quoted f-number for a given studio lens is a measure of the light transmittance of the lens at the center of the image plane. It is another of the frustrations of optical science that this light flux cannot be made perfectly uniform across that plane.

As discussed earlier in this series of lens articles, the vignetting components contribute to a fall-off in light intensity with field angle of view. This fall-off is typically specified as a curve showing that light level shortfall from picture center along a radial termed picture height. (See Figure 2.)

Digital interfaces on the compact studio lens

Today's studio lenses are expected to have the capability of interfacing with robotic systems and virtual studio systems. The new compact studio HD lens has a 20-pin connector labeled virtual, where the 16-bit digital

outputs of the three optical rotary encoders are made available for direct and bi-directional digital communication with digital robotic and virtual studio systems. Two other 20-pin connectors provide a direct communication interface with Canon's digital zoom and focus controllers.

An optional PC interface is available for the lens. This facilitates a digital communication link between the lens and a computer (using special software) for implementing lens diagnostics.

Precision control and digital display

The use of the new miniature 16-bit optical rotary encoders offers a whole new level of control precision. The combination of the controllers and the high-res lens system provides 13-bit repeatability for zoom and focus. The digital interface with a camera's digital iris control has 10-bit compatibility. The zoom servo provides an exceptionally wide dynamic range of control, from a fast zoom of 0.5 seconds to a super slow zoom of 3 minutes. The lens has a built-in informational display (mounted on the side close to the rear of the lens) that provides a great deal of information relating to the many digital operational features that are incorporated into the lens-control system.

Different zoom servo characteristics can be selected that offer wide diversity in creative shaping of the zoom movement. The lens also supports preprogramming a variety of functions, such as automatic shuttling between two chosen focal lengths, preset framing and presetting of zoom speed.

Conclusions

The design of the new compact studio HD lens (model XJ22x7.3B) responds to an increasing desire to deploy smaller and more cost-effective



Photo: Comparing the compact XJ22 HD studio lens with a typical full-size HD studio lens

portable production cameras within studio shooting environments. It is an example of a broadening strategy for HDTV lenses that seeks to march in step with the developments in smaller cameras and recorders.

While the performance of various imaging parameters does not fully match those of the larger studio lenses, the shortfalls are modest. The same broad optimization strategies applied to the large studio lens were carefully maintained in this new design in terms of the emphasis on MTF over the image plane, contrast and relative light distribution, optical sensitivity and color reproduction. This new lens facilitates a more cost-effective, smaller and lighter studio lens-camera system that allows use of a smaller pedestal and is ideal for studio robotic systems.

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Photo on page 1 courtesy of Ascent Media; photography by John Benson.