Through The Looking Glass

With the development of new solid-state imagers and compact HD cameras, lens technology plays catch-up ■ By C.R. Caillouet

Small lenses for video cameras have taken HD video to new places.

Myth: Lenses get sharper when you stop them down.

Actually, that may be true, but only to a point....

One of the most interesting areas of video technology is that of lenses. High-definition video as we've come to appreciate it is only possible because of advances in the quality of small lenses for video cameras.

In the 1980s, what we now call standard-definition video cameras evolved from vacuum-tube image sensors with continuous electron-beam scanning to solid-state imagers with a fixed pattern of small sensing sites spread evenly across the image area. This change in imaging technology had both positive and negative implications on image quality. Fixed imaging patterns and imagers improved stability by eliminating the variations in the scanning beam, but no longer was it possible to cover up lens aberrations with adjustments designed to compensate for those scanning variations. Lens designers were forced to build more precise imagers with fewer imaging errors. Fortunately, at about the same time, computerized design and fabrication tools started to become available to those designers. Consequently, lens designs improved as the nascent solid-state imagers began to make inroads into the camera market.

The leap in lens quality, along with improvements in processing electronics, paved the way for HD cameras, which were appearing on the scene in the late 1980s. The tube-based, high-definition cameras that introduced the new formats soon gave way to cameras with solid-state HD imagers. But the corresponding HD lenses were larger, heavier and more expensive in order to meet the image-precision requirements of the new formats. So goes the

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MISINFORMATION

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process—if you want higher-resolution images, you have two options: You can increase the size of the imager and the glass that goes with it; or you can increase the precision of the lenses for the same-size imager.

Concurrently with the development of solid-state imagers and HD cameras, market pressures were forcing camera manufacturers to build smaller, lighter and more sensitive cameras, with more flexible lensing. The increasingly stringent requirements made lens designs more difficult. Decreasing imager sizes meant that the lenses had to make more precise reproductions of scenes on the smaller imagers. Adding HD requirements to standard-definition ones made the problems even harder to address.

The small size and long zoom ratios demanded by users left some image errors. Those errors can be divided into two classes—chromatic aberrations and diffraction limits. Chromatic aberrations are small differences in size or position among the three sensors with changes in focal length, aperture and/or focal distance. Chromatic aberrations tend to be worst at the widest aperture settings, and the resulting misregistration of the red, green and blue images can reduce the useful resolution of the image significantly. Diffraction limiting represents the physical limit on the resolution because of the finite, albeit small, size of light waves. The smallest resolvable detail is proportional to the size of the image, the *ƒ*-number of the lens and the wavelength of the light. The resolution will vary somewhat among the colors, but the result is a difference in resolution rather than a position or size difference between two of the colors, so the effect usually appears to be monochromatic.

The combination of chromatic aberration and diffraction limiting creates the so-called "sweet spot" in a lens—usually between *ƒ*/4 and *ƒ*/8—but larger formats extend the useful lens opening farther toward the closed end. Conversely, the new, smaller formats may start to lose sharpness even lower than *ƒ*/8. This might not seem like a big problem—you always can add neutral density to control light—but it might limit the creative options by reducing the range of iris choices, and it can make run-and-gun shooting more troublesome. So the explanation of my original comment about lenses getting sharper as you stop down is that they should, until you start to hit the diffraction limit.

Some of the tools in camera design improve the integration between the lens and the camera. That integration can come in several ways. The first level involves close cooperation between the camera and lens manufacturers, allowing some design compromises on either side for a better match. The next level requires permanent attachment of a lens to a camera, thereby allowing the camera designers to deal with specific lens characteristics and to limit lens and camera operation to optimize system performance.

The third level has become available as the lens and camera designs have begun to mature and lens/camera communication has improved. Lens makers characterize typical imaging errors and supply them to camera manufacturers, who then, with improved image-processing techniques, program the cameras to use lens status information to correct some of the residual errors for improved overall system performance. In-camera lens error compensation can be useful for chromatic aberration errors, but doesn't do much for diffraction limiting because it represents a physical limit of the optics. Image enhancement can sharpen edges, but it doesn't actually improve resolution.

I don't have space to deal with the depth-of-field discussion here, but I'll try to visit that subject in a future column.

The need for greater lens precision to produce similar resolution on small imagers, the greater visibility on big screens of chromatic aberrations at wider apertures and diffraction limiting at tighter ones, and the difficulty of maintaining optical alignment with interchangeable lenses on small formats all contribute to the range of image quality coming from modern cameras. Whether any particular camera image is good enough for you is ultimately determined by how you'll process and where you'll view your images. Hmm...does it seem like you've heard that line before?

Keep your eyes open. No one else can decide what's acceptable to you. HDVP