LENS CONTROVERSY

BY DAVE WADDELL

CCD SENSORS GIVE LENSES SOMETHING TO SHOOT FOR.

The charge-coupled device (CCD) has revolutionized consumer and professional video cameras. CCDs eliminate geometric distortion and provide uniform light transfer over their surface. They are more reliable, lighter and smaller, consume much less power, and are less susceptible to picture degradation when shooting bright objects. The CCD made truly lightweight professional camcorders possible, and it has eliminated some of the most onerous problems of tube cameras.

Waddell is marketing manager for Fujinon, Wayne, NJ.

However, the CCD camera is a challenge for lens manufacturers, because, unlike the tube camera, it cannot be adjusted to match its characteristics with those of the lens. The lens must be superior in every respect and accommodate the CCD's unyielding demands.

Sealed at the factory

Before the CCD was introduced, professional cameras employed three pickup tubes, along with deflection yokes and associated electronics. The procedure for mounting a lens to these cameras required adjusting the back focus (by tweaking the physical distance between each pickup tube and the lens) to match lens characteristics, and adjusting the camera registration of the red and blue tubes. These steps minimized longitudinal and lateral chromatic aberration, which are inherent characteristics of zoom lenses.

The requirements of CCDs are much different. Their position on the prism is fixed at the factory and cannot be adjusted for centering, rotation or image size. Therefore, the lens must minimize longitudinal and lateral aberrations.

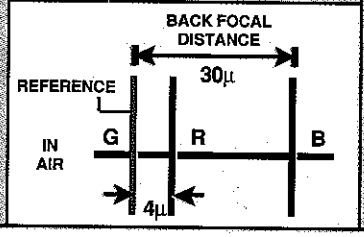
ITEM	SPECIFICATIONS	REMARKS
Longitudinal chromatic aberration	Prism material F5 CCD is to be positioned as follows: 	Affected by precision of master projector and physical placement Filter material BK-7 16.2mm Glass Prism material F5 30.0mm Glass

Figure 1. The new standard for cromatic aberration in ²/₃-inch 3-CCD cameras defines a reference lens and pattern projector for positioning and fixing the CCDs to the prism.

TABLE 1 - TARGET VALUES FOR CCD-COMPATIBLE LENSES

CRITERION	TARGET	REFERENCE
Transmission	Greater than 60%	450nm to 650nm wavelength
Lateral chromatic aberration	Telephoto to wide ±10μ	f/4, zone 2. Standard distance to object
Distortion	Less than ±1.5% from tele to wide	Standard distance to object
Peripheral light ratio	More than 30	At open iris, distance = infinity
Optical axis	Less than 0.5% of the image diagonal	Add tolerance of mount
Registration error from temperature	Less than ¹/₈-pixel from -15C to +45 C	Includes fluctuation of 400,000-pixel CCD prism and CCD attachment device

Toward a standard

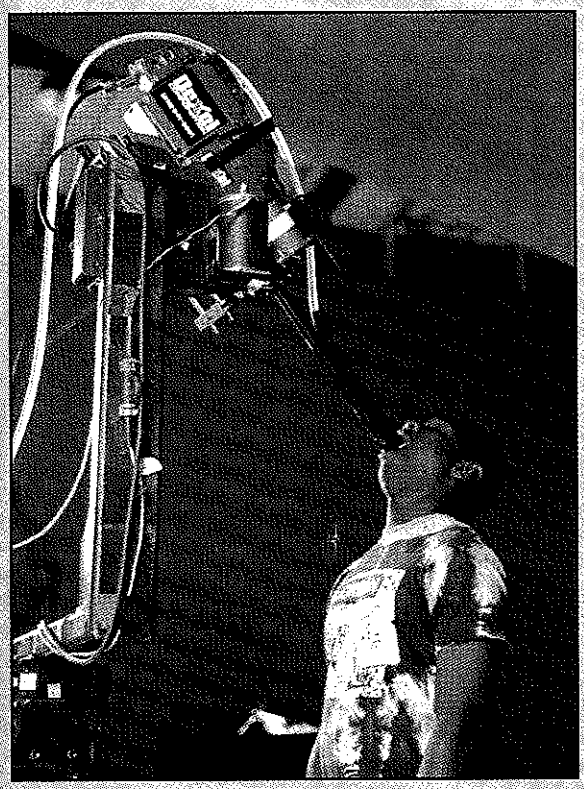
With the tube camera, lens manufacturers didn't need uniform standards, because you could make compensations in the camera for differences among lenses. The CCD has changed all of that, and users pleaded with lens and camera manufacturers for years to produce a standard for lens compatibility.

After months of negotiations, NHK (the Japanese national network) and lens and camera manufacturers reached an agreement on a standard optical reference for ²/₃-inch 3-CCD cameras. (See Figure 1.) This standard allows optics manufacturers to make a reference lens and pattern projector for posi-

(Continued on page 26)

LENSES FOR TABLETOP: NEW OPTIONS, NEW LOOKS

BY CHRIS LEONARD



Today's economic climate places many budgetary constraints on professional videographers. At the same time, the intensely competitive environment often demands *Star-Wars*-type effects and creative genius. Although budgets may decrease, you don't have to compromise on quality. What you need is more creative flexibility and less expensive means of obtaining it. One small but mighty tool for achieving this objective is simple — the lens.

An economic alternative

The stampede toward computer graphics continues. However, many production concepts can be satisfied through a new perspective in live action, which you can get by using certain specialty lenses — at a fraction of the cost. Various specialty lenses are offered through such companies as Century Precision Optics, Kenworthy Lens Systems, and CPT Lenses.

One company, Innovision Optics, Santa Monica, CA, provides complete tabletop production systems, including lens systems, lighting motion control and camera support equipment. They have a unique overall design, with their long-barreled tubular systems that are one-half to one inch in diameter. They allow the camera to shoot over, under, around and through objects and areas at extreme close-up range and from a variety of angles. The lenses are adaptable to virtually every video camera. Because they are fully sealed, they can be immersed in fluids, including oil and salt water. The complementary mini-jib arm and motion control system allow movement of either the camera or the object.

Such special lens systems can expand your creative options. They allow shots never before available with live action. You can use them to find new and different ways of looking at the same old thing. You can even obtain microscopic close-ups around and within areas previously unseen. Thus, they are often a viable alternative to computer animation at a fraction of the cost.

Uncommon perspectives

For example, in a current Nike commercial, the directors, Big TV, used one such lens with a real-time motion control rig. In the finished shot, a huge basketball appears to soar down a player's throat. To create this image, the production crew did a reverse shot with the Probe lens, starting deep in the talent's mouth and coming out to a height of 21 feet. They then blue-screened in a scaled replica of a basketball court. After rewinding and speeding up the shot, they merged it with the remaining footage to complete the desired effect.

Another example is the solution found by Fleming Foods, one of the largest food wholesalers in the country. The company's dilemma: How do you make canned goods look new and exciting? The directors found a new look and image for the food products by using the Innovision lenses, which provided a microscopic view that started inside a can and moved around, over and through it, giving audiences an unexpected perspective.

The Gemological Institute of America (GIA) has an in-house school for teaching professional jewelers. The organization wanted to include videos in its course work that showed some minute detail work, such as the setting of tiny diamonds. The micro lenses allow students to see the procedures enlarged and close up. According to video supervisor Betsy Shuster Winans, such shots allow them to better understand jewelry-making theories and to improve their performance.

LSI Graphic Evidence is in the business of providing demonstrative evidence to attorneys through video re-creation. It uses 80% computer graphics in its techniques. However, production manager Brian Bradley found that he can offer more options and competitive pricing to his clients with specialty lenses. He shoots some projects in live action using this type of lens and then plugs in 3-D graphics. According to Bradley, "Clients have more options, they're happier, and they are more likely to return."

Tighter creative control is also possible, because the director doesn't have to rely on a computer artist's interpretation of the original concept.

Computer graphics can be a powerful production tool. However, before you automatically turn to the computer for your tabletop creative challenges, consider rethinking the concept in terms of live action. Today's innovative tabletop technology — including lighting, motion control, models and miniatures, camera support equipment and especially lenses — offers you new flexibility with a high-tech look, and for less money.

Leonard is an independent industry consultant.

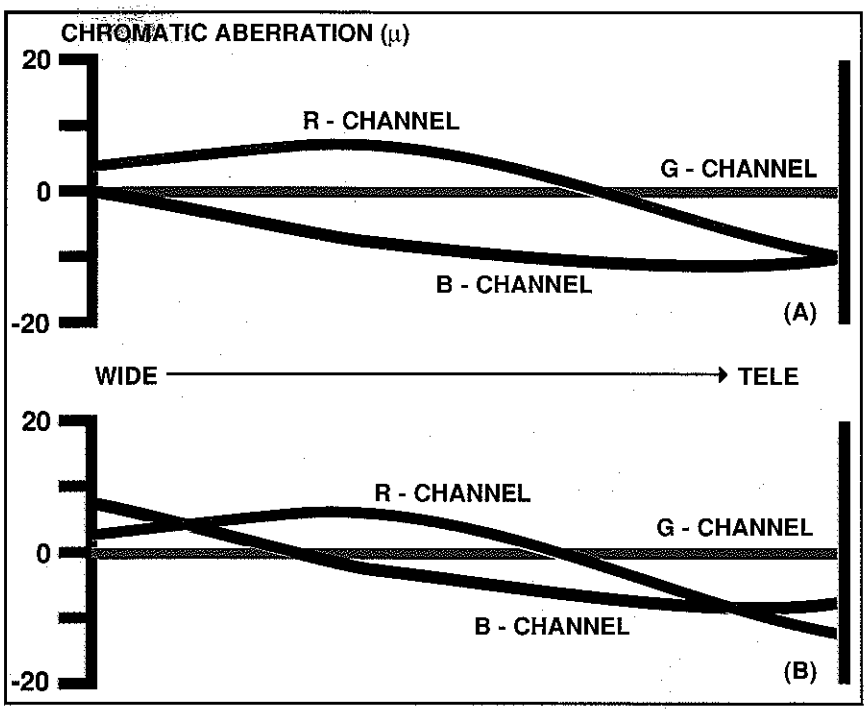


Figure 2. Lateral chromatic aberration in a lens designed for tube cameras (A) and for CCD cameras (B) shows that performance of the CCD lens is better throughout most of the zoom range.

(Continued from page 22)

tioning and fixing the CCDs to the prism. (See Table 1.)

This reference lens has a fixed focal length with minimum lateral chromatic aberration. Longitudinal chromatic aberration is manufactured into the reference lens according to the standard. To increase the accuracy of the focus position, the aperture number is set between f/1.4 and f/1.6, in accordance with the refractive index of the glass.

Aberrations

A camera can perform no better than the lens attached to it; the lens ultimately determines camera performance. One principal obstacle to high performance is *chromatic aberration*. There are two kinds of chromatic aberration: longitudinal and lateral. Efforts to minimize them consume great amounts of manufacturers' research and development budgets.

Light at different wavelengths travels through glass at different intervals, much like RF energy in air. Because of their varying frequencies, red, green and blue images form at different points on the camera's focal plane. This is longitudinal chromatic aberration, and it changes slightly as the lens zooms from wide angle to telephoto. Lateral chromatic aberration is caused when various wavelengths of light are magnified differently by the lens elements. It is manifested as

(Continued on page 30)

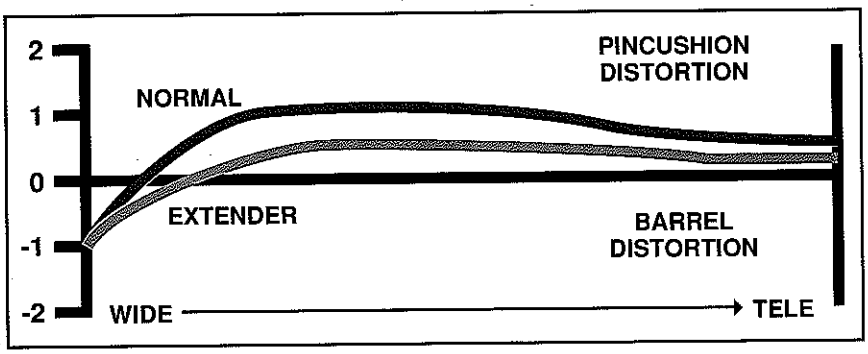


Figure 3. Geometric distortion is a more critical specification for lenses used with CCD cameras, because, unlike tube cameras, the CCD camera inherently has no distortion.

(Continued from page 26)

changes in image size; in the camera, it appears as misregistration.

When designing lenses for CCD cameras, you must minimize aberrations to fall within the tolerances set by the new standard. To meet this standard, manufacturers have needed a completely new approach to lens design, as well as the use of new materials for optical elements.

Currently, two types of optical material — artificial fluorite and extraordinary dispersion (ED) glass — meet the criteria for high-quality optical use. CCD cameras require lenses with incredibly tight optical and mechanical tolerances to improve overall optical performance. Even the slightest deviation from the specified tolerance can ruin an otherwise superb optic.

Tube cameras compensate eclectically and mechanically for individual lens characteristics. CCD cameras offer no such adjustment, so lenses must have much tighter mechanical tolerances. While advances in lens manufacturing techniques continue, the best CCD lenses use every bit of today's precision machining capability.

For example, consider the chromatic aberration when zooming an ENG tube lens and a CCD-compatible ENG lens. (See Figure 2.) The fluctuation of the aberration and its absolute value at the mid point in the zoom range are considerably different. A tube-camera operator can match camera and lens performance, but a CCD-compatible lens must maintain image deviation of less than 6μ for a 400,000-pixel CCD with a 12μ pixel pitch to avoid apparent registration error.

More hurdles for lenses

Besides chromatic aberration, the manufacturer of CCD-compatible lenses must deal with other problems. For example, modulation transfer function (MTF), which defines the frequency response of the lens, varies in tube cameras from the center to the edge of the picture. The MTF of CCD cameras is the same in all areas of the image plane, placing the onus on lens manufacturers to achieve the highest and most linear MTF.

The scenario is similar for geometric distortion. CCDs have no distortion, but lenses do. (See Figure 3.) Lens manufacturers strive to maintain a distortion level that falls within the NHK guidelines to optimize camera performance.

Ghosts and flares must also be better controlled. An experienced tube-camera operator would never shoot a bright object, such as the sun's reflection from a car bumper. However, because a CCD is much more tolerant of bright light, camera operators routinely point CCD cameras at bright objects.

When light enters a lens and reflects or is dispersed by the inside of the barrel or an element and reaches the image plane in an unrecognizable shape, it is called *flare*. *Ghosts* occur when high-luminance light is similarly dispersed or reflected but reaches the image plane in a recognizable shape of a high luminance value. Flares and ghosts cause additional problems for CCDs when the light reflects from the CCD face into the lens and then back to the CCD.

The higher sensitivity and better signal-to-noise performance of CCD cameras allow use of zoom lenses in low light. Ghosts and flares commonly result when bright objects are shot against dark backgrounds in low light. They can be minimized by improving the spectral transmission of the zoom lens, applying optical coatings, and improving coating finishing tech-

INTERNAL FOCUS

BY BOB MANIS

Dave Dorsett, CBS camera operator of 26 years, said this about camera technology: "I started shooting Walter Cronkite in 1965 and Dan Rather in 1966, back when he was anchoring *60 Minutes*. When I think about how far (technological changes) have come in such a short time, sometimes I wonder when the lens is going to exceed the operator."

It's doubtful that the lens could ever exceed the camera operator, who is as much an artist as a technician. However, you can't deny that tremendous advances have taken place over the years. Technological changes in semiconductor devices and in the digital circuitry of VTR systems have brought radical changes in the professional hand-held camera. The quality of cameras has greatly improved, and yet the cameras are smaller and lighter than ever. The improved CCD chip has significantly decreased image distortion and degradation at the corners of the image field.

These inventions made it necessary for lens manufacturers to design compact, lightweight, high-quality and high-specification lenses to best use the properties of the CCD camera. Voilá! Internal focus lenses.

Canon, Fujinon and Angenieux have developed their own designs for internal focus lenses, and Nikon is considering it. Fujinon's internal focus lens, the A8.5x5.5, is a wide-angle lens used primarily for production rather than ENG. Angenieux introduced its internal focus ENG lens four years ago. Standard focal length is 8mm to 112mm. Instead of rotating like a standard lens, it focuses via a pump that moves the barrel in and out horizontally.

Canon's J14 is the first standard ENG lens with internal focusing that leaves the outside of the lens completely stationary. Standard focal length indicates a range of 8.5mm to 119mm, which generally excludes such lenses as specialty wide-angle and telephoto. Although the same focusing system has been used in studio and certain specialty lenses, it was difficult to apply to a standard broadcast hand-held lens, which must be small, light and high-performance.

Bottlenecks in development existed in optical design, mechanical design and manufacturing technology. Many people doubted that it was possible. An ENG lens that isn't small and lightweight is worthless, yet no sacrifice of optical quality and ability is acceptable.

Internal focus lenses require a split front structure, which is more complicated and heavier. Through close 1µ tolerance machining, Canon overcame these bottlenecks.

In conventional lens focusing systems, the front element rotates out. (See Figure 1.) The convex front elements move in and out of focus. The focusing group is furthest out at minimum object distance. This system is widely used because it is simple, small and lightweight.

Internal focus lens technology is more complicated. The focusing lenses are mounted separately from the front lens. A helicoid screw, on which the focusing lenses are mounted, connects to the driving pin. (See Figure 2.) The pin moves the focusing elements back and forth, keeping the front lens elements and mechanical barrel stationary. In essence, the focusing elements "float" within the lens.

CCD cameras produce no format deformation so lens distortion is a serious consideration. The design of Canon's internal focus lenses, with their *floating* insides, allows precise focusing because focal length never changes.

Internal focusing also allows you to use a square hood that is proportional to the aspect ratio. This cuts more stray light than a round shape does. Thus, this hood provides compactness and prevents harmful light influxes. It also acts as added protection from the elements. For example, raindrops that land on a conventional lens during focusing will move and become a source of distortion. Internal focus eliminates movement of the front element and filters, leaving the lens stationary and more transparent.

Internal focus lenses also allow the use of lighter and more flexible matte boxes. Matte boxes are available in single or double fully rotational stages and generally accept standard 82mm filters, such as star, cross, snowcross, polarizer, multivision or half ND, for video production similar to film-style shooting. With previous lenses, any filter on the end would change position when you focused, whether or not you wanted it. With internal focus lenses and their stationary front elements, re-indexing is a thing of the past.

Furthermore, the weight of an optical accessory attached to the front of the lens is no longer important. Because the weight doesn't affect the movement of the front element, it can't harm the focusing operation. Therefore, response time is greatly improved.

Although lenses may never exceed operators, the CCD chip is probably the most significant advance in camera technology in years. Similarly, the development of hand-held ENG internal focus lenses brings lens technology to an unprecedented level of quality and performance.

Manis is president of Manis & Company, Boca Raton, FL.

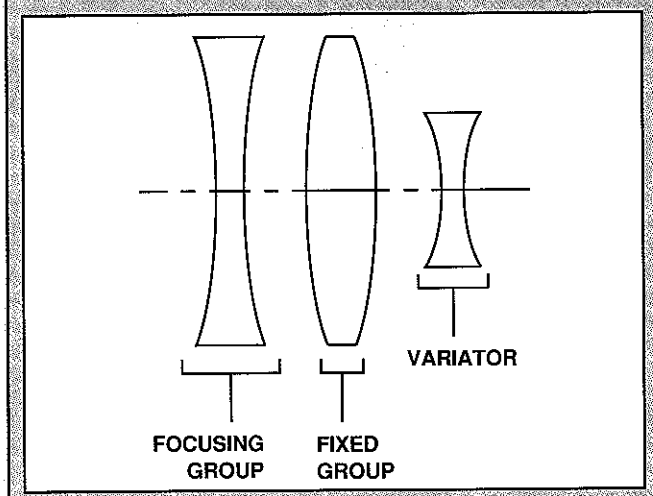


Figure 1. Conventional focusing system

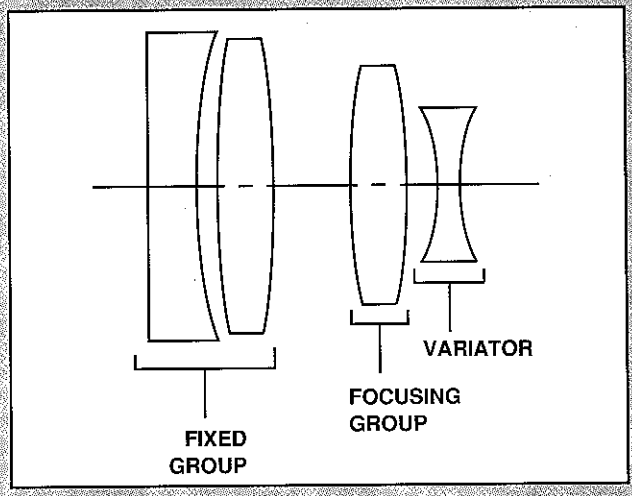


Figure 2. Internal focusing system for J14a x 8.5B IR5

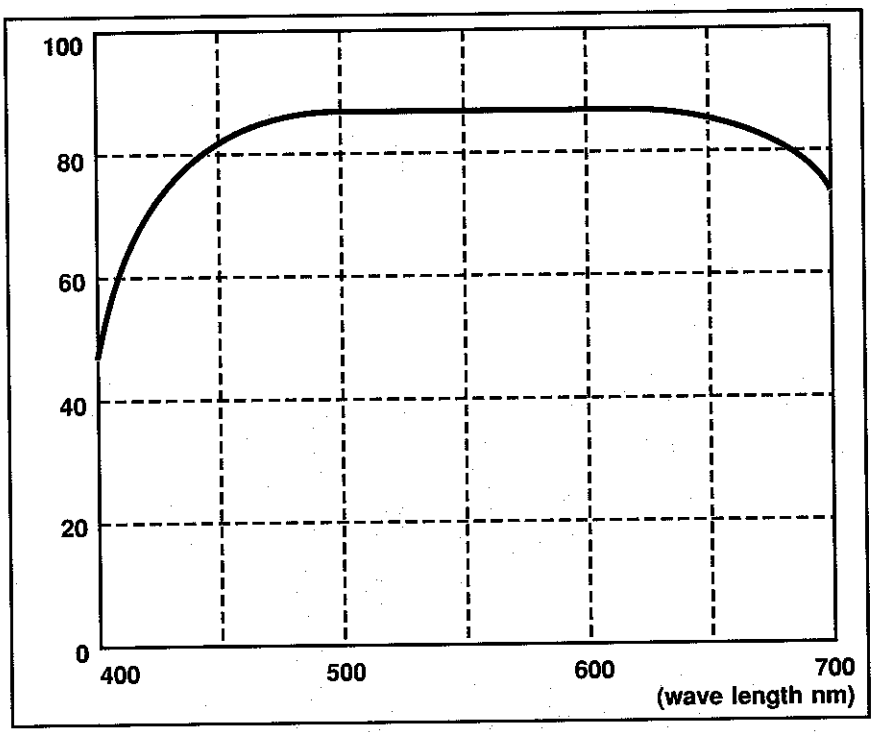


Figure 4. Light transmission in lenses designed for CCD cameras is high at most wavelengths, resulting in a near even distribution of RGB signals.

niques and lens barrel design. Optimally, these techniques dramatically improve light transmission at all wavelengths, resulting in a near even distribution of RGB signals. (See Figure 4.)

CCD cameras are much lighter than their tube predecessors, making lens weight more important, especially for ENG use, where light weight and balance are key design goals. Unfortunately, optimum performance and light weight are conflicting goals because larger optics — necessary for increased light capture — are heavier.

Nevertheless, after thousands of computer simulations and countless prototypes, CCD-compatible lenses have been improved optically while becoming smaller and lighter. Advances have been made through improved MTF and peripheral light volume at full iris, effective use of lightweight glass, better parts manufacturing by computer-controlled equipment, and the adoption of magnesium castings to reduce weight.

As CCD-camera performance continues to improve, even greater demands will be placed on lens manufacturers. Fortunately, advances in materials and manufacturing technology, along with more comprehensive computer-simulation capability, promise to keep progress climbing higher. ■

Acknowledgment
The author thanks Makoto Ohmura of Fuji Photo Optical Company Ltd. and Akira Higo of Fujinon USA for providing information for this article.