Are Today's Tele Lenses Really Better?

by Bennett Sherman and Jason Schneider

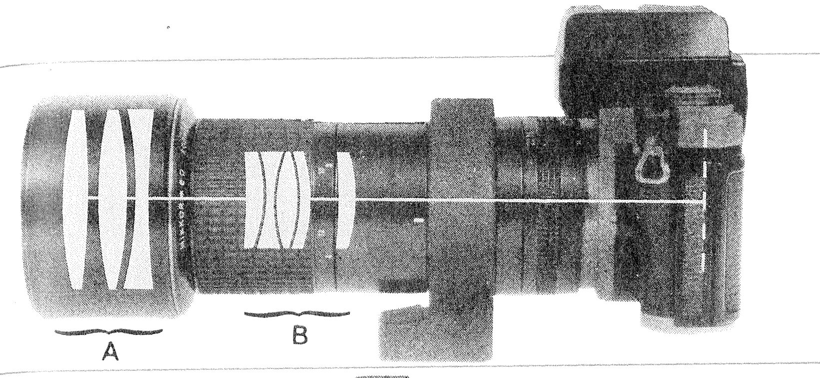
Ever since the early 1930s, when 35mm cameras began to sprout such startling appendages as coupled rangefinders and interchangeable lenses, the telephoto has been a vital part of the small-format photographer's arsenal. Indeed, the early development of convenient, portable, hand-holdable "long reach" optics is undoubtedly one of the prime technical factors that enabled the once-despised 35mm format to gain professional respectibility, and the proliferation of long and short teles designs, and the need to compose and focus them accurately most assuredly spurred the rapid development of the clunky and ponderous single-lens reflexes of yore into today's sleek automatons.

Of course, as always, the name of the game is pictures—and the underlying reason for the "triumph of the telephoto" center around the unique viewpoint, perspective, and operational capabilities these lenses can provide. Whether your object is to capture unposed, insightful glimpses of people being themselves, to record sports action or a flock of birds across a distant canyon, a telephoto lens, because of its ability to "shrink" distances and compress apparent perspective, is a useful—often indespensible—tool. (To get a better idea of the graphic possibilities teles provide, we suggest you take a look at the pictures on pages 94 to 101.)

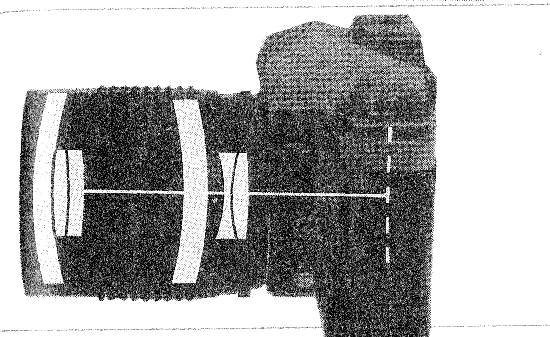
In a certain sense, the telephoto shoe is now on the other foot—instead of the lenses exerting a great influence on camera design, cameras are now returning the compliment. The result is a series of ever smaller, lighter teles to match the handling characteristics of the current range of compact and semi-compact SLRs. Furthermore, the ongoing quest for improved optical performance (especially color correction), wider aperture, closer focusing distance—in short, all the features photographers have dreamed of and clamored for—has not abated. But, as we'll presently see, not all these improvements have been achieved without paying a price.

For telephotos of 300mm focal length and longer, achieving a high degree of color correction is one of the most important problems. For example, the 400mm teles of a decade ago produced different focus points between green and blue light (the discrepancy was greater than 0.5mm) evidenced by prominent

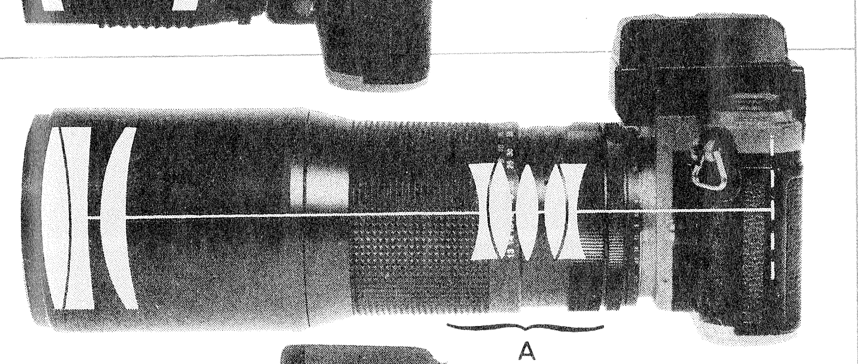
Special glass: In the new Nikon 300mm f/4.5 ED lens, right, the letters "ED" refer to the "extraordinary dispersion" glass used to make the first element in the front group (A). When combined with other, more ordinary crown and flint optical glasses in the second and third elements, this lens design reduces or eliminates the green-blue color aberration which causes color fringing in many long tele pictures. This lens also features a five-element rear group (B) which moves inside the lens barrel as you turn the focusing ring, eliminating the usual heavy outside thread.



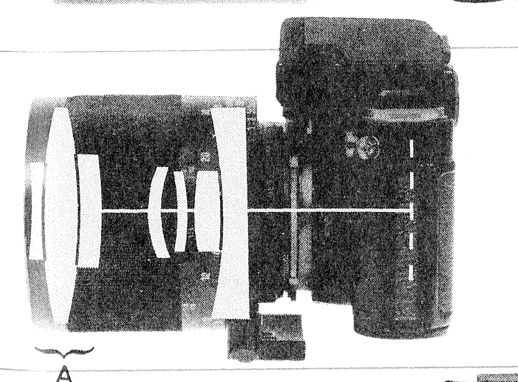
Super-compact mirror lens: The Minolta 250mm f/5.6 demonstrates that mirror lens design can be made very compact. This lens is hardly larger than the Minolta 85mm f/1.7 lens. To avoid internal scattering, the light shields in this design are tightly fitted around the reflected light beams. As a result, the optics must be designed as an f/4.5 lens, so that the moderate amount of vignetting caused by the close fitting light shields does not reduce the true speed of the lens below that barrel-marked f/number. This arrangement also prevents excessive falloff due to vignetting in the corners of the film format.



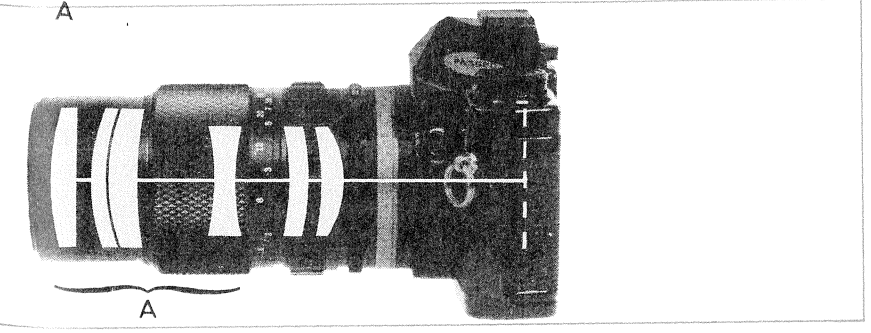
Internal focusing: The Vivitar 400mm f/5.6 is an example of the use of internal focusing to make a more stable, solid telephoto lens that can be mounted securely on the camera. No external lens barrel thread, with its problems of looseness and possibly inaccurate alignment, is used. Notice the complexity of the rear lens group (A). Although there are five elements in total, only three of them are moved by the focusing ring. The remaining two are stationary and serve to correct minor aberration changes as the moving group is shifted for focusing. The outside barrel is solid and accurately aligned.



Close-focusing mirror design: The new Tamron 500mm f/8 SP mirror lens, shown in the diagram at right, has a more deeply curved, stronger front lens which also carries the second mirror. This stronger front correcting lens (A) yields a sharper final image and also permits close-in focusing without excessive movement of the correcting lens and second mirror. This 500 can be focused so close that the image is as large as ⅓ life size, with the object only 1.7 m from the front of the lens. A matched SP 2X teleconverter can be fitted to this lens to yield a high-performance 1000mm f/11 optical combination.



Compact short telephoto lens: To fit the Olympus OM series cameras, a number of new, compact Zuiko lenses were designed. Included in this series is the lens illustrated at right: the 200mm f/5 Zuiko, just about as small as previous 135mm lens designs. To get this more compact lens, Olympus engineers increased the number of elements in the front group to four (A), and added a relatively wide space between the third and fourth elements. This lens layout, combined with the section of higher index-of-refraction glasses for several of the elements, makes the overall length of the 200mm much shorter, while image quality is as high as before.



green color fringing at contrasty image edges. Thus, at f/8, the best resolution which could be attained was usually less than 45 lines-per-mm. Only by stopping down to f/11 or smaller apertures could higher resolving power (sharpness) in the image be achieved. By choosing some unusual optical glasses and designing front optical groups of three elements, lens engineers were able to keep the color error down a bit and to increase the resolving power to about 56 lines-per-mm.

This seemed to be the limit until, recently, some of the major lens manufacturers decided to use crystal fluorite, or an equivalent special fluoro-crown glass made especially for this purpose. By combining these special materials with the latest optical glasses, the color aberrations could be reduced to as small as 0.1mm. In a 500mm lens design, this meant that the color error would be less than 0.025 percent! Putting such special optical material into an actual telephoto was not without its problems, though. These "exotic" materials are usually more brittle than ordinary optical glass, and change their index of refraction (light-bending power) more rapidly with changes in temperature. So, the special material had to be protected, as in the Minolta 400mm f/5.6 Apochromatic Rokkor, by including a fourth glass element up front, ahead of the fluorite element. Nikon opted for fluorocrown glass instead, and did not add the protective element. This glass is not quite as effective in its color correction properties as the crystal fluorite, but it's noticeably sturdier, and shows less change of index of refraction with temperature. For focal lengths up to and beyond 800mm, the fluoro-crown glass is effective enough to minimize most color aberration problems, such the green-blue focus shift mentioned above.

Increasing the number of elements in the large front lens group gave the lens designers another tool to deal with the other major problem in telephotos: zonal spherical aberration. This causes an overall softening of the image and a loss of resolving power without regard to color. Even at f/5.6, a 400mm tele lens might have a zonal aberration of .25mm or more. This also limited the best resolving power which could be obtained with a two-element design. As a result,

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most 400mm f/5.6 lenses have at least three elements up front. But, when one of these elements is crystal fluorite or fluorocrown glass needed to obtain super-correction of color aberrations, then three elements may not be enough to reduce the zonal aberration sufficiently. In the 300mm f/4.5 ED Nikkor lens, four large elements are used to eliminate the zonal problem (see illustration on page 103). Unfortunately, this tends to increase the cost of the lens. But, when the extra speed is essential, the higher price is usually acceptable.

Almost from the very beginnings of photography, the color aberration problem was serious, particularly for astronomers, who were the principal users of extreme long focus optics, both for visual and photographic purposes. Using the concave mirror, the astronomers simply side-stepped the color aberration difficulty, since mirrors, unlike lenses, have the inherent property of bringing all colors to a common focus point. In the 1950s, camera lenses began to be made using advanced mirror-lens designs. Even though these early mirror teles used lenses as well as mirrors in their construction, the color error was less than half as large as that obtained from a non-mirror or refractive lens.

Hot mirrors for sharper teles?

Recently, these mirror tele designs have gone through a change—not in principle, but in some details. As a result, the latest mirror telephotos are much more compact than before, and can, in some cases, focus closer. The major change is in the mirror itself. Unlike most mirror lens and telescope mirrors, these new concave mirrors have their reflecting surfaces on the back. Thus, the light passes *through* the glass of the mirror to the reflecting surface and then back through the glass again. This gives the optical designer another optical surface to use in producing a well-corrected lens. When this technique is used, the mirror is referred to as a "hot" mirror, meaning that the light passes through the mirror glass. This is now a common feature found in virtually all new compact mirror lens designs. In the Tamron 500mm f/8, for example, both the main mirror and the smaller second mirror (which sends the converging light back through the middle of the main mirror to the film beyond) are back-surface types. This permits the large, thin correcting lens—needed to sharpen the off-axis images—to be a bit more powerful *(i.e.* it has a shorter focal length and steeper curves). This, in turn, makes close focusing more practical. The focus thread on the barrel does not have to be as long as it does with a weaker correcting lens.

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Folding up the light path so that the final image plane is behind the main mirror usually requires a large second mirror—as much as half the diameter of the main mirror. This results in peculiar-looking, out-of-focus images. The doughnut-shaped blurs exhibited by such lenses are almost a trademark of mirror tele pictures. To reduce this, the new mirror lenses have extra-powerful main mirrors. This helps to make the system more compact, but it's more difficult to correct all the important aberrations. To attain compactness, along with high performance, 500mm designs are presently limited to an aperture of about f/8, but Minolta has just developed a new 250mm mirror lens with an aperture of f/5.6. The second mirror of the 250mm Minolta is somewhat large—31mm in diameter with a 56mm-diameter entrance aperture. By the way, an entrance aperture of 56mm means that the Minolta 250mm mirror lens has a mathematically calculated aperture of f/4.5. The light loss, partially due to the large second mirror, reduces this to the actual f/5.6 marked on the lens barrel.

A 250 no bigger than an 85?

The Minolta 250mm mirror lens is a paragon of compactness—it's hardly larger than a typical 85mm f/2. This is in keeping with the weight and size reduction that has been taking place in the cameras themselves. Some of the more standard telephotos are also being shrunk. One outstanding group is the tele Zuikos for the Olympus. However, as the length of the telephoto lens is reduced, the danger of increased zonal aberration must be overcome. Once again, optical designers have increased the number of elements, some in front, to get the image sharpness needed, even when the lens is more compact. The 200mm f/5 Zuiko is a good example. Its length from front to film plane is about 145mm—definitely less than the effective focal length. Although the lens design is more complex as a result, the compactness is well worth it. The newest cameras, with their lighter, shorter teles are much easier to carry and hold—especially for hand-held shooting.

When the long telephoto must also be relatively fast, then compactness goes out the window. There is simply no way to make a really long, fast tele that's truly compact. But one of the new ideas being widely used in the latest teles is *internal focusing* (see diagram on page 103). Consider a 400mm f/4.5 or f/5.6 telephoto. To focus in on a subject less than 5 meters away, you have to turn the helical focusing ring which moves the front group, and therefore the front of the lens, forward more than 30mm. The

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focus thread on the lens barrel, therefore, has to be precise and strong enough to handle this motion without mechanical errors or excessive play. That is why there's great advantage to fastening the lens to the camera without any external or massive movement of any part of the barrel. This is accomplished by using internal focusing—in other words, when you turn the focusing ring the barrel length remains the same, and focusing is achieved by moving a group of elements back and forth within it. When the tele lens consists (as do most of them) of a big, positive-power front group, and a smaller negative-power rear group, it is possible to focus the lens by moving the rear group inside the lens barrel. The Vivitar 400mm f/5.6, the Nikon 300mm f/2.8 ED, and the Minolta 600mm f/6.3 Apochromat are outstanding examples of this type of design.

Internal focusing, pros and cons

The technique is not without some problems, though. Moving the rear group does not do much to correct the problems which develop when the subject is as close as 10 focal lengths away. The front group aberrations change when the subject is nearby. To avoid adding to those close-focusing problems, the moving rear lens group used in the internal-focusing design is often more complex than before. In the Vivitar 400mm, for example, the rear group consists of no less than five elements. Added to this is the fact that only three of the five rear elements move to accomplish the focusing.

These design changes to the long-focus and telephoto lenses of today are not simple. They often involve an almost complete redesign of the lens, its mount and the barrel mechanisms. But, as new material becomes available—particularly new optical glasses—today's latest tele designs will undoubtedly be further improved. What sort of new lenses, new features and more advanced designs can we expect? The five lenses featured on pages 102 and 103 provide some pretty good clues. If the tendencies they exhibit continue in the expected direction, you'll see sharper, faster, closer focusing and still more compact telephotos in the not-too-distant future.

Of course, no discussion of the major changes in today's tele lenses would be complete without mentioning the recent progress in the design of tele converters—those relatively inexpensive, add-on optical devices that increase the focal length of the tele lenses to which they are attached. Previously, three or four element teleconverters provided adequate optical performance, but they worked best with prime lenses of 200mm or

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longer, having apertures of f/5.6 or slower. The main reason for using three or four elements was to prevent any aberrations in the converter from adding to the residual aberrations of the prime lens, thus reducing resolving power and contrast in the image. However, distortion and lack of image flatness were persistent problems which limited the types of tele lenses to which such converters could be attached without unduly sacrificing image quality.

Now, with the new telephotos, both mirror and all-lens types, the need for highly corrected converters which do not add any image errors of their own, is greater than ever. In fact, some of the latest converters are designed to be matched exactly to a specific tele, to sets of tele lenses, or to a particular range of focal lengths. For example, the Tamron SP 2X converter is matched to Tamron SP lenses, including focal lengths from 300mm to 500mm, and the 70-210mm zoom. The 400mm Minolta Apochromatic Rokkor is accompanied by a specially designed 2X converter which is an exact match, so that the combination is a fine-performing 800mm f/11. Nikon recently developed two new converters, including one (the TC-200) used with many lenses having focal lengths less than 300mm, and another (the TC-300) matched to the longer, slower telephoto lenses.

Are matched converters best?

All of these new converters are five- or six-element designs, which gives you an idea how complicated it is to engineer a converter so that it is optically neutral (i.e. does not add any aberrations of its own to the final image). By the way, the final image delivered by the latest tele-plus-converter combos is still a bit lower in resolving power and sharpness. Even a perfect 2X converter multiplies the residual aberrations of the prime lens by a factor of two. Hence the final resolving power can be expected to be a bit lower. When we compare, for example, the Minolta 400mm f/5.6 Apochromatic Rokkor combined with its matched converter, to a very well designed 800mm f/11 prime lens, the latter might ordinarily provide slightly sharper imaging. But, for both of these lenses, in actual use, the sharpness of the final image will be limited by such factors as the turbulence of the atmosphere. Undoubtedly, the convenience of having a fine-performing and compact 400mm with the option of converting it to 800mm focal length, is attractive to many photographers.

Compactness and convenience factors may also spur the return of the 1.5X converter. It can be very small, add virtually no aberrations of its own, and it will make a handy combination with the latest compact teles.—THE END