Canon

WHITE PAPER

CINEMA EOS LENSES

PERSONALITY OF THE CANON CINEMA EOS LENS: *CONTRAST*

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The Personality of the Canon Cinema Lens – Session #4

The Role of Contrast in a Cine Lens

Central to the design of all lenses is the quest to achieve a high contrast. Cinematographers often speak of the "clarity" and "brilliance" of a specific lens and in so doing they are largely referring to the optical contrast performance of that lens. In seeking a high contrast, the design goal is to achieve as high a transmittance of the light level impinging upon the input port of the lens through to the output port (the primary "signal" transmission) while simultaneously subjugating any internal light scatter that would impair a deep black portion of a given scene (this can be likened to optical "noise"). This optical "signal to noise ratio" is formally specified as a *Contrast Ratio*.

The Challenge to Achieve High Contrast

As suggested in Figure 1 – when the lens images a black and white chart – half of which is white and the other half a deep black – the transmitted white light through the optical system incurs a loss in transmissivity due to reflections at each and every air-glass surface (approximately 4% for each *uncoated* surface – this varies with different glass materials). The accumulated reflections cause a light scattering within the overall optical system – creating flare and veiling glare that contaminates what should be zero light transmission for the black portion of the chart.

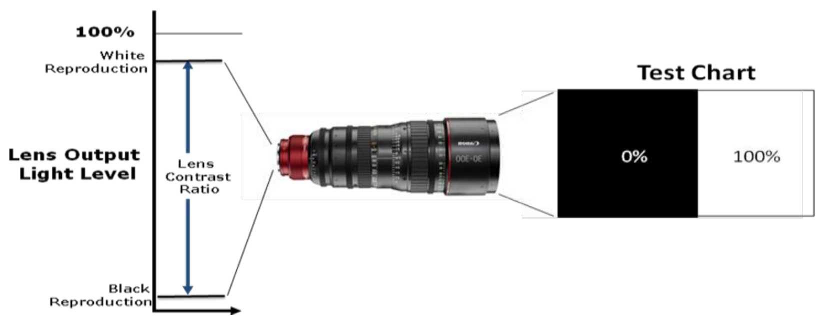

Figure 1 *Conveying the concept of the dual factors that bear on the contrast ratio of a lens*

Figure 2 illustrates how rapidly lens transmittance is attenuated when using *uncoated* lens elements.

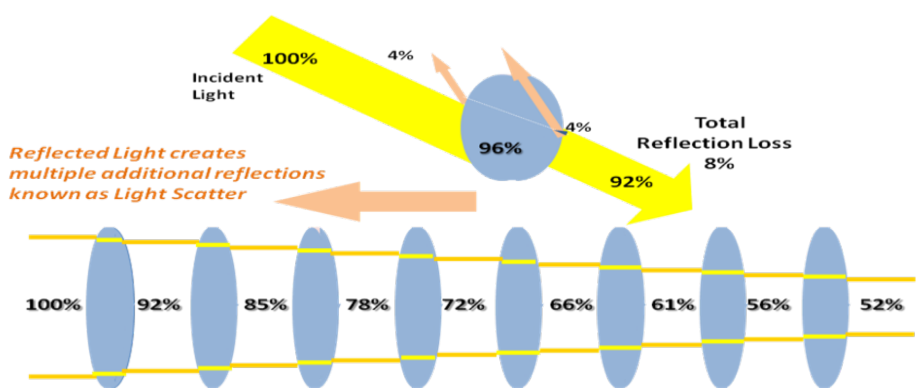

Figure 2 *Showing an optical system of eight uncoated lens elements and the progressive 8% light loss per element due to reflections at each surface – which in turn creates light scatter that causes flare and veiling glare*

Achieving a high contrast ratio in a lens entails the simultaneous overcoming of two inherent optical challenges in a multi-element lens:

1. The quest to elevate the level of light transmission through the each and every lens element

2. The attendant struggle to minimize internal optical reflections that contaminate the reproduction of a true black in the scene being imaged.

Compensation for both constitutes a central design strategy for lens designers – and ultimately will produce a lens contrast ratio characteristic typified by that shown in Figure 3. As a simple illustration – if a given lens accepts a white light level input (normalized as 100 %) and delivers 75% of that light level at its output port, and at the same time the same lens introduces flare and veiling glares of 0.5% on the black portion of the scene then the contrast ratio is 75/0.5 = 150.

As discussed in our last Session #3 – the spectral transmittance of a lens is shaped to achieve a desired color reproduction in association with the digital cine camera. That transmittance characteristic defines the optical signal transmittance efficiency at each wavelength.

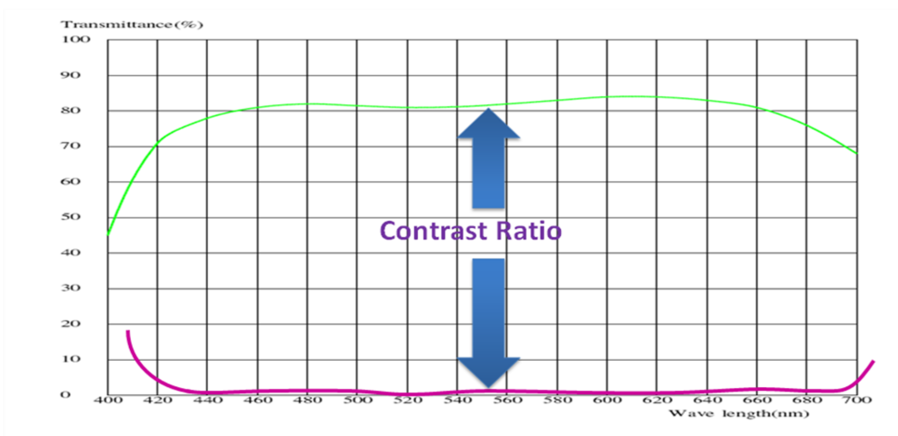

Figure 3 Lens contrast ratio is the ratio of the percentage of 100% input white light that reaches the lens output to the residual unwanted light level when imaging a true black in the scene

“Secret Sauces” for Achieving High Contrast – Glass Materials and Optical Coatings

The technical means to achieve high lens contrast entails choices in glass materials used for each lens element, the anti-reflective coatings applied to those elements, and optomechanical strategies to curtail, to the degree possible, optical artifacts that can be stimulated by strong light sources outside of the field of view of the lens. Anti-reflective coatings were first developed during WWII and have been a technology of unceasing developments ever since. The principle is the deposition of a thin film material on the lens surface that engenders a destructive interference – within the now four surfaces – that effectively cancels the primary reflection. It becomes a complex technological challenge to ensure cancellation across all wavelengths of interest – entailing multiple layers of different materials with each tailored to a specific range of wavelengths. The removal of the reflection at each lens surface elevates the total light transmittance through the lens optical system while simultaneously lowering the light scatter that would have been associated with those multiple uncorrected reflections. So, the lens contrast ratio is widened by this dual action as indicated in Figure 4.

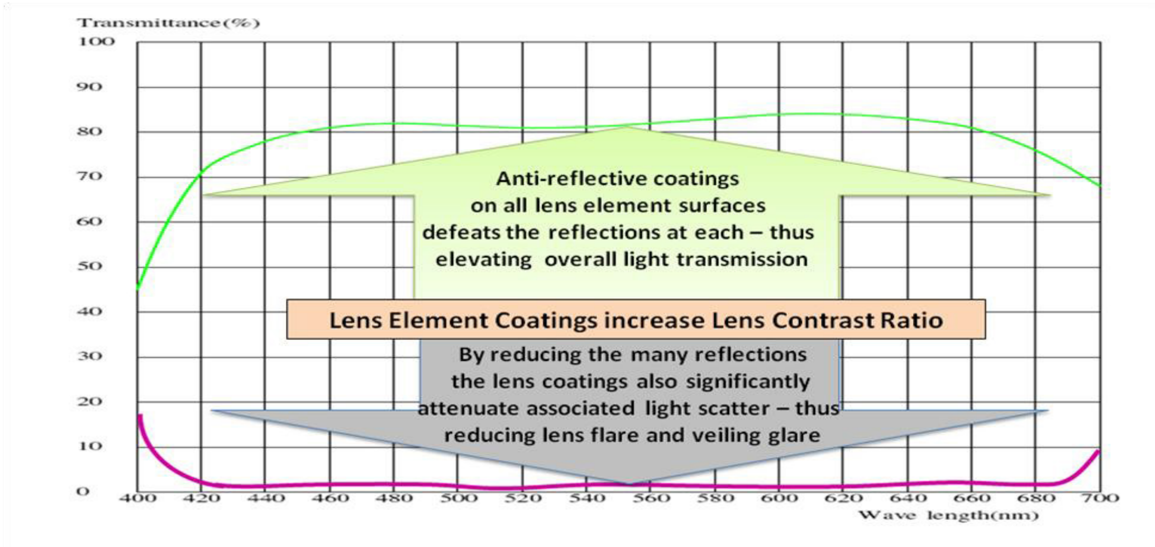

Figure 4 *Dual benefits of optical coatings on each and every lens element*

Contrast Personality of a Lens

The brief description above outlines the challenge facing all optical manufacturers who seek to produce a lens with contemporary contrast performance. The actual implementation of the requisite technical strategies has, over many decades, devolved into highly proprietary materials, and allied technologies and manufacturing techniques. Indeed, it can be said that the "secret sauces" of the disparate optical manufacturers are largely bound up in the individual choices they make in selecting – from some hundreds of optical glass materials presently available to all – the specific glasses to be dispersed among the optical elements that comprise a given lens system. Even more proprietary – and an unceasing R&D project within all major optical houses – are the quite exotic thin film materials selected for the multilayer optical coatings applied to each of those lens elements. And, even more secretly guarded, are the many innovative deposition techniques used to apply those coatings. As a consequence, the degree of enhancement to a given lens transmittance and the attendant subjugation of optical contaminants to reproduction of black portions of a scene acquire characteristics unique to that specific lens. It can be said that the spread in *contrast personalities* among lenses – and especially between those of different optical manufacturers – may well constitute the greatest distinction in overall "personalities" in terms of the final look that they each produce.

But, there is yet another twist to this particular personality of a lens.

If Only Contrast Was So Simple

In the simplistic description of the contrast ratio of a lens in the previous sections, it was assumed that light transmission was uniform across the image coverage circle of the various lens elements. Optics, however, is not so kind. The famous "Cosine to the Fourth Power" is a mathematical law – long ago discovered – that defines a light transmissivity that falls from a maximum at the lens element center to a progressively lower level toward the image extremities. This is termed the Relative Light Distribution performance of the lens.

Clearly, it entails an uneven brightness distribution across the image plane, and attendant with this, is of course, a contrast distribution. Ingenious optical system designs have evolved within each optical house that can ameliorate this fall-off – but only to a degree. All lenses are imbued with this inescapable limitation – typified by the characteristic shown in Figure 5. It is impossible to eliminate the effect when the lens aperture is wide open – but technical strategies can be mobilized to limit the effect when the lens is stopped down. These strategies vary between optical manufacturers and as a consequence the distribution of contrast across the image plane will be unique to a given lens –adding yet another dimension to lens personality.

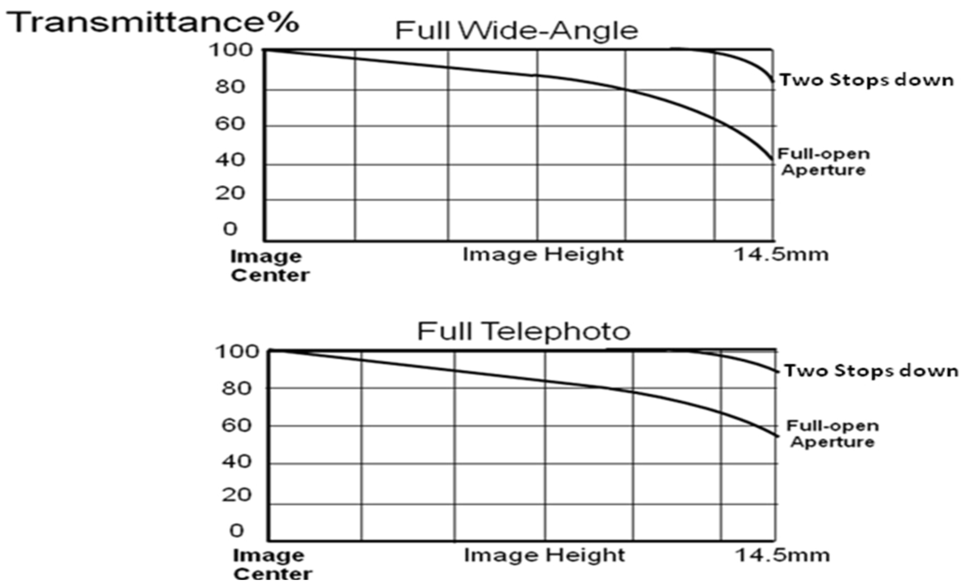

Figure 5 *Showing a typical Relative Light Distribution characteristic for a Super 35mm cine zoom lens*

A Further Twist to Lens Contrast Personality

Optomechanical design is a sub-discipline of optical engineering tasked with integrating lens elements within mechanical structures so as to form an optical system of extremely high precision. Optical ghosting and flare are caused by harmful light reflections – both within the individual lens elements (as discussed) and within the optomechanical lens housing. Over many decades a variety of strategies have evolved (many proprietary) to suppress lens barrel reflections. They entail special paints applied to angled surfaces and mechanical joints, as well as electrostatic flocking processes that apply an extremely fine pile to surfaces requiring anti-reflection finishes. Various structural techniques such as light blocking grooves and knife edges are deployed to reduce the reflection surface area. Fixed and moveable diaphragms are used in zoom lenses to act as flare-cutting devices. The surfaces of aperture blades are also treated with special anti-reflection coatings.

Summary

Achieving a high contrast ratio is universally sought by cinematographers (there are exceptions, of course, for special shoots) and as a consequence it is always a central design goal for the optical designers. While the core optical strategies are common to all, their actual implementations have become diverse and proprietary to each optical manufacturer. It is inevitable, therefore, that the subjective manifestation of contrast will be different between all of these lenses. These differences, in turn, will constitute a significant element of the individual "personalities" of these lenses