Leica M-Lenses

Their soul and secrets

by Erwin Puts

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Secrets revealed

It is well known that Leica M lenses, in spite of their compact design, deliver imaging performance with the highest quality. But what are the reasons behind the fact that, over the many years that new Leica M lenses have been computed, designed and produced in an ongoing succession, additional improvements still continue to be achieved? These improvements, in the opinions of the advertising experts at Leica, leave all previous advances far behind.

In this brochure, Dutch photojournalist Erwin Puts explains the principles on which the secrets of Leica M lenses are based and how the extensive knowhow and the great competence of Leica optical designers succeed again and again in achieving ever higher peaks in maximum performance in their optical systems.

The author also pays special attention to the popular concern expressed by numerous Leica users, who wonder whether the „old" lenses are superior to current Leica M lenses in terms of contrast range, contour sharpness and resolving power. With his knowhow and the experience of numerous test series, he juxtaposes comparable lenses and their performances. In addition to factual explanations, he also presents charts and measurement curves that have never before been published in this form. Guidelines for interpreting these tables and curves make these graphics even more practical.

Erwin Puts has been making photographs since 1960 and he explored the technical aspects of photography even while he was studying business administration. The author has been working with Leica since 1989, and in a series of more than 30 articles published around the world since 1992, he discusses the history, technology and the operation of Leica cameras and lenses. The core of his work consists of lens test reports that are conducted with a meticulous thoroughness that is recognized by his competitors. The work brings together optical parameters and practical applications, clarifying the limits of performance capability, with proper attention to their interplay with the different types of film materials.

For many readers, this brochure will reveal many a secret, thus clarifying the reasons for the performance characteristics of Leica M lenses. We wish you much enjoyment in reading this brochure!

Leica Camera AG

Ralph Hagenauer
Marketing Communication

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The soul of Leica M lenses

Ever since Professor Max Berek designed his first lens for the Leica, the 50 mm f/3.5 Anastigmat/Elmax, in 1924, the optical capabilities of Leica lenses have been intensively analyzed and discussed. Some reviewers state that Leica lenses are the standard against which others are to be judged. Others expressed the opinion that, even though Leica lenses perform very well, they are basically as good as the products of other manufacturers. Leica lenses are also said to have a special kind of image-recording quality that is often compared with three-dimensional rendition or with pictures that convey a three-dimensional impression. This peculiar "optical fingerprint" is frequently discussed among Leica aficionados and collectors. Sometimes it is even claimed that older Leica lenses have certain mythical qualities that gradually disappeared in newer lenses that were designed later. Then the fact is brought up that optical design is being performed more and more by computers, so that the personal "fingerprint" of the designer is no longer as evident as it once was.

It is undoubtedly true that Leica lenses had and have particular characteristics and qualities that are the very reason for the fascination and the challenge of working with these lenses. In my opinion, the question whether a photographer always achieves the best results when he or she uses a Leica lens is quite unproductive. Every lens has a large number of specific qualitites and it is highly unlikely that every one of these qualities will always be of the highest degree.

Behind every Leica lens one can sense a passionate determination to control and to eliminate the geometrical aberrations that are present in every optical system. It is true, of course that contemporary manufacturers of optical products can no longer operate without using sophisticated computer installations. It is a fact that modern computer programs can produce new optical designs in accordance with prescribed specifications nearly without human intervention or control.

The likelihood that a design generated in that manner is an ideal solution for the intended purpose is about one in a billion. And that is the reason why the creativity of the designer is essential, even decisive for creating an optical system that has optimal performance.

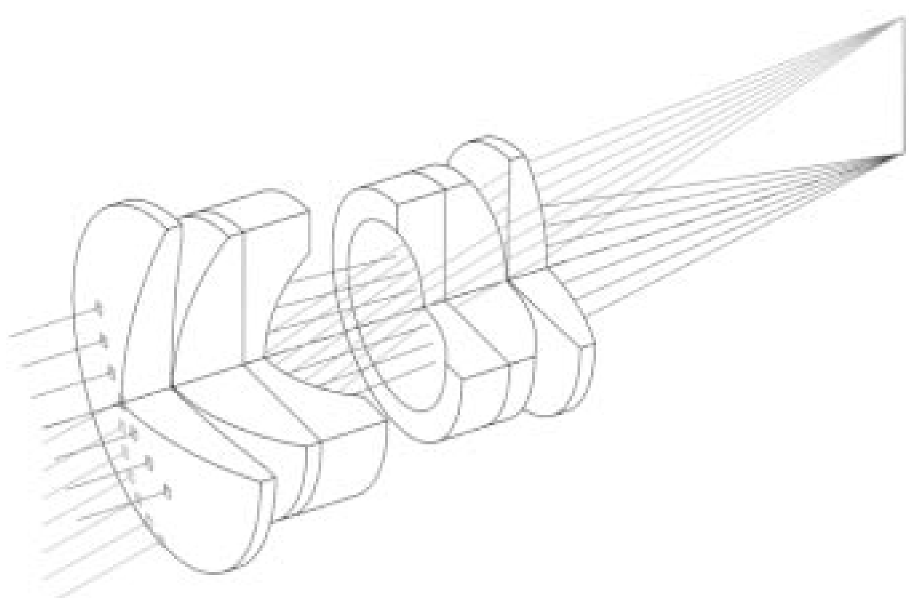
It might seem strange that I wish to draw attention to the importance of the creativity and the art of the lens designer as an important factor in optical design.

The fundamentals of modern optical design are rooted in mathematical and physical theories. The widespread application of computer-assisted design methods by all manufacturers has fostered the impression that lens design nowadays is a highly automated process.

Leitz was one of the very first optical manufacturers to use computers to accelerate the extensive and laborious calculations of ray tracing significantly. That was around 1955. Today the software programs used by the "Optisches Rechenbüro" (optical design department) are highly refined proprietary algorithms. Even so, current high performance optical systems could not have been achieved without a good measure of intuitive creativity.

In order to understand this soul that is present in every Leica lens, let us take a brief look at computation techniques, design procedures and optical evaluation techniques. After this small "tour de force" we will be able to sense and appreciate the "Leica spirit in the glass".

Let us begin with a basic explanation. If we take a simple lens, for instance the good old burning glass, to create an image of the sun on a piece of paper, the sun is rendered as a very bright spot and the paper begins to burn because the lens causes the sun's energy to concentrate in one point. In early times, a single lens element was the only means of obtaining an image. For very small angles of view, like those of a telescope, for instance, one was satisfied with such an image. Louis Jacques Mandé Daguerre, who made his very first photograph in 1839, needed a considerably larger angle of view for his image plate. The image created by a single lens element was quite sharp in the center, but very blurred along the periphery. At that time, optical aberrations were still unknown and better solutions

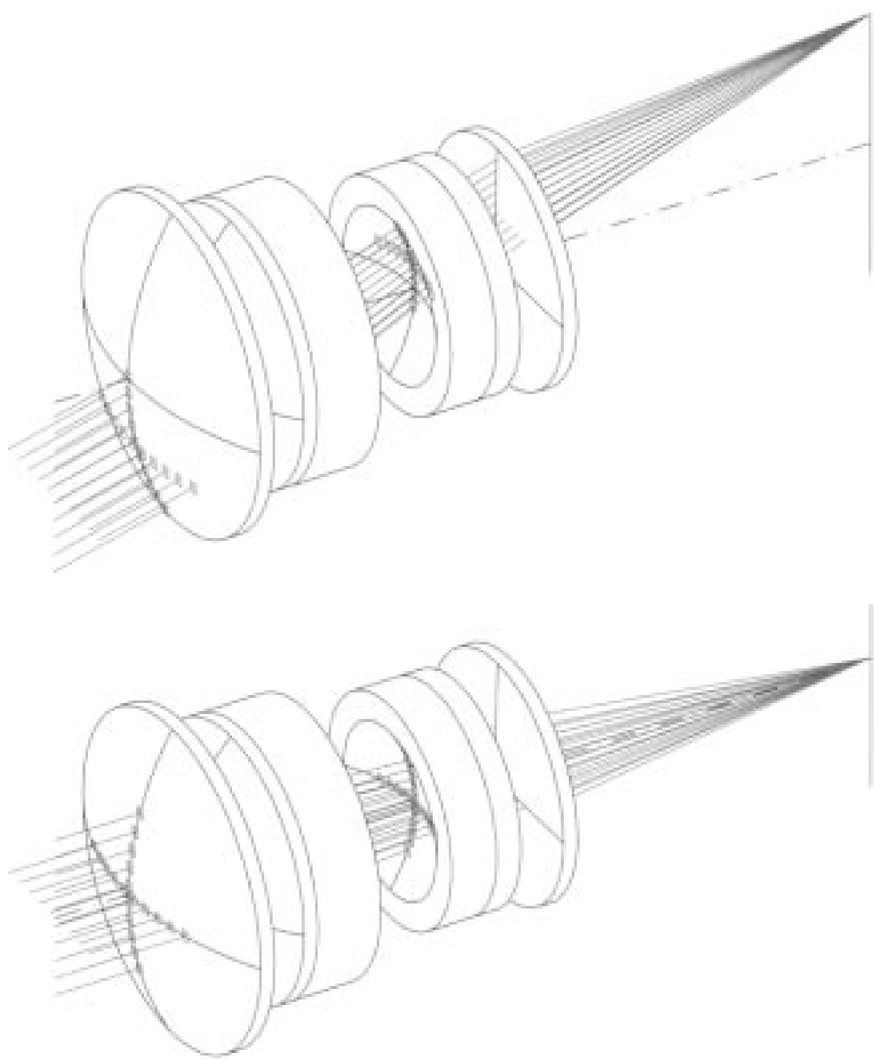


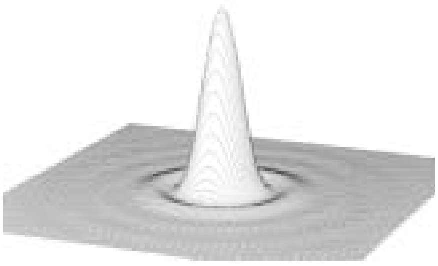
could only be found by means of experimentation. The phenomenon of the dispersion of white light into various spectral colors had been known for a long time, but now it became a problem in making Daguerreotypes. The photographic plate was sensitive to blue light, but the human eye is more sensitive to yellow light. That is why it was possible to use a simple lens element to focus an image on the ground glass with yellow light, but the image formed by blue light could not be focused at the same time. It was possible to correct this longitudinal chromatic aberration by using two lens elements, each one of a different type of glass, so that the dispersion of one lens was compensated by the other lens.

The curved surfaces of a lens also generate a curved image (just as they did in the old box cameras). But since the photographic plate was flat, a compromise had to be found. This was still based on knowledge obtained from experiments. The first opticians and lens designers disregarded theories, even though the laws of optics had been known for a long time. The law of refraction, which is the foundation of optical computation, was formulated in the 17th century. Every ray of light coming from an object that strikes the glass lens at a certain angle, is bent in accordance with a known mathematical formula. When this light ray passes through many lenses, the path of the ray can be traced clearly and methodically. When the object is a very distant one, such as a star in the sky, all the rays coming from that point light source will be parallel as they strike the lens, and they will also converge into a point after passing through that lens. At least that is what we hope. As proven by Daguerre's lens, this is not the case. Let us consider two rays of light, one of which strikes the lens near its edge, the other at its center. We can then use the law of refraction and knowledge of the type of glass to calculate the points where these rays will strike the image plane. If all the rays converge into a point on the image plane, everything will be in order. If they do not, we have a problem. The first person who designed a lens using this kind of mathematical computation instead of using experimental methods was Joseph Petzval. And his portrait lens was clearly superior to lenses that had been cobbled together experimentally. Although now it was possible to use formulas to trace rays quantitatively, the knowledge was still lacking as to why the rays were bent in this manner and why they did not reach the ideal or the theoretical location of the image point. Around 1850, Ludwig von Seidel researched the basic laws of image formation with lenses and he was the first person to establish a theory of imaging performance. Aberration (from the Latin "ab" = from, and "errare" = to stray) literally means "to stray from the right path". He discovered that there are seven so-called imaging errors of the third order that are independent of each other, and which together cause unsharpness and distortions in the image.

In principle, the next step is still easy. Now that we know, at least theoretically, what causes the unsharpnesses in an image, all we need to do next is to correct these aberrations. And this is precisely where the creativity of the optical designer comes in.

There are imaging errors that are caused by faulty design and there are manufacturing errors, both of which affect the end result (the image on the film) significantly. The seven Seidel aberrations are divided into three groups: 1 - sharpness errors: spherical aberration, coma, astigmatism; 2 - positioning errors: curvature of field and distortion; 3 - chromatic errors: longitudinal chromatic





aberration and lateral chromatic aberration.

Every lens has certain characteristics, such as the type of glass, surface curvature (the radii of its two surfaces). These characteristics are called "parameters" or "degrees of freedom". The theory states that each individual degree of freedom can be used for the correction of an aberration. Conversely, every degree of freedom is also involved in all the aberrations. This means that the optical designer can assign aberration components to every individual surface.

The significance of the above can be explained by means of an example. This example is very important, because it demonstrates how an optical designer goes about his task and why creativity still plays such a large and decisive role in that task. The seven aberrations can be corrected with a minimum of eight independent system parameters (degrees of freedom). (The focal length also has to be taken into account). A triplet (a three-element lens) normally consists of two collective outside elements (crown glass) and one inside dispersive element (flint glass). That results in six radii and two separating distances between the three elements. At the beginning, the designer selects basic system parameters, such as types of glass, element thicknesses, distances between elements, and curvatures (radii) of the glass surfaces. That makes six surfaces available to the designer, and he or she can now calculate the amount and kind of aberrations that each surface contributes. As an example, we can establish (in a very simplified manner) that in the case of the triplet, the radius of the second surface (of the first lens element) contributes spherical aberration and chromatic aberration, and that the radius of the third surface contributes coma and astigmatism.

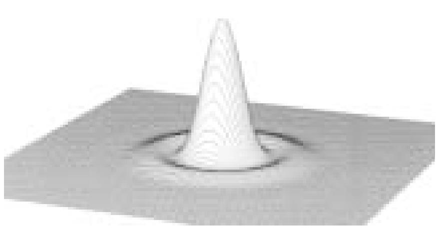
The optical designer must now decide how to correct these aberrations. He might try to change the curvature of the first lens in such a way as to reduce spherical aberration. But the curvature also determines the focal length, which should not be changed. It may also happen that a change in the curvature will reduce spherical aberration, but that the amount of coma will simultaneously increase. The designer may also choose to distribute the correction over several system parameters in order to reduce the likelihood of increasing other aberrations. When the task of correcting one particular aberration as much as possible is assigned to a single system parameter, there will be a problem in manufacturing if that very parameter is not within established tolerances. One could also find that, if tolerances are too tight, the manufacturing department may be unable of staying within those tolerances.

But let us return to the correction of aberrations. The optical designer will keep altering system parameters until the correction of the seven aberrations have reached a level where residual imaging errors are very small. The designer will also strive to correct each aberration by using several degrees of freedom at the same time. The "burden" of correction will then be distributed over several surfaces and the entire system will appear more balanced. The designer can select the types of glass and the curvatures within certain limits, but each combination will result in a different kind of overall correction. When the triplet has been configured in such a way that it comes close to meeting specifications, we may find, for instance, that astigmatism has nearly vanished from along the edges of the image, but that it is still quite evident in the field. Here we encounter a new problem: The seven Seidel aberrations are not the only optical aberrations. The Seidel aberrations are classified as imaging errors of the third order. Logically, there are other imaging errors of higher orders. The most important ones are the errors of the fifth and seventh order. These groups of errors are encountered only when the apperture is well corrected.

Theoretically, a very small object point is also reproduced as a very small image point. This does not hold true in practice, because these additional aberrations manifest themselves and spoil the fun. A point is not reproduced as a point, but as a small circle with various levels of brightness. See illustration: Point spread function. A soon as the diameter of these disks becomes smaller than a certain size, the higher order aberrations become noticeable. This is a simplified statement, because in reality these aberrations are always present, except that they only become noticeable when the residual errors of the third order are small.

The example of the triplet, in which astigmatism is still present in the field, shows the effect of the higher order aberrations. One can use a certain very well controlled residue of the Seidel aberrations to compensate these errors of the fifth and seventh order. Naturally this is only possible to a limited extent, and a triplet will render an acceptable image quality only when its angle of view and/or aperture are small.

This statement is very important. A particular optical system (number and configuration of lens elements) has a limited possibility for the correction of aberrations. In essence this means that, when a new design is to be made, an optical designer can only make the right choices if he or she has considerable experience and knowledge.



An impossible task?

In earlier times, when there were no computers, optical designers only had slide rules and logarithm tables at their disposal. Ray tracing was straightforward, but laborious. Normally, the paths of several rays are traced from an object point as they travel through the optical system. These calculations are quite numerous and in the case of oblique rays, they are also complex. Before the advent of computers, ray tracing was very laborious. An experienced mathematician required two to three months to calculate a sufficient number of ray traces through an only mildly complex optical system, like a triplet, for instance. It is understandable that approximations were used and that very complicated calculations were simply omitted. The resulting optical design showed inadequate knowledge of the exact extent of optical aberrations. Still, one has to recognize that these approximations helped the designers to determine the characteristics of many aberrations exactly, and their experience constitutes valuable background for today's optical designers at Leica.

All optical designs that are based on analytical methods are solutions that can never be exact, and they only represent approximations of the precise solution. That is why an actual prototype of the lens had to be built, so that the practical performance of the lens could be tested. Two potential difficulties caused many problems for the designer: the lens did not deliver the performance that was expected, or the manufacturing department complained that the lens could not be built within the specified tolerances. In either case the designer had to start all over again.

It was not easy to optimize a design. Success required much creativity and a very well developed instinct for the effects of the aberrations. When one looks at some of the older designs today, one is compelled to admire the achievements. An unbiased evaluation with modern instruments shows that these famous designs lack refinements, but that they do have a worthy character.

As mentioned above, only proper ray tracing can produce accurate results. But that causes a new array of problems. First, the designer needs a large number of ray tracings. In the past, trigonometric formulas and logarithm tables were used. At Leitz, the chief designer drew a diagram of the proposed optical system and then instructed each member of a large group of individual mathematicians to perform a part of the ray tracings and to hand the results to a colleague. At the end of the day or the week, the chief designer evaluated the results and planned the next phase of the lens computation. For all rays that travel in a flat plane that also contains the optical axis, the equations for tracing their paths are based on plane geometry and are relatively easy to use. Oblique rays require three-dimensional or solid geometry. The respective equations, however, are very complex. Therefore in those days oblique rays had to be traced by means of approximation formulas or not at all. Here too, only a partial knowledge of the performance of the respective optical system could be gained.

With the introduction of computers, the limitations of optical calculations were lifted, so that the (more exact) numerical method could now be employed to full advantage. Numerical methods can be used to achieve better control of important aberrations and they can also be used to optimize an optical system. This wealth of information can also entail its own problems. Did anyone ever tell you that the task of an optical designer nowadays is easy?

The magnitude of the optical designer's task can be illustrated quite forcefully. There is a certain relationship between the number of lens parameters (such as curvature, thickness, spacing between elements), i.e. the degrees of freedom, and the level of correction of the optical system. With more degrees of freedom, the optical designer has a correspondingly greater number of possibilities of correcting a system. When a lens designer employs more lens elements, a higher level of correction might be achieved. But that entails significant increases in costs, furthermore the system may become highly vulnerable to tight production tolerances and/or to increases in weight.

Therefore the optical designer needs to acquire a thorough understanding of the basic optical potential of a given design. All systems require optimization after an initially promising design. When a design is not suitable for fine-tuning, the designer is only able to achieve an inferior product. A six-element 50 mm f/2 Summicron lens has 10 airglass surfaces and radii, six thicknesses (one per lens element) and four distances between elements. In addition, each type of glass has a refractive index and a dispersion number. The exact position of the iris diaphragm must also be determined. With these 36 parameters (or degrees of freedom), the designer has to correct more than 60 (!) different aberrations. Every parameter can have approximately 10,000 distinct values and more than 6,000 different ray paths have to be computed for every change in a parameter.

The 36 degrees of freedom also are not fully independent. Some need to be combined, and some are tightly constrained by other parameters. Thus the 36 degrees of freedom are in fact reduced to only 20, making the task even more complicated. Given the specified conditions and considerations, it is not surprising that hundreds, if not thousands of designs can be generated that are very close to the desired solution. It has been estimated that a complete evaluation of all possible variants of the six-element Summicron design, using high speed computers that calculate ray traces at a rate of 100,000 surfaces per second, would require 10^{99} years!

That is obviously impossible. In order to select the best design from this virtually infinite number of possibilities, the designer needs to have intimate knowledge of the effects of all the aberrations on the quality of the image. He or she also has to be able to identify those components of image quality that provide the necessary characteristics of the lens system. Today the design process can keep a small staff busy for up to two years in order to keep expenses within an economically viable range. There is no better way to illustrate the overriding importance of the art of optical design that is needed at the start of a new lens system.

It appears that that the creativity of the optical designer today is even more important than it was in the past. And indeed it is!

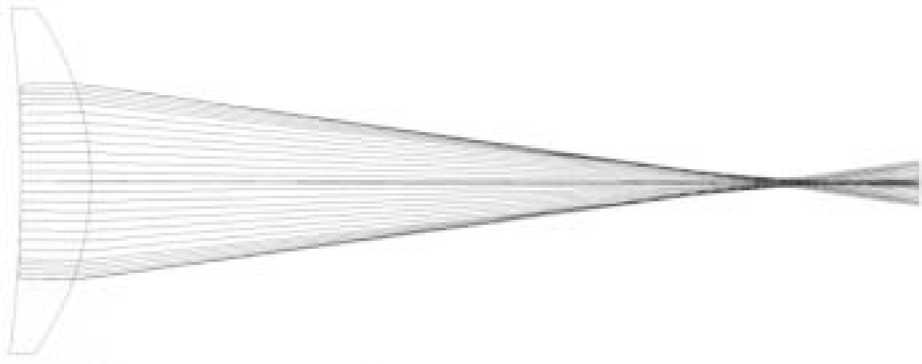
As stated in the description of the computation of the triplet, an important task of the lens designer is to assess the various aberrations and then to undertake the corresponding alterations in design specifications (radii, thicknesses, spacings and glass types). It is also most important that the starting design type be selected judiciously, so that the desired correction will even be possible.

The merit function

When there are so many possibilities for defining and correcting a particular optical system, the designer has to be able to sense exactly when the desired level of correction has been reached. Computers and optical design software can easily produce numerical data. They are able to trace millions of rays within a short time. The optical designer can use this information to gain an insight into the kind and the order of magnitude of the various aberration components. After that, two questions remain to be answered:

- Does the lens that has just been computed meet the requirements? and

- Is there an even better solution?



This is where the art of Leica lens designers becomes evident. It is not only at Leica that one is familiar with optics and aberrations, and with the fundamental fact that every photographic lens is a compromise between ideals and reality that incorporates a fine balance of the many aberrations that have to be compensated with one another. There is always a small residual aberration component in a lens. In the end, it is the weighting and the method of compensation of the aberration balance that determines how the resulting imaging performance is perceived and accepted by photographers.

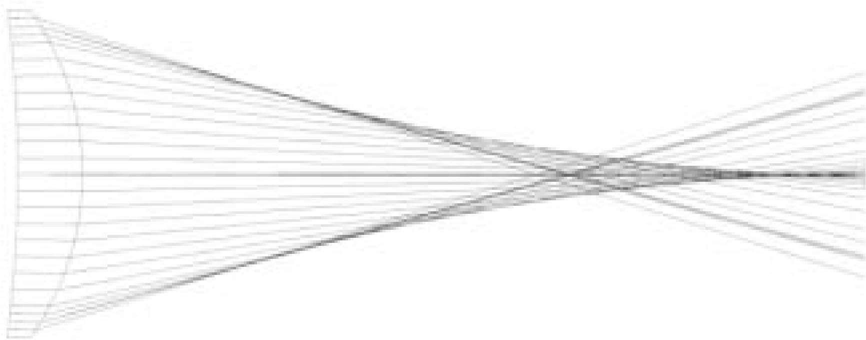
Leica lens designers have a very strong ambition for developing optical systems with a particularly high optimization of the various errors that will reduce residual aberrations to their lowest possible level. If one would claim that a particular computation is not good enough, one should have a standard with which one could compare what one has and what one wishes to have. The computing program is of no help in this case. Imagine that you are in a helicopter flying over a hilly landscape and that you are trying to locate the deepest valley. You will certainly be able to locate a valley that is very deep in relation to its surroundings. But you don't know what is beyond the next mountain. An optimizing program seeks to find a deep valley and it will certainly find a local low point. But without overall knowledge of the entire landscape, one will keep on searching, never knowing whether one has really found the deepest valley. One can only obtain this structural information if one knows the peculiarities and the characteristics of an optical system. Leica lens designers call this the soul of a lens. The merit function that one associates with a lens must be realistic and it should elicit the very best performance from a lens. It should be pointed out, however, that every lens designer interprets and defines "the best performance" differently.

We are accustomed to imagining light rays as individual lines. That makes sense for the computations. But in reality a flow of energy consisting of the sum of all the light rays radiated by all the object points in the direction of the filmplane will traverse the entire lens. The complete flow of light strikes the front lens element and is transmitted through the optical system. This is called luminous flux. Knowledge and understanding of this flow are extremely important during the design stage of a lens. Light energy should traverse the lens smoothly, without much deviation or resistance. That almost sounds like a concept of Zen philosophy.

Steps in the design process

When a new lens is to be developed, the designer normally selects an existing system and uses it as a start towards an improved design. The constraints of dimensions and weight are particularly important in the case of Leica M lenses. The first attempt is constrained by ancillary specifications such as physical dimensions. Lenses should be small and handy, and they should not obstruct the view through the viewfinder. These characteristics are quite logical from the user's point of view, but they constitute a constraint for the designer. Greater optical performance often entails a greater physical volume, a good reason for applying new solutions, like aspherical lens surfaces in order to achieve the desired result. Excessive weight must be avoided, and this limits the number of elements and the selection of types of glass. The focal length and the maximum aperture already dictate the possibilities. The designer has to find a creative starting point that can lead to success or that is at least promising for optimization (finding the deepest valley). Here too, there is a philosophical consideration: an optical design should have a kind of beauty that one can recognize. There are cross-sections of lenses that look very daring, and there are others that possess an optical beauty. The latter are the best lens designs. Without a good starting premise, no lens will deliver the performance that is expected. Optimization will go around in circles and sometimes no progress can be made. When there is a starting premise with which one feels comfortable, one can proceed with the next step, which is the correction of the Seidel aberrations.

To correct the Seidel aberrations is basically not very difficult, but we know that they are also used for influencing the higher order aberrations. Therefore



one should make a judicious choice of promising system parameters at the very beginning, otherwise one can only achieve the desired result by using more complex procedures. Every additional lens element can be used for correcting an aberration, but this also creates new problems. It will quickly become apparent that these problems can become utterly overwhelming. A typical feature of Leica lenses is their relatively low number of lens elements. The 90 mm f/2 Apo-Summicron-M ASPH. has only five elements and it delivers outstanding performance.

The next step is the optimization of the system: small alterations of the lens curvatures, the choice of glass types, spacings and thicknesses are implemented to achieve the desired level of correction of the aberrations. The last step is to balance the residual aberrations in relation to one another in such a way as to achieve the imaging performance that has been specified.

One of the quiet revolutions at Leica has been the very close cooperation between optical and mechanical engineers. There is no benefit in designing a lens that cannot be manufactured or that cannot be fabricated with sufficient accuracy, or that is too expensive to produce. The optical designer has to be very creative in this regard. For a lens that can only reproduce fine structures, the manufacturing tolerances that are required are different from those that are needed for producing a lens that can clearly reproduce the very finest structures. That is logical: when one wishes to record tiny object details on film, one can tolerate fewer errors than one would tolerate in recording coarse object details. Very tight manufacturing tolerances in the assembly stage assure the possibility of achieving the computed optical performance in every individual lens. It is not an easy task to stay within these tolerances, and it can only be done if these tolerances have been worked out in close cooperation by the optical and mechanical departments.

Leica-specific characteristics of Leica M lenses

The progress that has been achieved in the performance of Leica M lenses in recent times can be explained in the following manner:

The optical design programs have been improved and they take into account the latest findings in aberration theory, optimization and weighting of imaging performance. Knowledge of the characteristics of the various types of glass has also been expanded. The time has passed when new types of glasses were introduced in quick succession. Large suppliers of glass have catalogues that are quite stable. Leica lens designers would like to have a few additional exotic glasses created, but it is questionable whether this will ever happen.

The cooperation between the mechanical and optical departments has been intensified. The input of manufacturing engineers to the computation of a high performance lens is a prerequisite for a good result.

Leica has extensive experience with the various aberrations, with their effects on the photographic image and with the more complex inter-relations of these aberrations. Current Leica M lenses possess certain outstanding characteristics that can be classified as family characteristics. The latest Leica M lenses feature a performance at full aperture that is a quantum leap better than the performance of their predecessors. This does not pertain so much to the performance in the center of the image, but mostly to its field, i.e. in the image zones. The overall contrast has also been considerably and visibly heightened. Stray light has been very well suppressed and this can be verified by examining the very fine structures in the image. Older lenses render these tiny details blurred or they don’t record them at all, whereas the latest lenses render them clearly and distinctly, which becomes especially evident in large projection. The fine gradation of highlights and shadows in light and dark portions across virtually the entire image area proves that the important monochromatic aberrations, like spherical aberration, coma and astigmatism have been extremely well corrected. Brilliant and delicately shaded colors are rendered accurately, which is an indication of outstanding color correction. Chromatic errors that often become noticeable as peripheral unsharpness are well corrected. Another characteristic is the optimal aperture in the new lenses, which is already reached by stopping down only one stop from full aperture. The old axiom that states that an aperture of f/5.6 or f/8 has to be used for achieving the best performance is no longer valid so universally. The clarity of the image is also improved because stray light, i.e. light energy that does not contribute to image formation and that is scattered in the optical system, is controlled effectively.

These general characteristics of the latest Leica M lenses are clearly discernible in the photographic image. The full performance potential of Leica lenses can only be exploited when the photographer has a thorough grasp of his technique. The correction level of these lenses is of a very high level, and it can only be fully appreciated when the demands are high. A good 20 x 25 cm

(8" x 10") black-and-white print cannot show all the details that a lens is capable of reproducing and systemic unsharpness in the small details cannot be seen. But when a greater enlargement is made, for instance 30 x 40 cm (12" x 16"), the results are much more dramatic. Now it is essential that every link in the performance chain is utilized to best advantage. In this case the lens becomes the most important link in that chain and the photographer can make good use of its characteristics.

Unsharpness and sharpness transition

There is only one plane of sharpness, and that is the film plane. That means that a bundle of light rays that comes from an object point traverses the film plane like a cone of light. In the ideal case, the tip of the cone will be located exactly at the film plane, and the point that is being reproduced will be rendered as small as possible. The cross section of the cone on both sides of this point is larger and the point is reproduced as a small disk. This is normally called the circle of confusion. If the cone of light is generally narrow, then the difference in the diameters of the point and the circles in front of and behind the tip is also small. In that case the transition from sharpness to unsharpness is smooth. New Leica M lenses are corrected in such a way that they are capable of reproducing the finest structures and details of the object. That also means that the tips of the light cones have to be very small and that they have to subtend a larger angle (see illustration). The circle of confusion will be relatively larger (also absolutely larger) than it was in the previous example. A characteristic of current Leica M lenses is a visually faster transition from sharpness to unsharpness. This is helpful in composing the picture at full aperture, because pictorially important portions of the picture will stand out distinctly from the background. The circles of confusion will often appear somewhat more disturbing, and this should be taken into account as the picture is created.

The latest Leica M lenses are not only superior to their predecessors optically, they also have a different kind of image rendition that must be taken into account when one changes over from an older to a newer version of a lens. But that is precisely the fascination and the beauty of Leica M lenses: one should become familiar with them and one should study their "personalities".

Core technologies

Current Leica M lenses embody a thorough understanding of, and a sensitivity to issues of geometrical and physical optics, of mechanical engineering, of optical fabrication, of glass selection, of the relationship between residual aberrations and image quality. Leica lens designs result from ingenuity, creativity and from a solid scientific knowledge of all relevant aspects of an optical system. Most important are, of course, the guiding principles of the great designers of the Wetzlar era, notably Max Berek, and the accumulated experience and insights of his successors. Part of this knowledge has been incorporated into current computer programs. There is one aspect of overriding importance, however, that cannot be codified into rules or algorithms: the culture of studying the true image potential of a new design and the know-how for transforming such a design into a real masterpiece of photographic optics.

Leica lenses are not only highly corrected, they are also meticulously crafted works of optical art. They are honed to deliver a fidelity of reproduction that reflects the combination of philosophy and state-of-the-art optical design that is so unique to Leica designers.

If we were to identify the most important tools of Leica designers we would produce this list:

- aspherical surfaces
- apochromatic correction
- glass selection
- thin film coatings
- engineering of lens mounts.

None of these areas is an exclusive domain of Leica. In fact, many manufacturers around the globe use aspherics, apochromatic correction and have access to the same glass catalogs that Leica designers use.

When I discussed these topics with Leica designers, I cited the example that aspherics technology has been in use since the thirties and is now in widespread use by many optical manufacturers. They responded with characteristic modesty that they themselves might know a few things about aspherics that helps them to design lenses with improved imagery. Let us look at these tools, some of which are surprisingly old.

Aspherical surfaces.

Most lenses used in photographic optics have spherical surfaces, which means that the curvature of the surfaces has the form of a sphere. The limiting case is a plane or flat surface, i.e. a sphere with an infinite radius. Spherical surfaces are relatively easy to make and ray tracing is also simple (at least conceptually). An asphere (a-sphere) is defined negatively: any surface with a shape that departs from a sphere is called an asphere. A spherical surface has a radius R with the center of the curvature somewhere on the optical axis. The radius will define all points above and below the optical axis. For an aspherical surface we need more information. We define the difference between the reference sphere and the actual asphere at several heights above and below the optical axis and enter these figures into an equation. The equation can be very complex, but in its simpler forms it defines a parabola, or ellipsoid or hyperbola. An asphere may have a surface that has several zones of asphericity, one paraboloid, and another ellipsoid. The complexity of the surface should be weighted against the cost of manufacture and the function within the overall optical system.

There is a tendency to interpret the use of aspherical lenses in an optical system as a sure sign of superior optical performance. It is not. Some optical designers can create fabulous designs by using a particular computer program, while another person employing the same program will get moderate results.

An aspherical surface introduces some carefully controlled aberrations on top of the aberrations that result from spherical surfaces. If you do not have a very thorough understanding of the basic aberrations in the system, the addition of an aspherical surface may not be successful.

A prototypical case would be a lens with spherical aberration, among several other aberrations. The designer could use the spherical system to correct all aberrations, except the spherical aberration. Then, by adding an asphere, he or she can correct the spherical aberration.

The use of aspherical surfaces on mirrors and telescopes is very old. Aspherics were already produced in the 18th century, using trial and error methods. Therefore they are not new tools for aberration correction.

Aspherics are used when systems using only spherical surfaces become very complex, or when systems become too large, and for many more reasons.

Using an aspherical surface gives the designer an additional degree of freedom in the correction of optical systems, which enables the designer to build high quality optics quite compactly. The advantages from a correctional perspective are the elimination of spherical aberration and the correction of the spherical aberration of the pupil (distortion). Aspherics can be used to achieve wider apertures, wider field angles, reduction of weight and volume (one aspherical surface replaces two spherical ones). In fact, many optical and mechanical challenges can be met with aspherics.

The manufacture of aspherical surfaces requires extreme precision. The aspherical deformations are calculated to a very small fraction of the wavelength, but this level of precision is not attainable in manufacture. The required precision for high quality optics is 1/4 wavelength of light (that is 1/3000 of the width of a human hair!). In optical shop testing, this level of precision can be approached by using interferograms. It is very difficult to test aspherics in this manner and in order to guarantee a precision of 0.5 micrometer, one needs to use CNC grinding and polishing equipment.

Leica, however, does use an interferometer to check the sphericity of lenses. They employ a compensation system to adapt the spherical wavefront from the interferometer to the asphericity of the lens surface. These compensation systems can consist of a spherical lens. The most recent method for a compensation system is the use of CGH's (computer generated holograms). Leica is now using this technique.

The required aspherical form can be pressed in plastic, or it can be a hybrid form consisting of a glass lens with a molded plastic form attached to it or, as used by Kodak on the disc camera, it can be a glass lens with pressure-molded aspherical surfaces.

The 50 mm f/1.2 Noctilux, introduced in 1966, was the first lens produced by Leica that had two aspherical surfaces. In those days, aspherical lens surfaces were polished to an approximate shape and then hand-corrected afterwards. As the level of deformation is very small on most aspherical surfaces, there is a risk that the polishing at the end may restore the spherical form! Only a very few workers at Leitz were able to manually correct the aspherical form, and even they produced surfaces beyond the required shape. This costly and laborious manufacturing process was soon abandoned. The potential of the aspherical surface for vast improvements of the image quality, however, was too attractive not to pursue. Huygens described its theoretical potential as early as 1678. Three hundred years later the manufacture of precision aspherics became reality. At first Leica used a new technique, jointly developed by Leica, Schott and Hoya. Leica contributed the technology of the molding tool. This methodology was first employed in the 35 mm f/1.4 Summilux-M aspherical (the 21 mm, 24 mm and 35 mm f/2 lenses are all of the Summilux type). It generates high precision surfaces, but the technique is restricted to lenses with a small radius (about 20mm). Furthermore only a few glass types can be used that can withstand the heating, pressing and cooling without adverse effects. This restricts the choice of glasses and many designers complain that the more than 100 glass types now in glass manufacturers' catalogs of the are not sufficient.

The next step is the use of computer-controlled grinding and polishing machines that allow the designer freedom to choose glass types and radius as needed. In the line of Leica M lenses, the 90 mm f/2 Apo-Summicron-M ASPH is the first lens to have an aspherical surface produced by this promising technique.

The Leica designer always needs more possibilities for the correction of aberrations. As soon as a certain level of image quality has been reached and the understanding of a lens system has improved, a higher level of aberrations has to be dealt with. Therefore the designer needs more parameters to change and influence. The demand for ever more exotic glass types, more lens elements never ends. Aspherics are a very effective and elegant technique for the design and construction of complex optical systems.

The theory and technology of aspherics is in its infancy, however, and it is certainly not as well understood as spherical technology and correction theory. Leica designers employ aspherics whenever there are clear advantages for improving image quality, reduce volume or number of lens elements or when designs can be created that would not be possible without the use of aspherics.

The mere use of aspherics does not automatically signify a high performance lens. Sometimes the designer can create a lens with spherical surfaces that theoretically has the same performance as the aspherical one. It might, however, be impossible to build that lens with the required precision and tolerances. So when Leica designers employ aspherical surfaces, it is a well considered component of the complete lens design.

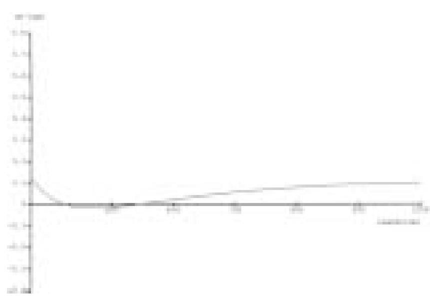
Apochromatic correction.

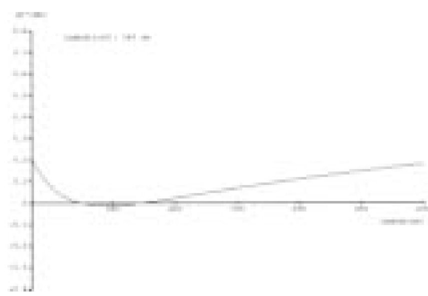
Ernst Abbe computed the first apochromatic lenses around 1895. In those days, the field of microscopy was expanding rapidly and the very high resolution required for microscopic lenses demanded that all aberrations be very small, that is, close to the diffraction limit. There is always an apochromatic error in the photographic image and this error extends over the whole image field. Generally it has a lower magnitude than other aberrations and so will not be identified separately. The visible result of the apochromatic error is a degradation of contrast and a fuzziness of small image details. One should look for the apochromatic error in the center of the image (on axis). On axis the most disturbing aberrations have been corrected quite effectively and so one is left with the more difficult aberrations, like spherical aberration, chromatic error of the spherical aberration and apochromatic error.

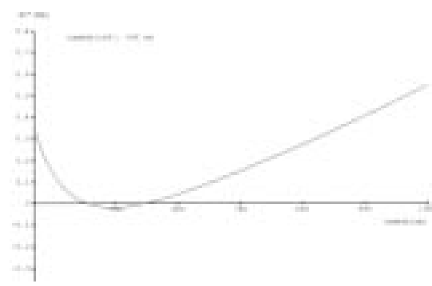
What is this apochromatic error? If polychromatic light enters a glass, it will be refracted into a number of rays, each of a different wavelength. Each ray will follow a slightly different path. The blue color will be focused closer to the lens than the red color. The difference in length between the two locations is called the longitudinal chromatic aberration. Because the blue light converges to a focus closer to the lens, the resulting patch on the image plane will also be larger. This is called lateral chromatic aberration. One can see this defect as a series of color fringes around a spot.

The magnitude of the chromatic aberration depends on the Abbe-number, the refractive index, the focal length and the field angle. Note that the focal length is important, which explains why lenses with long focal lengths need to be corrected for chromatic aberrations in particular. The change in focal length that results from the fact that the refractive index of a glass is different for different colors is called dispersive power. As an indication of the very small magnitudes that are involved, we may note that the distance between the red and the blue focal points corresponds to 1/60 to 1/30 of the focal length. This chromatic variation of index is called dispersion. If one would plot the curves for refractive index versus wavelength for two different glasses, for example Schott BK7 and SF2, the curves would be non-linear and different. Every glass has its own and unique graph. Crown glasses have relative low dispersions and flint glasses relatively high dispersions. Overall dispersion defines the general dispersion characteristic. But if we are interested in the blue part of the spectrum we need to study the dispersion of the blue part. Two glasses have different amounts of dispersion and the shape of the dispersion curve is different. So, in addition to the overall dispersion, we also need figures for partial dispersion, ‘partial’ referring to a part of the spectrum. If a glass produces a long blue spectrum it is called a long glass. A glass with a short blue spectrum is, not surprisingly, called a short glass. Most crown glasses are short and most flint glasses are long. Some glasses do not conform to this general rule. We have a few long crowns and short flints. These ‘out of line’ glasses are called glass with anomalous dispersion.

Most glasses on the glass chart lie along a straight or slightly curved line, the so-called normal glass line. The out-of-line glasses, the ones with anomalous dispersion, are also referred to as glasses outside the normal line.







It is quite easy, at least in principle, to match two glasses with opposite dispersions in order to make sure that at least two colors (red and blue) will come to a focus at the same point on the optical axis. Then we have an achromat, which is quite often a flint/crown pair. Other colors of the spectrum (apart from the blue and red) such as green and purple will still be out of focus. These residual errors are called the secondary spectrum or secondary color.

The apochromatic error is the result of different partial dispersions or different proportions of partial aberrations of the glass types.

Theoretically it should be possible to get an apochromatic correction by using three glasses with different dispersions. But the non-linearity of the dispersion curve and the partial match of the partial dispersions will make life hard for the designer. For the correction of the apochromatic error, the use of special glasses outside the normal line may be advantageous. But these glasses have properties that make them hard to employ. They are soft and very difficult to polish, they may be not available in the required diameters, and they may also be very expensive. As a result, designers can attempt to achieve an apochromatic correction with normal glasses (the three-glass-solution). In order to use such glasses, however, one must take into account monochromatic errors. Sometimes the designer also encounters difficulties in the correction balance and he may run out of useful parameters so that he would need a system that is too complex.

I mentioned earlier that the designer, when he corrects a system for two colors, is left with residual chromatic aberrations. There is no rule that states how large this residue should be. Nor is there any rule that specifies how small the apochromatic error must be in order for the lens to be called a true apochromat.

Pragmatically, all one can say is that there is a long bandwidth between an achromat, a semi-apochromat and a true apochromat. Therefore, any lens with very small chromatic aberrations can be called an apochromat, even when the correction has been accomplished by using glasses from the normal glass line.

Leica uses glasses for its apochromatic corrections that lie outside the normal glass line. These glasses are also known incorrectly as APO-glasses, which is a misnomer. In reality they are glasses with anomalous dispersion. The dispersion curves are non-linear, making it difficult to compute corrections with these glasses. The curves will never match completely, so that some residual aberrations will be left in the system. The residuals left after achromatic correction are called the secondary spectrum, and it is no surprise that the residuals left after apochromatic correction are called the tertiary spectrum.

Leica designers know the non-linearity of these glasses very well. The art is to know what glasses to employ where in the design. As noted before, glasses with anomalous dispersion can be found in the catalogs of Schott, Hoya, Corning and others, which also list all the glass characteristics. Using such glasses may not be unique to Leica. But the knowledge and expertise needed to extract the most out of these types of glass, in combination with the creativity and experience that the designer draws upon to balance the conflicting characteristics of the lens system, are part of the core technology of Leica. The result is a lens with a very small apochromatic error that has been balanced with all the other aberrations and that has been corrected over the entire image area, for excellent results at full aperture or stopped down.

Thin-film coating.

Uncoated glass reflects a small part (4%) of the incident light per surface. The resulting problem is not so much a reduction of the transmitted light, but the increase of stray light. This stray light is scattered over the image plane, causing a dull and flat image with lower contrast.

There are two possible solutions. On is the application of thin film anti-reflection lens coatings, invented in 1935 by Dr. Smakula of Zeiss. The other is the careful prevention of internal light reflections by interior mechanical surfaces of the lens mounts.

The coating technique is basically a simple process. A very thin interference layer of a material of lower refractive index is applied to a glass surface with a higher refractive index. The actual mathematical computations are very complex. The thickness and the refractive index of a layer must be computed so that a destructive interference will result. A single layer coating can be optimized for only one wavelength, usually green, which is why the surface looks purple by reflected light. This type of coating has an optical thickness of 1/4 of the wavelength that is targeted. It is also called quarter-wave coating. The coating material is often Magnesium Fluoride with a refractive index of 1.38.

For glass with a low refractive index a single coating often suffices. It is not effective on glasses with higher refractive indices. With three or more layers, a more effective broadband low reflection coating can be achieved. A three-layer coating produces an anti-reflection curve with three minima that correspond to the selected wavelengths. The number of layers can become quite large (6 to 11 stacks of layers), and they may be multi-purpose, used for reduction of reflections in order to improve transmission and for balancing spectral transmission.

It can be shown that a four-layer coating with two different refractive indices is very effective. The most frequently used technique of coating a lens is thermal evaporation coating. The coating material is heated in a vacuum chamber that contains the lenses to be coated. The coating vapor is then deposited on the glass surfaces. The correct thickness of the layer is monitored by a photometer, but irregularities can occur. Not all coating materials can be deposited in this manner and sometimes much higher temperatures are required. That is when the technique of electron beam coating is employed. Also in a high vacuum, the glass is bombarded by a beam of high-energy electrons, which forms a layer on the heated glass.

This heating and cooling must be performed very carefully as the glass is very sensitive to this treatment. The layer must be deposited on a smooth and clean surface, as any irregularity will cause unwanted local reflections. The cleaning process is very important. Leica requires that some lenses must be coated within a few hours after cleaning to ensure that the air does not affect the surface. After the application of the aforementioned coating techniques, the lens surfaces are covered with a layer of a microscopically small pillar-like structure. The structure of the surface of this layer is not amorphous, it consists of rows of very small pointed pillars, somewhat like rows of nails with the tips pointed upwards. The resulting coated surface still has a microscopically small roughness.

The complicated and time-consuming processes of cleaning, heating, vaporization, cooling for many layers inevitably generates errors.

Leica now uses a new technique, developed in cooperation with Leybold: the plasma ion-assisted deposition. (IAD: ion-assisted deposition). With this technique the heating and cooling stages are no longer necessary and the growth of the coating layer is not pillar-like but amorphous, producing a smoother surface. The technique basically consists of bombarding the target, which consists of the coating material, with argon ions, setting free atoms that are deposited on the substrate to form the coating.

The employment of this technique is another example of Leica core technology.

Every aspect of the optical system, be it glass selection, cleaning of glass surfaces, coating, mounting, computation, or quality control, is scrutinized to find the best solution to achieve the goal of high performance optics.

MTF diagrams: those seductive curves!

The best and most convincing proof of performance is, of course, a picture. It can be in the form of a black-and-white print, a color print, or a projected image, which is still the most impressive presentation of Leica photography. In practice however, there are too many variables that have to be taken into account when we compare pictures. We don't just compare lenses, we compare the entire chain of performance. Therefore we need a standard for the imaging performance of an optical system. In the past, it was thought that a simple solution was to use resolving power in lines per millimeter for these evaluations. But various problems surfaced, some of a visual kind, others of a theoretical nature, which made the use of such a standard unreliable. We are not just interested in reproducing separated lines but, more important, whether these lines can actually be seen as clearly separated lines. That is why an indication of contrast is needed. The difference between a bright and a dark band can be discerned far better when the contrast between the two bands is significant. When we look at a light gray / dark gray pair of bands instead of a white and black pair of bands, the difference is certainly less pronounced.

Residual aberrations that remain in the lens basically only cause unsharpness in a picture. By unsharpness we mean that light rays do not converge into a miniscule spot, but that they come together into a slightly larger spot called circle of confusion, which only means that contrast is reduced.

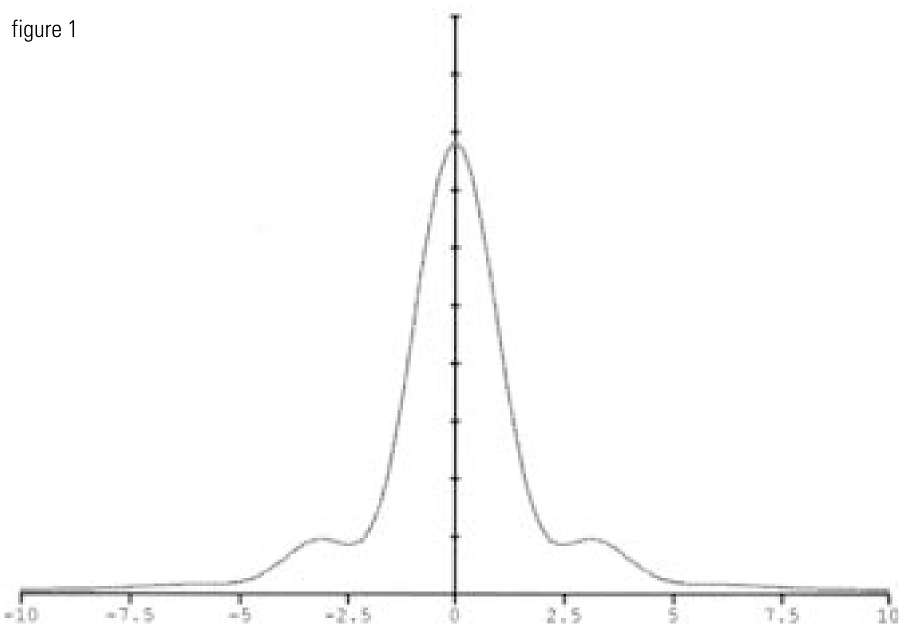
Let us imagine a grid that consists of black and white stripes of equal width. When such a grid is reproduced by a lens, diffraction, aberrations and stray light cause part of the light from the white stripes to reach the black stripes. This redistribution of light results in the reduction of contrast. The narrower the stripes, the more light from the white stripes will spill into the black stripes, further reducing the contrast. A lens with inadequate correction of aberrations has larger circles of confusion, which means that contrast will be even lower, whereas a lens with excellent correction of aberrations will also have excellent contrast rendition. Unfortunately the reverse does not hold true, in that a good contrast rendition does not necessarily mean a well-corrected lens. Design begins with a concerted effort to correct the many aberrations and when that has been achieved, high contrast is one of the results. The reverse is not always true.

The fineness of the grid can be adjusted by changing the width of the stripes. Let us consider stripes with a width of 1/10 of a millimeter. Therefore 10 such stripes make up 1 millimeter. This is defined as spatial frequency in lines per millimeter. In the aforementioned example, that spatial frequency amounts to 10 lines/mm. Because one cannot see black without white, it was agreed to use line pairs as a structural period. Therefore the figures stated in MTF diagrams, such as 5 or 10 l/mm, must be interpreted as periods or line pairs per mm. In other words, 5 lp/mm means 10 stripes that are alternately light and dark.

Leica furnishes MTF diagrams for 5, 10, 20 and 40 line pairs or periods (10, 20, 40, 80 light/dark stripes). The more stripes per millimeter, the finer the details that can be reproduced.

One often wonders why the finest structures are limited to these 40 lp/mm. There have been articles in the press citing lenses that can record 200 or more lines per millimeter. But now it has become clear that the number of lines per mm is interesting only when stated in conjunction with the respective contrast. At 200 lines per mm the contrast is so low that it is virtually impossible to distinguish anything at all. The 40 periods used by Leica as a sensible lower limit result in a dot size of 1/80 mm or 0.0125 mm. It is difficult to imagine how small that dot is on a 35 mm negative! Take a negative and a ruler calibrated in millimeters. Then subdivide the width of one millimeter into 80 tiny individual units. That gives you an idea of the performance capability of today's lenses. Once we have established an understanding of how narrow such a unit is, then it becomes obvious that the smallest vibration can spoil the entire picture. And a small amount of unsharpness from inaccurate focusing has a disturbingly large effect when such small image details are important.

figure 1



How to read MTF diagrams?

The vertical axis is calibrated in percent of contrast, always based on an original contrast of 100%. The subject that is being reproduced is that grid of light/dark stripes in ever smaller widths or periods. Every light/dark pair of lines in the original subject, even if it is very fine, has an ideal contrast of 100%. This means that all the light energy comes from the light stripe, and none at all from the dark stripe. The lens distributes this energy over both stripes, thus reducing the absolute contrast. The finer the structure, the more that contrast is lowered. With 5 lp/mm one can still achieve a contrast of nearly 100%. At 40 lp/mm however, one would be pleased if contrast were as high as 50%.

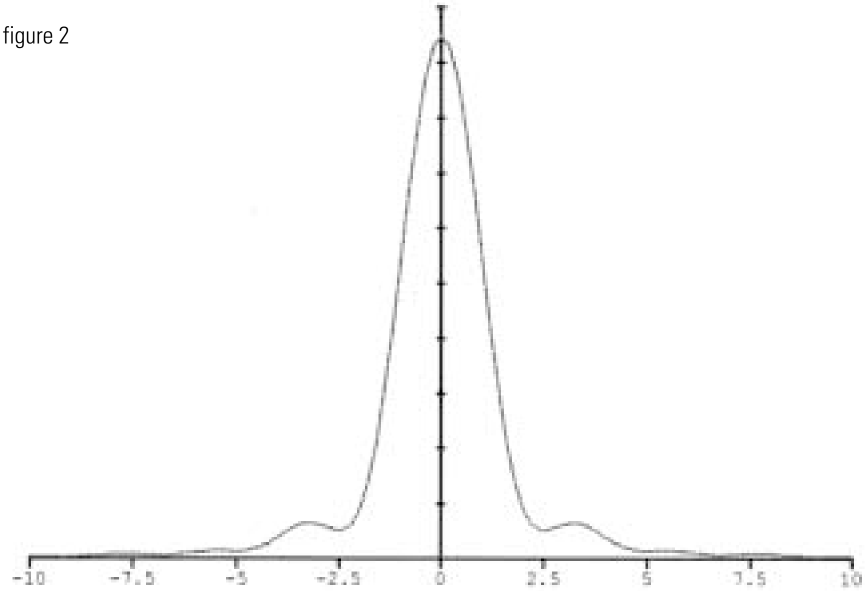
Thus the reduction of contrast is a function of spatial frequency. Since the contrast in an image is an interpretation, or a transfer (modulation, change) of the original contrast, the relation between the original contrast and the reproduced contrast is called the Modulation Transfer Function, or MTF.

The effect of aberrations is less pronounced in the center of the image than in the outer parts of that image (i.e. in the "field"). A standard 35 mm negative has a diagonal of 43.2 mm. Therefore the maximum distance from the center of an image to its outermost corners is 21.6 mm. The performance of a lens varies between the center of the image and its field, because there are aberrations that disturb the field more than the center. That is why the horizontal axis of an MTF diagram is calibrated in distances from the center of the image, i.e. '0' represents the center of the image and '21' (mm) its corner. Therefore '12' indicates the height of a standard horizontal 35 mm frame, and '18' its maximum width. When one wishes to examine an MTF diagram more closely, one should concentrate on the region between 6 and 15 mm from the center of the image, because that region contains the pictorially important part of an image. The central portion of the image, from 0 to 6 mm from its center, is satisfactory in most cases.

An MTF diagram thus provides a great deal of information because it shows the contrast reduction for different kinds of image details for the entire 35 mm format. The 5 lp/mm curve describes the reproduction of very coarse image details, the 10 lp/mm curve the reproduction of clearly visible details, the 20 lp/mm the reproduction of very fine structures and the 40 lp/mm curve the reproduction of the finest details of the subject.

Low contrast values for 5 and 10 lp/mm indicate a flat image, and high values for 20 and 40 lp/mm indicate that fine details of the subject are reproduced cleanly and clearly separated.

It should be kept in mind that each diagram is valid for a specific aperture. When diagrams are available for various apertures, one can observe the behavior of performance as the lens is stopped down. All the MTF diagrams shown here display the curves for full aperture and for optimal aperture. The direction of the stripes is also taken into account. They can be orientated horizontally or vertically, and this has an effect on imaging performance. When the two curves (tangential = vertical and sagittal = horizontal) are widely separated, this often means a blurry reproduction of figure 2



subject details. In such cases, a reproduction with good contrast is achieved only when the details are orientated in the "good" direction.

MTF data therefore provide an accurate and comprehensive description of the imaging performance of a lens. Nevertheless, it has to be used with caution. In practice, small differences between the curves are of negligible consequence. One should examine the entire image. One should also keep in mind that, although these diagrams provide a very good description of all the aberrations, they do not cover all the considerations. Stray light, vignetting, color correction, distortion, performance in the close-up range, for instance, cannot be evaluated by means of MTF diagrams. Because the method of creating these diagrams is not standardized, one should only compare the data provided by different manufacturers with great caution or better yet, not at all if it is not known whether they were created by the same method. An important factor is the quality of the light that is used for obtaining the measurements. White light contains a great number of wavelengths. Measured values are different when only three wavelengths are used, compared to readings obtained with seven wavelengths. The weighting of the wavelengths is another influential factor.

One often wonders whether MTF data can really describe optical performance in a way that can be used in practice. We know that the objects being photographed are three-dimensional, that they have depth. Even a wall has a surface texture that has depth. We assume that the test grids (with the light and dark stripes) that are used for obtaining MTF measurements are only two-dimensional (i.e. they have height and width, but no depth), so that they are not representative of real photographic subjects.

One should disregard these thoughts. The transfer of the contrast of the structural periods (the grid) is a measure of the optical efficiency and the optical performance of a lens in general. What is actually measured is how much light energy from a subject point reaches the corresponding image point and how the energy distribution is shaped in the image point (actually the image disc). This actually shows the effects of the aberrations. These image points can be located in the plane of sharpness but also in front of, or behind that plane, i.e. in the range of unsharpness. Although the reproduction of the subject point will be different, but the principle remains the same. The aberrations determine the location and the shape of the image point, as well as its energy distribution. Because points in the range of unsharpness create the impression of three-dimensionality, MTF data is also valid, in principle, for depth perception.

How are MTF measurements actually obtained?

There are two methods: one method computes MTF data, the other method measures MTF values. Basically, there are no differences, and Leica uses either method, whichever is most appropriate: the optical design department computes the MTF values, and the manufacturing department uses an MTF-measuring instrument to obtain MTF data (see the diagrams). Both methods are based on the same theoretical principles, so that their results should not be different from one another. A variance between the two values only occurs when the lens assembly department can not conform to calculated tolerance values.

Let us return to the image point as a representation of the ideal subject point. This point source is reproduced as a tiny disc in which light rays are distributed within a circle. Most of the rays will converge in the center of this circle, while some of them are scattered towards the perimeter of that circle. Light distribution can be described in the form of a point spread function or spot diagrams by means of a 3D-diagram (with x-, y- and z-axes). The x- and y-axes (depth and width) show the shape of the disc and the z-axis (height) shows the intensity of the light distribution (see the illustration of a point spread function). Figure 1 (point spread function) shows an ideal image point. The width of its image point spread is small and the peak is very high. This means that nearly all the light energy is concentrated in a very small circle (like a point). The actual height of this point reproduction is 20 µm (twenty thousandths of a millimeter) and the "point" is 5 µm wide at its base (five thousandths of a millimeter)! That means 200 points within one millimeter, or 100 line pairs per mm (lp/mm)! Figure 2 shows this point again, but this time as a cross-section. It contains the same information, shown in a different manner. Figure 3 shows a point spread function with a different shape. Its base is now approximately 8 µm wide, and its height is smaller. This point can be described as having 62.5 line pairs. This is logical: the light energy coming from a given subject point remains the same, but this energy can be distributed over small circle with a high peak, or a large circle with a lower peak. These computer-generated values and images are based on classic ray-tracing principles. The computed position and distribution of the light rays from the subject point can be used for generating the point spread function with mathematical methods.

For actual MTF measurements, an instrument is used that is capable of analyzing the distribution of light across a narrow slit. This narrow slit is illuminated from behind and a lens images it on a detector. A synchronous motor drives a scanner with another slit (which is much narrower than the rear-illuminated slit) across the width of the illuminated slit. Measurements at the edge of the slit show the transition from dark to light. This measurement is shown in Figure 4. The distribution of light energy at the edge of the slit has the same shape as the cross-section of the point spread function. There is no mathematical difference between a point and a line, which is defined as an infinite number of points in a row.

Using mathematical formulas once again, one can use the measured light distribution of the slit (which is a line image) to arrive at a point image. Conversely, it is also possible to derive a line image from the point spread function.

One can occasionally read or hear claims that an MTF diagram derived from measured values is superior to a computed MTF diagram, but this should not be taken very seriously. One should also consider the fact that at Leica, the measured version and the computed version are nearly identical, which is also a sign that the manufacturing department is capable of producing what the optical designers have devised.

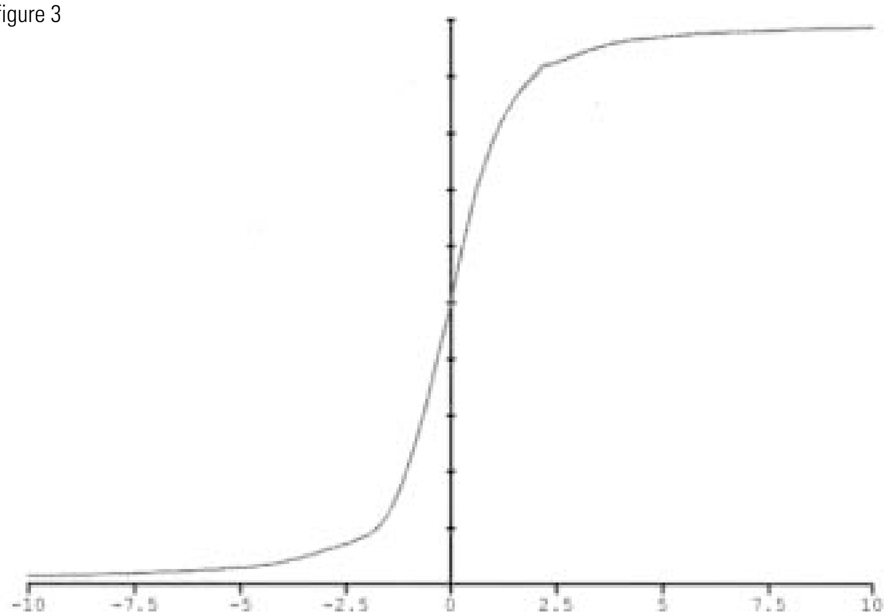
In conclusion

MTF diagrams are not intended to replace your own practical evaluation of a lens. Nevertheless it has been proven that an MTF evaluation comes very close to a visual and subjective evaluation of a lens. While MTF diagrams can only be evaluated by someone with a good fundamental knowledge of optics, they nevertheless also represent a good general indication of lens performance. If personal photographs do not correspond to expectations that are based on MTF diagrams, one should re-evaluate one's own photographic technique. The entire chain of reproduction especially, should be analyzed. MTF values represent pure lens performance, which does not take into account exposure circumstances and material characteristics. The MTF is an excellent means for comparing and evaluating different lenses. In practice, it is very difficult to evaluate comparison photographs that have real expressive power. Small variations in exposure circumstances have a significant effect on the resulting photographs.

After all, in practice there are a great many variables in exposure techniques and also in personal conditions and evaluations. An individual who only creates photographs using small apertures, certainly has different evaluation criteria than one who frequently uses full apertures. When comparing MTF diagrams, one should also observe another fundamental rule: it is not customary to compare lenses that have different focal lengths. First of all, the correction of aberrations is different. A wide-angle lens has a greater angle of view, and oblique light rays have a different weighting than those in a lens with a longer focal length, in which chromatic aberrations have a greater influence. One should also be aware of the fact that, while all lenses are described in terms of contrast values for 5, 10, 20 and 40 lp/mm, this data must be correlated with the reproduction ratio. A 28 mm lens reproduces an object much smaller than a 135 mm lens, and since the lp/mm values are valid for the reproduction on the film, they should be interpreted accordingly.

Personal experience and expectations, not purely MTF-based considerations, are the basis for the acceptance of a newly purchased lens. Even so, at a certain moment in the decision process, MTF diagrams provide a very neutral and objective evaluation of the performance capability of a lens. MTF is necessary when an objective evaluation of a lens is wanted, but it is not the only criterion for purchasing a lens: methods are only as good as the way a photographer uses them, and information is only useful when one knows how to interpret the data correctly.

figure 3



Color rendition

The color rendition of a lens is obviously a very important characteristic which may take precedence over other characteristics. The photographer is often very sensitive to changes in color transmission when changing lenses, especially when photographing the same scene.

Lenses with a yellowish or reddish color cast are called warm and those with a bluish cast are called cool.

Some glasses (for example extra dense flints) contain a large amount of lead oxide and appear to the eye as pale yellow. If such a glass is used in a lens, the resulting color cast will be warm. The cast can be offset by suitable coating, but there are limits here.

The notion of color rendition and color fidelity is a very tricky one. The eye is hardly an accurate detector of color differences as the eye is easily fooled, partly by its great adaptation powers.

But the existing light changes also. At 12.00 clock on a summer day the sun in a blue sky may have 10.000 degrees Kelvin and a few hours later 6.000 degrees. The eye may not detect this difference, but the film does. Films also differ in their spectral responses.

The imaging chain of existing light, scene to be photographed, color rendition of the lens, color response of the film and the eye, introduces so many variables that a meaningful discussion and assessment is difficult.

The International Standards Organization has introduced standard #6728, which is called: "Determination of ISO color contribution index" (ISO/CCI) in 1983. To start somewhere, the ISO analyzed 57 typical camera lenses of high quality in 1979 and used the average relative spectral transmittance values as a base figure: the ISO standard camera lens.

As the typical photographic daylight the ISO used 5.500 Kelvin, which is also used by the emulsion industry. This is the situation when the sun is 40 degrees above the horizon in a cloudless atmosphere. Flashlight is also designated 5.500 Kelvin, but the spectral distribution may be different.

For the spectral sensitivity of films, data from the manufactures for the sensitivity of the blue, green and red sensitive layers were weighted so that a normalized sensitivity per layer could be established.

The spectral characteristics of a lens can be evaluated in terms of its total effect on the several layers of an average color film. The effect on the blue sensitive layers is called the blue photographic response of the lens. These responses can be calculated.

The CCI value is computed by multiplying the relative transmittance values of a lens by the weighted spectral sensitivity values for the blue, green and red sensitive layers. The total response is obtained by summation. and will give a number for blue, one for green, one for red. To simplify, make the smallest element of the three number designations equal to zero. If a lens has a Color Contribution Index of 0/5/4, this means that the average color film in standard illumination sees the lens as providing more green (5) and more red layer (4) response relative to the blue (0) than that obtained with no lens in the system. This lens would give a yellow cast.

The ISO however has established that with the sensitivity data of emulsion manufacturers, the standard lens should conform to the 0/5/4 index.

The tolerances are established as follows.

Blue is 0 with +3 and -4.
Green is 5 with +0 and -2
Red is 4 with +1 and -2.

These tolerances must be derived from a trilinear graph and not by addition. Leica lenses are aimed at the CCI of 0/5/4 and can be considered as neutral in transmission when they are within the tolerance band.

The following is a list of representative Leica M lenses and their CCI values. Values lower than -/5/4 produce a bluish cast, values above -/5/4 a reddish cast

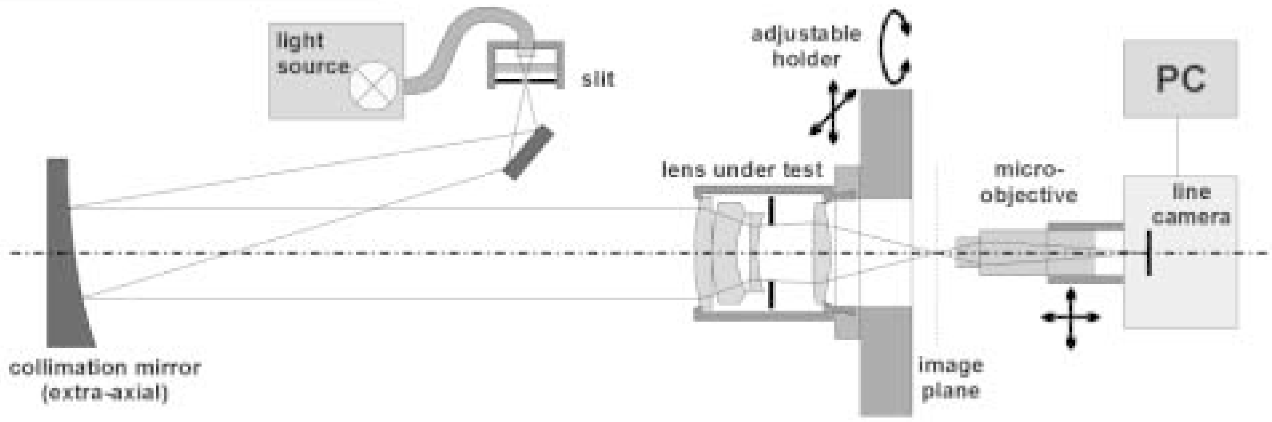
Elmarit-M 2,8/21 ASPH	0	6	5
Emarit M 2,8/21	0	5	2
Emarit M 24 mm f/2.8 ASPH	0	5	5
Elmarit-M 2,8/28 current	0	5	4
Elmarit-M 2,8/28 previous	0	4	2
Summilux-M 1.4/35 aspherical	0	6	6
Summilux-M 1.4/35 ASPH	0	5	5
Summilux-M 1.4/35	0	4	1
Summicron-M 2/35 ASPH	0	4	3
Noctilux -M 1/50	0	8	6
Sumilux-M 1,4/50	0	5	2
Summicron-M 2/50	0	5	4
Elmar-M 2.8/50	0	6	5
Summilux-M 1.4/75	0	6	3
APO-Summicron-M 2/90 ASPH	0	6	4
Apo-Telyt-M 3.4/135	0	5	4
Elmarit-M 2.8/135	0	6	4
Tri-Elmar 4/28	0	5	3
Tri-Elmar 4/35	0	5	3
Tri-Elmar 4/50	0	5	3

From this list you can get a very good impression how of close to neutral most Leica lenses are.

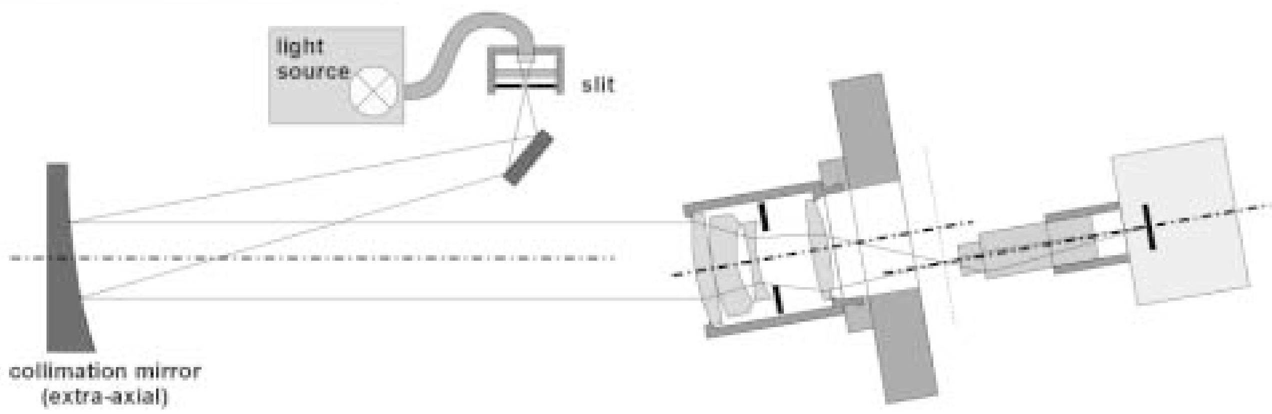
The Summicron-M 2/50 or the Apo-Telyt 3.4/135 might be considered as reference lenses. Take pictures with onr of these lenses and your favorite film. Then take pictures with other lenses under identical circumstances and on the same film, preferably slide film, so that the lab can not introduce additional color corrections. Then compare the pictures carefully and try to find differences in color rendition. This will give you a good idea of what shifts to expect and what filters to use, if any, to correct a small cast.

The difference of 1 point may not be noticeable.

measurement in the center



measurement in the field



21 mm lenses

The optical system with a 90º angle of view is a comparatively late addition to the line of Leica lenses. The design of such an extreme wide-angle lens for the 35 mm format had to contend with three serious problems. Distortion is the obvious one. Optical vignetting is the real villain here. For a lens with a 90º angle of view, peripheral illumination is only about 25% of axial illumination, assuming distortion-free imagery. To beat this so-called Cosine-Fourth vignetting, the designer should accept distortion, but this is not acceptable. An optical 'trick' can be used, however, to increase the level of light energy towards the periphery without increasing distortion. Basically one uses the properties and relations between the entrance and exit pupils to accomplish this feat. A wide aperture is the third villain. Earlier designs had to be stopped down to f/11 or even smaller apertures to get acceptable or even usable image quality. These earlier designs were used on larger format cameras where the need for enlargements is less pronounced than it is in the 'small negative-big enlargement' philosophy of 35 mm photography. Zeiss gets the credit for being the first in 1954 to cross this barrier with its seminal rangefinder-coupled 21 mm f/4 Biogon lens for the Contax camera, that perennial and friendly challenger of the rangefinder Leica. Leitz introduced its version of a 21mm lens in 1958 in the form of the 21 mm f/4 Leitz Super-Angulon lens.

At full aperture, this lens features good performance in the center and, if the clear rendition of fine details is not the prime objective, that aperture is quite usable. The 21mm f/3.4 Leitz Super-Angulon followed in 1963 and it remained in production until 1980. Quite a long working life. But in those days optical progress could almost be measured in generations.

Generally speaking the 21 mm f/3.4 Super Angulon lens is a very good performer. It fine qualities are restricted only by the presence of astigmatism that reduces overall contrast and the crisp rendition of fine details at full and medium apertures.

21 mm f/2.8 Elmarit-M

The first fully Leitz-designed lens for the demanding 90° angle was introduced in 1980. This lens had to have a long back focal length (distance from the rear lens surface to the film plane) to make room for the M5 exposure metering mechanism. This retrofocus design requires a totally different type of correction. Coma, distortion and transverse chromatic aberrations are difficult to correct. In this case, a bit of distortion had to be allowed in order to achieve a higher correction of the other aberrations.

At f/2.8 the light fall-off is slightly less than that of its predecessor. Flatness of field is less well corrected than distortion. At full aperture, the on-axis performance (a circle with a diameter of 6mm) produces an image that is slightly cleaner than that of the Super-Angulon lens. This generally somewhat higher contrast results in a clearer delineation of fine details. Details are quite soft in the field and in the corners the image.

The general performance of the Elmarit-M lens is better than that of the Super-Angulon at f/3.4. This is partly due to the reduction of astigmatism, which results in improved rendition of fine details.

At f/4.0 extremely fine details are visible with good contrast in the center and within a 12 mm diameter circle around the center. From there to the corners the image details become progressively softer, but fine details remain within a detectable range.

Optimum performance is reached at f/5.6 with extremely fine details now visible over the entire image area into the outermost corners. Subject outlines, especially in the outer zones, have soft edges, giving an overall impression of a smooth, somewhat subdued image. Stopping down to f/11 and smaller apertures diminishes image quality. Decentering was not measurable.

Generally speaking, this lens is a commendable performer and an improvement over the Super-Angulon lens. In the field at the wider apertures, image quality is a bit modest.

Close-up performance

A 21mm lens by nature shows a great deal of empty foreground, which could be filled with some objects close to the lens. The essence of the 21mm focal length is the surrounding of an interesting object in the foreground by a large environmental background. It is of prime importance to know how the lens behaves at distances around 1 meter.

At f/2.8 the corners are noticeably darker, but vignetting is gone at f/4.

At full aperture the overall contrast is medium. The Elmarit, however, reproduces very fine details just a shade more crisply than its predecessors. From f/5.6 the performance becomes uniform across the entire frame and we have an excellent image with very fine crisp details into the corners.

Flare suppression:

The Elmarit-M handles light sources quite well at full aperture. In strong backlight the silhouettes of tree branches are dark (no leaking of light around the edges) and sharply outlined.

21 mm f/2.8 Elmarit-M ASPH

At full aperture, contrast is high and extremely fine details are rendered very crisply from the center to an image height of 11 mm. That is the coverage of an image circle of 22mm. From there to the edges, the contrast decreases a little but it is still vastly superior to that of all its predecessors. Astigmatism and curvature of field are almost fully corrected. Subject outlines and fine details have very high edge contrast and are rendered clearly, almost lucidly. In the outer zones and in the corners this superior performance decreases slightly.

The overall image quality is a quantum leap forward in relation to all previous 21mm lenses in the Leica stable.

To place it in perspective: the performance at f/2.8 is better in all respects than that of the f/3.4 Super-Angulon at f/5.6.

At f/4 contrast and the clear rendition of very fine details improve, with the corners still lagging a bit behind. Overall contrast is now at its optimum, with exceptional performance over a large part of the image field. At f/5.6 overall contrast drops a little, but very fine details are still crisp into the far outer zones.

From f/8 the performance drops ever so slightly and at f/16 it is noticeably below optimum.

Decentering is not measurable. Overall assessment: this lens produces outstanding image quality at full aperture, which continues to improve as it is stopped down as far as f/8.

It is by far the best 21mm lens in Leica history and the only recommended choice for the person who needs superior performance from a 21 mm lens starting at f/2.8.

Close-up performance

Close-up performance at full aperture is better than that of the Elmarit-M f/2.8, producing higher overall contrast. More important, the high level of micro-contrast gives a clear rendering of very fine image details over the entire field, including the extreme corners. Even the performance from the center to the corners for the complete range of apertures is quite impressive.

Flare suppression:

The Elmarit-M ASPH lens improves on the performance of its predecessor. The suppression of halos, especially at full aperture, can be described as quite effective.

Distortion

Look at the distortion graphs for the Elmarit-M and Elmarit-M ASPH lenses. The curve of the Elmarit looks better as the distortion at the fringe of the image area becomes zero, where the ASPH version shows more distortion. The abrupt inward curve of the Elmarit, however, increases the visibility of the distortion, while the smooth curve of the ASPH is easier on the eye and it reduces the noticeable presence of distortion.

Design considerations

I wish to draw attention to the very high level of finely tuned aberration corrections in modern Leica lenses. In the first part of this brochure I mentioned that any optical system can only be corrected to a certain level and that some aberrations will always be present as residual aberrations.

A careful design will not neglect these aberrations because they will generate ‘noise’ in the system. White light consists of all wavelengths, but photographically important wavelengths should be weighted more heavily for ultimate image quality. In the preceding Elmarit lens, slightly lower importance was assigned to certain wavelengths. Nowadays a Leica designer will strive to concentrate all these wavelengths into a spot that is as small as possible. This is the case with the 21 mm f/2.8 Elmarit-M ASPH. One can only see a faint trace of color residuals of the marginal rays.

Performance at infinity

This is an intriguing topic.

The performance of extremely wide-angle lenses at infinity is sometimes discussed as if it were a bit below expectation when compared to lenses with smaller angles of view. As I always use the same scene for a comparison, I was able to compare the image quality of a distant scene as recorded with a 28mm Elmarit-M lens (latest generation and a superb representative of its kind). The 28mm produces a high-contrast image, with extremely fine details, rendered very crisply. The overall image also has a clarity and lucidity that is difficult to quantify.

In direct comparison, 21mm lenses are softer, they lack the overall clarity and crisp reproduction of very fine details. The same amount of details as obtained with 28mm lenses can be noticed without difficulty, but image details are slightly 'fuzzier'.

Optical progress can easily be followed in the discussion that follows, with the 21 mm f/2.8 Elmarit-M ASPH representing a very high level of progress. It is the only 21 mm lens that compares favorably with the 28mm f/ 2.8 Elmarit-M.

The Elmarit-M at full aperture shows very fine details, but it renders them with slight fuzzy edge contrast and extremely fine details are lost. One needs to stop down to f/5.6 in order to render these extremely fine details with good separation.

The Elmarit ASPH produces better images at full aperture. Overall contrast is higher, and extremely fine details are just discernible. The ASPH gives a noticeably crisper image at all apertures and the level of just discernible details is higher (more details that is). At f/4 performance is as good as the predecessor's at f/5.6 to f/8.

Is a direct comparison between lenses of different focal length acceptable?

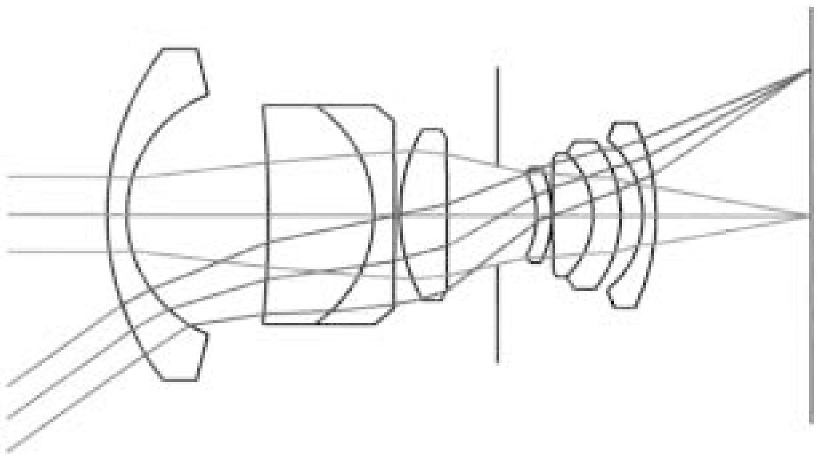
Not really! The reproduction factor of the extremely fine details is higher with a 21 mm than it is with a 28 mm lens. Even if the grain and the film would allow it, the 21 mm image needs a higher magnification to show the same details at the same size and therefore it needs a higher degree of optical corrections at a higher spatial frequency.

The prerequisites for such an infinity test are simple: extreme care must be taken if one wants best quality at infinity: rigid tripod, correct exposure, distance setting at infinity, low speed film.

The test shows clearly that performance at infinity with the latest generations of 21mm lenses is at a very high level. When comparing results between different focal lengths one should take into account the reproduction factor and all other image-degrading components.

I also conducted a test to ascertain whether the performance level changes if one sets the focusing ring just a fraction before the infinity mark, thus using depth of field to secure good rendition of details. The drop in performance between these two settings is clearly visible. So, if you need the best image quality at infinity, focus the lens at infinity and forget about depth of field concerns in such cases. We also noted that image quality will be reduced substantially if the objects at infinity are overexposed, which is quite often the case with small objects (like trees) against the sky. This behavior is inherent in 35 mm format photography where overexposure is one of the most serious causes of image degradation.

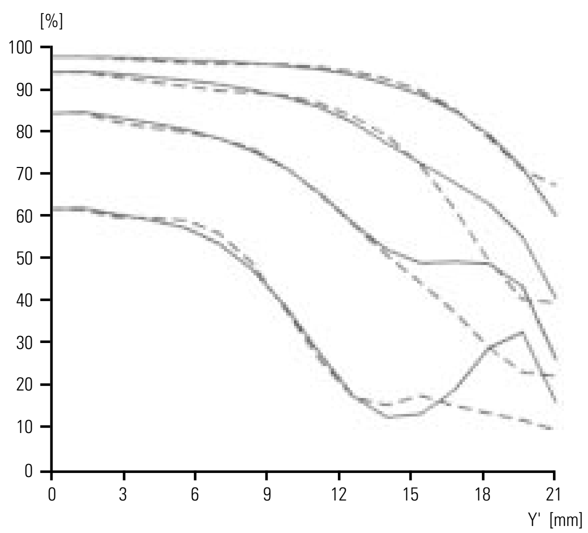
21mm f/2,8 Elmarit-M



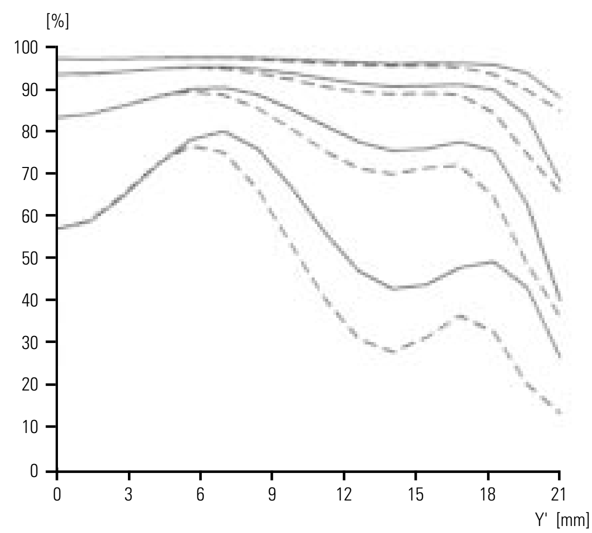
Summary

This lens is the first retrofocus design by Leica for the M body. Stopped down to medium apertures it delivers excellent image quality over most of the picture area. . At full aperture the on axis performance is very good, but in the field is only acceptable.

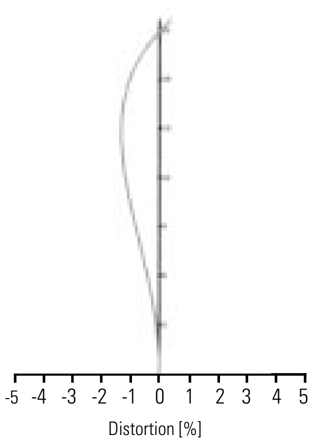
Full Aperture [2,8]



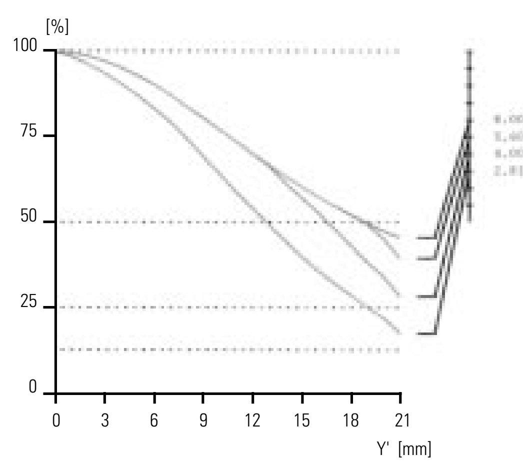
Optimum Aperture [5,6]



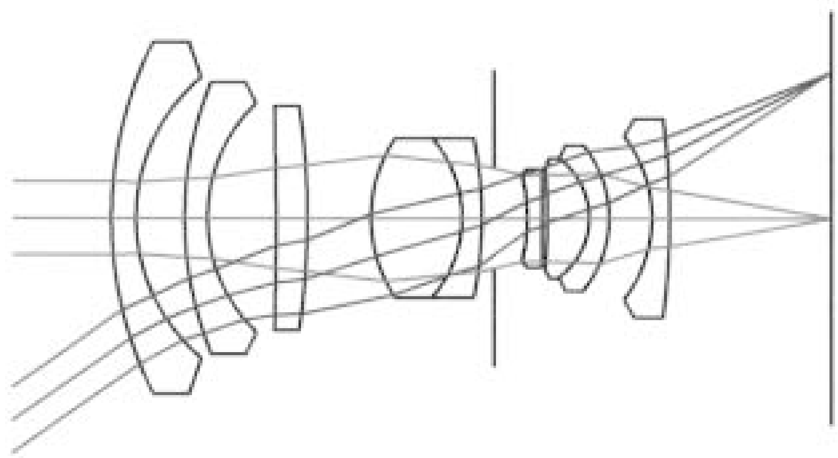
Distortion



Vignetting



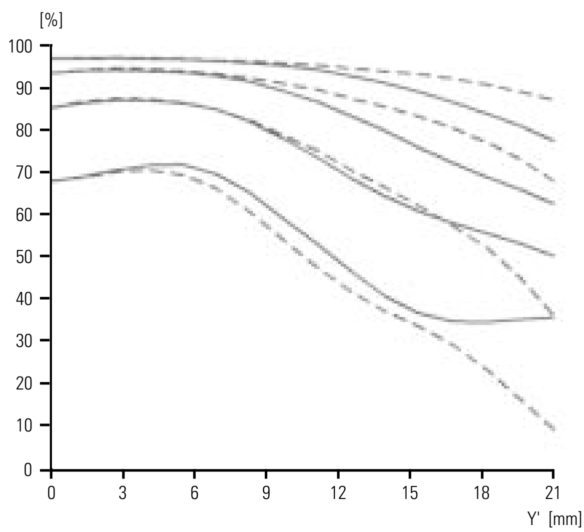
21mm f/2,8 Elmarit-M ASPH



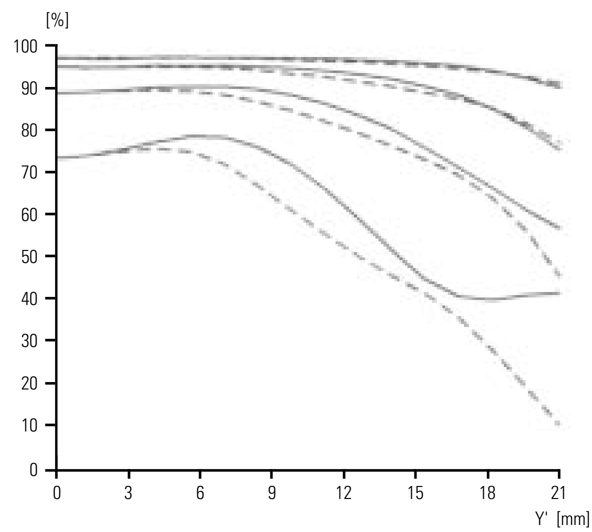
Summary

A truly outstanding lens and a fine example of Leica’s drive to design state-of-the-art lenses. At full aperture the lens already provides a high contrast image with a crisp rendition of very fine details. This performance improves when stopping down and extends to the full picture area.

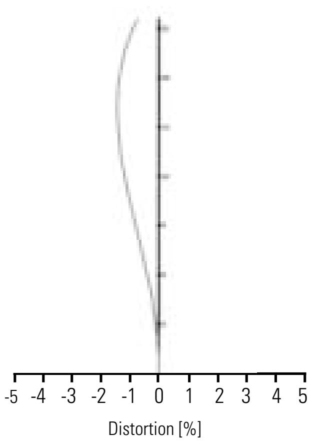
Full Aperture [2,8]



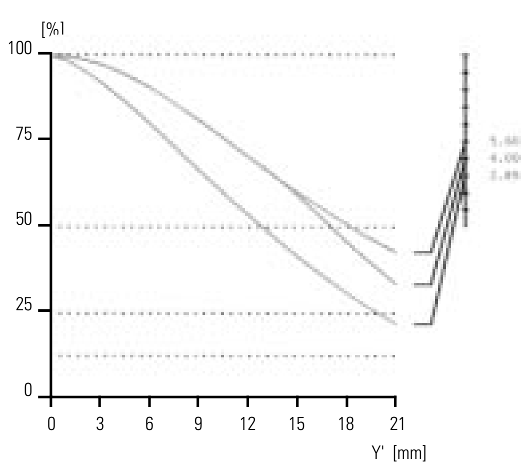
Optimum Aperture [4,0]



Distortion



Vignetting



24 mm lenses

24 mm f/2.8 Elmarit-M ASPH

The gap between 21 mm and 28 mm focal lengths has long existed in the range of Leica lenses for Leica cameras with coupled rangefinders. In the reflex world the 24 or 25mm focal length has a longer history. It maybe the renewed confidence of many users who chose the Leica M as the top reportage camera that inspired the Leica designers to compute this focal length for the M series. One may also note that the M body favors the design of high quality short focal length lenses. As a historical remark we may note that Nikon and Canon rangefinders from the glorious fifties offered the 25 mm focal length, thus closing the gap between the 21 and 28 mm focal lengths long ago.

I used an example of the 24 mm f/2.8 Elmarit-M ASPH lens and compared it to the 25 mm f/4 Voigtländer Snapshot Skopar lens. The 84º angle of view is very interesting, but also quite demanding creatively. Close range photography of single persons or small groups conveys an intimacy of close contact. At the same time you can make a strong statement about the wider surroundings where these people are located. Encapsulated intimacy might be the approach. When taking pictures you are naturally inclined to tilt the camera downwards a bit in order to include more foreground in the image. At eye level the 84 degree angle of view often encompasses too much horizon. In this position, perspective distortion of background objects at the sides of the picture area tends to be pronounced. This perspective distortion should be carefully separated from the optical one. Optically this lens shows hardly any distortion.

After some use I acquired the habit of taking pictures from a lower, but level perspective. Here the unusually good image quality really shines.

In use its angle of view is quite fascinating. I used it in reportage-style picture-taking situations and I was able to get very interesting pictures at close range. The trick in using this lens is the selection of subject matter at about 1 and 2 meters (approximately 3 to 6 feet).

If the subject in the foreground catches the eye because of its nature or because of its composition, the whole image will be interesting. In many instances you might be tempted to go for the grand view. Make sure the foreground space is dominant and full of interesting details.

At full aperture the lens exhibits a very high contrast image from the center across the entire field. Only the far corners drop in contrast and produce soft details. Over an image circle with a diameter of 12 mm the outlines of subject shapes and details are delineated with superb edge contrast and extremely fine details are rendered crisply and clearly. In the rest of the field, very fine details are etched crisply in the emulsion with extremely fine details rendered visibly but with softer edges. Exceedingly fine details are rendered just above the threshold of visibility, but with slightly lower contrast.

Going from center to corner the contrast of extremely fine details drops somewhat. While a bit soft at the edges and of lower contrast, these details are still clearly visible.

Stopping down to f/4 the contrast in very fine details improves and the exceedingly fine details now are clearly visible. Corners still lag a bit but center and zonal performance (12 mm image circle) is at its optimum. This aperture can be called the optimal aperture. Stopping down to f/5.6 we see that the finest possible details become a bit more crisp, but the outlines of shapes and details start to soften faintly. Thus overall contrast is a bit lower. It is a matter of priorities which aperture is ideal. I would say that this lens is at its best at f/4.

At f/8 corners continue to improve where the center now drops in contrast. At f/16 the overall image contrast is lower and very fine details suffer as diffraction sets in.

Close-up performance

At close range (± 70cm, approximately ±28 inches), this excellent performance is preserved. A wide angle lens like a 24mm is not recommended if its close-up performance is not the same as its performance at infinity. As most lenses are optimized for longer distances, we need to stop down to f/5,6 to get the best of performance in the close-up range.

Flare suppression and other topics

Flare suppression is perfect. Night pictures with Kodachrome 64 show excellent gradation in strong highlights and distance point sources are rendered clearly, without any trace of halo. This suppression of halo and flare gives pictures taken with the 24 mm f/2,8 Elmarit-M ASPH a very realistic, almost tactile rendition.

Of course some light fall-off is visible at full aperture, but it is negligible in most picture-taking situations.

On the optical bench a faint trace of decentering was observed. On the other hand flatness of field and astigmatism are very well controlled. No coma was observed.

Distortion is also hardly noticeable. Of course when you intentionally take pictures in oblique positions, perspective is out of line. Used in a level position this lens is virtually distortion-free.

In common with most recently designed Leica lenses, the out-of focus blur at the wider apertures is quite fuzzy. While the outlines of bigger subjects are preserved, finer details fade into the background blur quite rapidly.

Conclusion

The Elmarit-M is without a doubt a masterpiece of optical engineering, a landmark design within the Leica M range.

The M version of the 24 mm focal length is in a different performance league than the 25mm f/4 Voigtländer Skopar. It gives the discerning Leica photographer so great an imaging quality potential that it becomes a challenge to exploit. While the Skopar is quite a capable performer, the M version is simply outstanding.

At full aperture the M version is already nearly at its optimum, achieving a long-standing goal of Leica optical designers: to provide the best quality at full aperture over the entire image area. This lens is quite demanding on the capabilities of film emulsions. Pictures on ISO 400 transparency film however proved that this lens shows its qualities even when relatively grainy films are being used. The very high contrast of subject outlines of the 24 mm f/2.8 ASPH gives additional power to the crisp grain of modern high speed film emulsions.

Within the Leica lens range this lens has a premium position. Its angle of view will give fresh views of interesting objects in our world at close range and its optical capabilities add a novel impact to pictures taken with fairly wide angle lenses.

No Leica M user should be without this lens. The M style of photography demands intimate close range photography and the 24 mm lens is one of the best lenses to explore this area. At this writing it delivers unsurpassed quality in the 24 mm focal length.

Voigländer 25mm f/4 Snapshot Skopar

For some time a number of lenses for Leica rangefinder cameras have been available from other manufacturers. It is most interesting to compare the performance of these lenses to the Leica designs.

This lens does not couple to the rangefinder and it has a several fixed distance tabs on the distance scale. It shows a fair amount of decentering. In the outer zonal areas and at the edges small light sources produce halo-like degradation. Distortion is very low, but light fall-off is noticeable, but not disturbingly so. At full aperture the overall contrast is high and very fine details are rendered crisply over an image area with a diameter of about 6 mm. Fine details stay visible over most of the image area and become barely detectable in the corners. This excellent performance continues up to f/8, but with reduced contrast on axis. Close-up performance is as good as performance at the infinity setting

In comparison, the 24 mm f/2.8 Elmarit shows a high contrast image with exceedingly fine details rendered very crisply over an image area with a diameter of 12 mm. Corners are soft and slightly prone to flare. No improvements can be detected after f/4.0.

I shot comparison images on the same film (lens by lens) (my bayonet is the first item to exchange because of usage) and noted that the Skopar lens exhibits some characteristics of Leica lenses of earlier generations. Overall the images are duller and a bit muddier than those made with current Leica lenses.

A most interesting phenomenon became evident with these side-by-side-shots. The Skopar gives images with a grainier pattern and with grain clumps that are rougher than those in images made with Leica lenses. This is caused by the lower aberration content of the Skopar lens. When aberrations are abundant the light rays emanating from a point source of light do not converge to a point in the image but have a more random pattern around the central core. These more widely spread rays energize more silver grains around the center spot and they do so randomly. The result is a rough clumping.

Modern Leica lenses produce a smooth pattern of very tightly contained clumps of grains, which helps to preserve the rendition of very fine details and the smooth gradation of fine light modulations.

Leica lenses exhibit a crisp clarity of the finest possible details that third party designs cannot match. On its own the Skopar lens is an excellent value and the Skopar at f/4 is a capable performer on axis. But the outer zones are no match for the Leica (at f/2,8!) though.

The fine performance of the Skopar is partly the result of the modest aperture. The higher aberration content will not be detectable in many picture-taking situations, hiding as it were behind the depth of field, among other things.

The generally weaker performance in the field is another characteristic that distinguishes these lenses from Leica lenses.

The riddle of the wider apertures

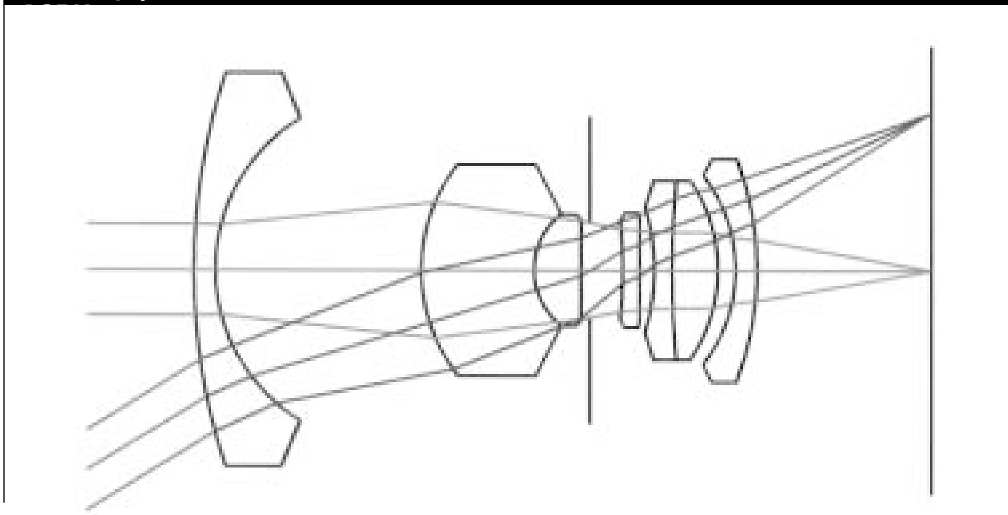
The increase of the maximum aperture of f/4 to f/2.8 seems a modest one. Just as the step from f/2.8 to f/2 looks easy with current computational power. But physics is not that simple.

What then is the optical problem? Any lens produces a circular image area within which the 24x36mm format has to fit. This circular area can be divided in three parts, the center or axis, the zonal area or field and the outermost zones or edges. The center (or the paraxial zone or Gaussian zone) is quite easy to compute. The zonal areas are more difficult to correct. Optical aberrations tend to grow disproportionately as the aperture and/or the field-angle becomes larger. Many aberrations grow at the rate of the square root or the cubic root in relation to the aperture diameter, or even more.

OK one might say, lets settle for a bit less image quality in the corners. There is a disadvantage, however: zonal aberrations have a strong influence on the performance in the center. Moreover, when stopping down, the effect on some aberrations is not reduced. The combined result of all aberrations is always a reduction in contrast: a softening of small details and a low overall contrast. The burden of the lens-designer however, is not lessened if he succeeds in reconciling all these conflicting demands. Aberrations can be classified as third order, fifth order and seventh order aberrations and so on, until the nth order. Third order aberrations are large and suppress all other aberrations in the series.

If a designer can tame these third order errors, he will be unpleasantly confronted with the next aberration in line. Balancing third order aberrations often requires a change in focus position. The well-known statement that you can compute a lens for high contrast or high resolution ultimately boils down to this kind of balancing. Fifth order aberrations are mathematically quite challenging. The high quality of Leica lenses is based upon a thorough understanding of this group of aberrations. As usual, balancing of conflicting demands and fine-tuning of parameters is needed to compute a lens to this very high level of correction.

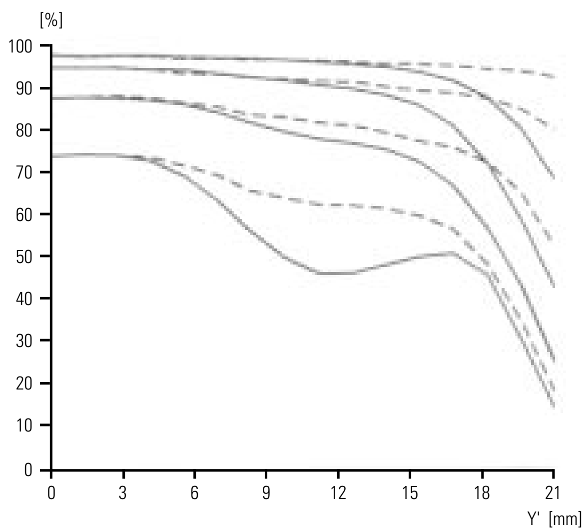
24mm f/2,8 Elmarit-M



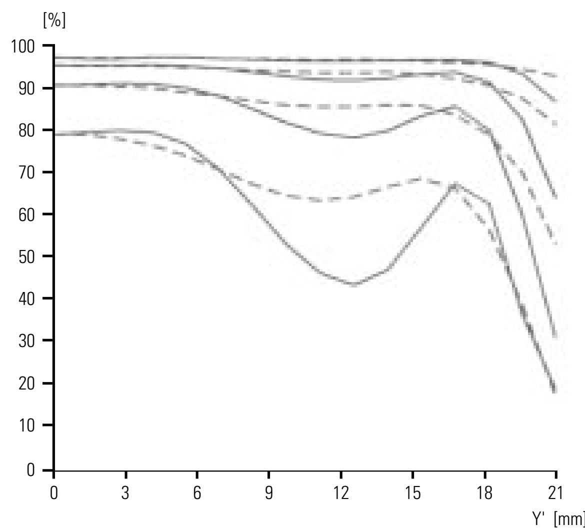
Summary

A landmark design in the M series, the lens delivers astounding performance at full aperture, becoming outstanding when stopped down a bit. The angle of field encourages the style of close range reportage photography that made the M famous.

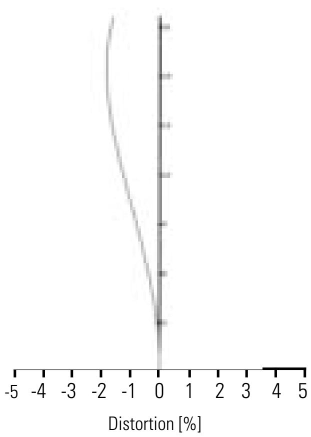
Full Aperture [2,8]



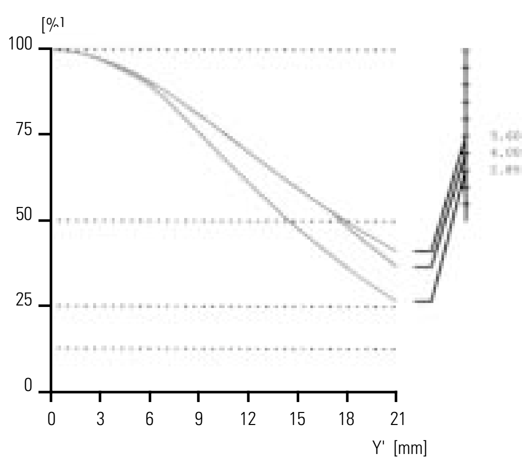
Optimum Aperture [4,0]



Distortion



Vignetting



28 mm lenses

The 28 mm lens for the Leica rangefinder cameras was introduced in 1935. The Leitz Hektor 28 mm (1935) had a very modest full aperture of f/8. At this aperture, image quality was quite good and this lens remained in production for 20 years. Leitz produced three different 28 mm designs and for versions of the last design. The 28 mm lens is a strong candidate for being the most redesigned lens in Leica history.

The photographer who employs a 28 mm lens with its 74° angle of view has some strong demands. A high-contrast image with very fine details over the whole image field, evenly illuminated and distortion-free would be high on the list. Pictorially the 28mm excels with images where the main object is relatively close to the camera and is surrounded by the background. The 28 mm is a lens for story-telling. With an aperture of f/2,8, this lens will be used quite often in spaces or buildings with strong light sources that will be in the picture. Excellent suppression of flare and backlighting is a clear advantage in such circumstances. To provide an impression of optical progress, we will compare the Hektor at f/6.3 with the Elmarit-M (third version of 1979) at f/2,8.

A demanding subject would be part of a dark alley with some illumination from street lamps. Recording this night scene the Hektor gives a low contrast image, the highlights are washed out and point sources show strong halos. The black parts are darkish gray as flare and unwanted stray light 'illuminate' the shadows, which show very few details.

The Elmarit-M gives a high contrast image with finely graded details in the highlights, flare is nonexistent, allowing clean black areas. The shadows have a rich tonal scale showing small details with good clarity and clean colors.

The first versions of the 28 mm Elmarit-M (from 1962 and 1972) were improvements of the 28 mm f/5.6 Summaron. A two-stop increase in aperture and a retrofocus design were quite demanding. The narrow diameter of the bayonet mount did not make life any easier for the designer. The first 28 mm Elmarit showed the familiar pattern of many older designs: low to medium overall contrast, good image quality on axis, rapidly dropping in the field, soft edges of the larger object contours, and a high level of image noise that reduces the clear rendition of fine details. This optical 'noise' is, of course, the effect of residual aberrations that could not be corrected to a high level. Images with older Leica lenses at wider apertures exhibit a veil of dullness and an absence of really fine textural details. This performance has been identified sometimes as smoothness of rendition, because the gradient from sharp to unsharp and from details to outlines is not very abrupt.

Stopped down to medium apertures in bright daylight the differences between modern and older lenses diminish to a surprisingly small level. The higher corrected lenses are able to exploit the current emulsions to a fuller extent than the older ones.

28 mm f/2.8 Elmarit-M

The current version of the Elmarit-M has an unusual design with a plano front lens element. Primary design objective was to achieve improved imagery in a smaller package. The M user wants superior optical performance and lenses small enough not to obstruct the clear view of the viewfinder. These two demands (optical performance and small size) are difficult to achieve together.

The latest (1993) version of the 28 mm Elmarit-M shows many characteristics of the new era of Leica M lens design. Between 1980 and 1990 no new designs for the M were computed. The last of the previous generation were the 21 mm f/2.8 Elmarit-M, the 75 mm f/1.4 Summilux-M and the first of the new generation was the 35 mm f/1.4 Summilux-M (with two aspherical surfaces).

The 28 mm f/2.8 Elmarit-M at full aperture gives a very high contrast image with extremely fine details crisply rendered over much of the picture field (image circle of 16 mm). Only the far corners and outer edges (left and right) are noticeably softer.

This clarity of very fine textural details is a hallmark of many modern Leica M lenses. In addition to high overall contrast and a virtually free of flare transmission of light energy, this lens at full aperture should provide the user with first order recording capabilities. Stopping down one stop brings already the optimum aperture and at f/5.6 macro contrast drops a little, while of course the corners still improve somewhat. As marginal rays are cut off from reaching the emulsion (when stopping down) the edges of fine details become somewhat more crisp. Presumably these small differences are lost in the emulsion and in other small image-degrading effects.

Compared to its predecessor, center performance at full aperture is almost the same. In the field and when looking at very fine details, the current lens has clearly improved optical capabilities. Modulation transfer function (MTF) graphs also show a more rigid correction of the nasty sagittal rays, which blur the rendition of finely graded color hues on small object areas. Clearly, the current lens is corrected to a higher degree and it is at least one stop ahead of the 1979 Elmarit. The fourth version of the 28 mm focal length lens has only one drawback: its modest aperture of f/2.8.

The 74° angle of view is very useful in cramped spaces and, spoiled as we Leica M users are with very high speed moderate wide-angle lenses, we would occasionally wish we had a handful of photons more to activate our silver halide-based emulsions.

Summicron-M 1:2/28mm Asph.

The optical prescription of the lens is quite fascinating. It fits in the genealogy of the seminal Summilux ASPH, a design that decisively departs from the classical Double-Gauss formula. This design-type, now more than a 100 years old, has been stretched to the limits and a performance plateau has been reached. The new Summilux design, incorporates the negative front and back surfaces and the aspherical surface. It is probably the first lens that has been designed specifically around the use of aspherics. Retrofocus designs are a second approach to step out of the shadows of the Double-Gauss formula. More lens elements can potentially improve performance, as more parameters can be controlled. The new Summicron-M 1:2/28mm ASPH picks up design elements of both: the lens group in front of the aperture is an enhancement of the Summilux (front group) design and the lens group behind the aperture fits into the retrofocus family and is a derivative of the 2.8/28 formula. We should not press the point, however, as a lens design is a creative whole and not a mix of ready made components. The message should be that the new Summicron is based on the best design principles currently available in Solms thinking. The location of the aspherical surface is different and probably decisive for this design.

The ergonomics

The new 2/28 is indeed a very compact lens, comparable to the current 2.8/28 version.

Measurements are (2.8 version in parentheses): length from flange: 41mm (41.4mm), overall diameter: 53mm (53mm), front diameter: 49mm (48mm). Both lenses use filtersize E46.

For a lens with twice the speed this is a remarkable feat. This design indicates the direction of future Leica M designs: compact and high speed and high performance. The somewhat weak performance of the old Summilux 1.4/35mm could be excused with reference to its compactness, which forced the designers in those days to find a compromise between size and performance. Now the circle has been squared.

The lens operates very smoothly, and the aperture ring clicks with just the right amount of resistance and fluidity. When taking pictures with the new Summicron 28, I was amazed how quickly I could focus with the focusing tab and I have to confess that I hardly missed a shot, when focusing moving objects. The depth of field with a 28mm lens, even at an aperture of 1:2 exceeds of course the DoF of the Summicron 50 by a factor of 2, which brings real advantages in street shooting.

The performance

At full aperture this lens exhibits a high contrast with crisp definition of exceedingly fine detail over most of the image field, softening in the field from image height of 9mm. A faint trace of astigmatism and field curvature can be detected. Stopping down to 2.8 improves the center area (diameter 12mm) and also brings in a higher microcontrast in the outer zones. Corners however lag a bit and stay soft with a limited definition of coarse detail. Stopped down to 4, contrast becomes very high and the optimum is reached with a very even performance over the whole image area, excepting the extreme corners. At 5.6 we se a small drop in microcontrast of the fine textures and from 8, the overall contrast drops a bit. We have to put this in perspective, of course as we relate it to the optimum aperture. At 5.6 and smaller, the Elmarit-M 2.8/28 is a bit behind the new Summicron 28.

Distortion is about the same as with the Elmarit 28mm and vignetting is just visible with 2 stops in the corners at full aperture, about the same as the Elmarit at 1:2.8. In general use, this falloff can be neglected: even on slide film one has some difficulty noticing the darkening of the extreme corners.

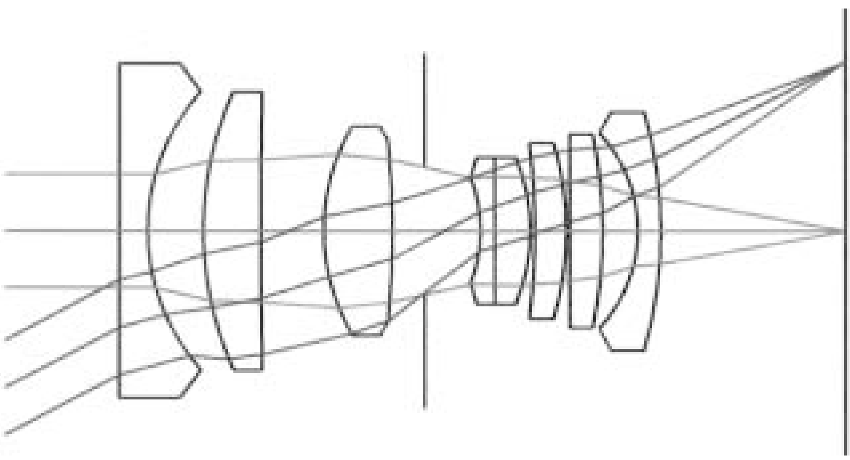
Close up performance at 0.7 meters and full aperture shows excellent performance with high contrast rendition of very fine detail.

Night pictures retain high contrast in the shadow areas, and (when exposure is right) finer gradations in the highlights are recorded as well. At least with slide film and Black and White. Bright light sources have cleanly delineated outlines, indicating effective elimination of halo effects. Coma cannot be detected in these situations (light points in the image field).

Flare is very well suppressed in daylight shooting too, in contre-jour situations and when the sun strikes the front lens obliquely. Of course: you can construct situations where secondary images and veiling glare is quite visible, but even here the images retain contrast and some saturation. A lens shade is needed, when the light sources may shine in or close to the front lens. I will give this topic a separate treatment. Leica has redesigned the front part of the lens where the shade is attached for easier handling. All wide angle lenses suffer the same problems here. It is a tribute to the design team that they have given this topic additional attention.

The transition from the sharpness plane to the unsharp areas is relatively smooth, but really out-of-focus areas show the tendency to break up details in coarse and fuzzypatches. There is a certain harshness in the out of focus rendition that is typical of modern Leica lenses. It is related to the level of aberration correction.

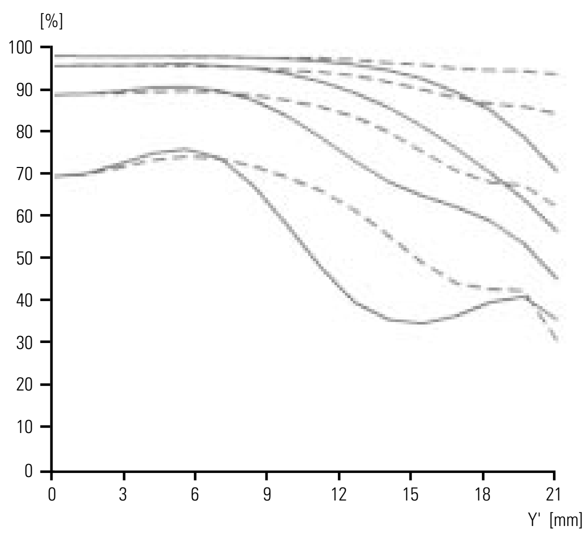
28mm f/2,8 Elmarit-M (1993)



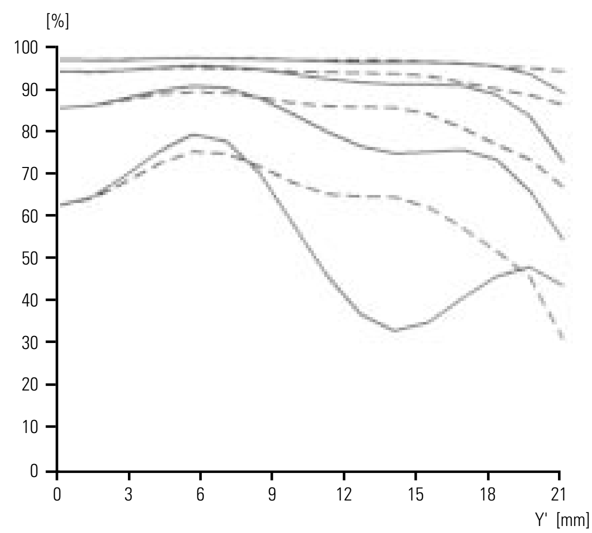
Summary

This redesign aimed at reduction of volume and improved full aperture performance. At f/2.8 this lens now has better image quality than the predecessor at f/4 does. It is a first-class performer, but one would not expect less given its modest aperture and angle of field.

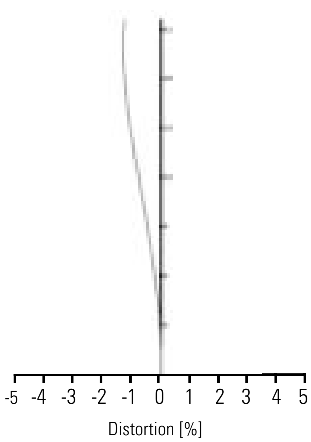
Full Aperture [2,8]



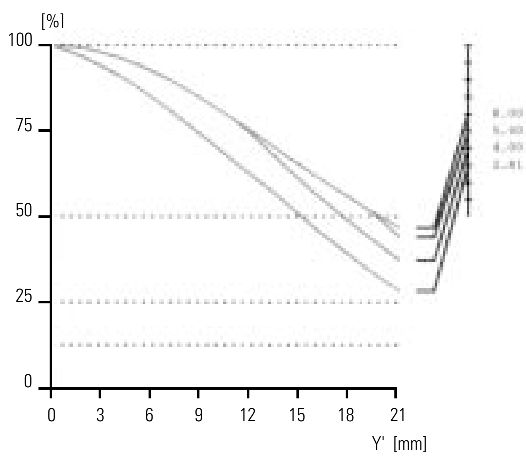
Optimum Aperture [4,0]



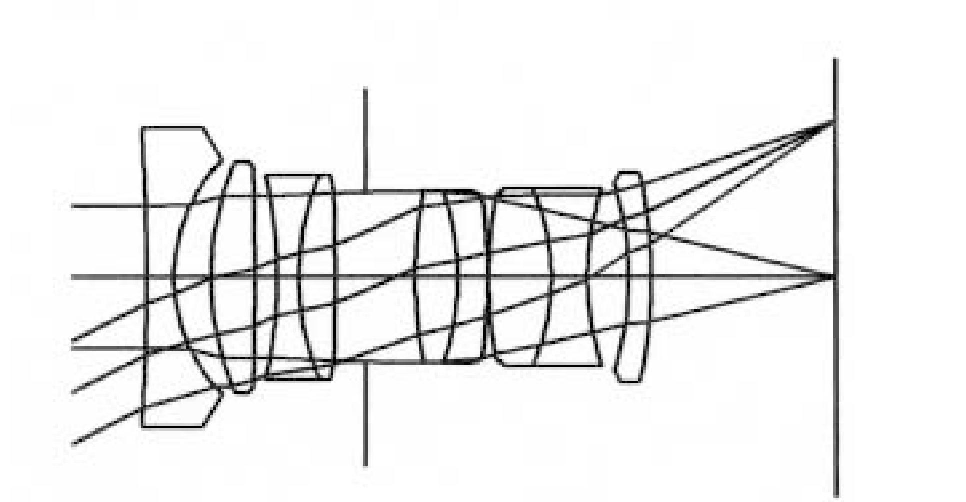
Distortion



Vignetting



SUMMICRON-M 1:2/28mm ASPH

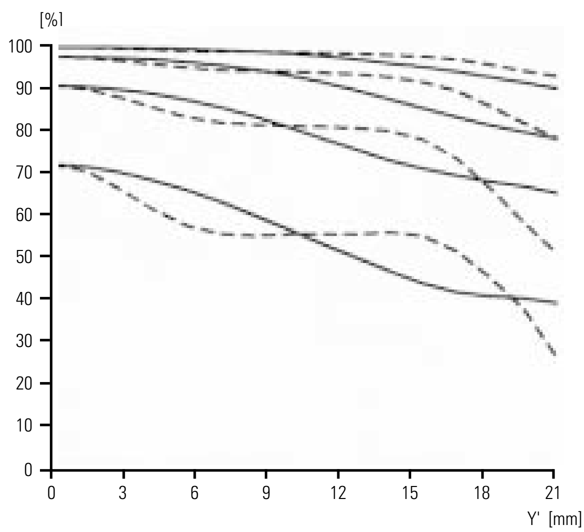


Summary

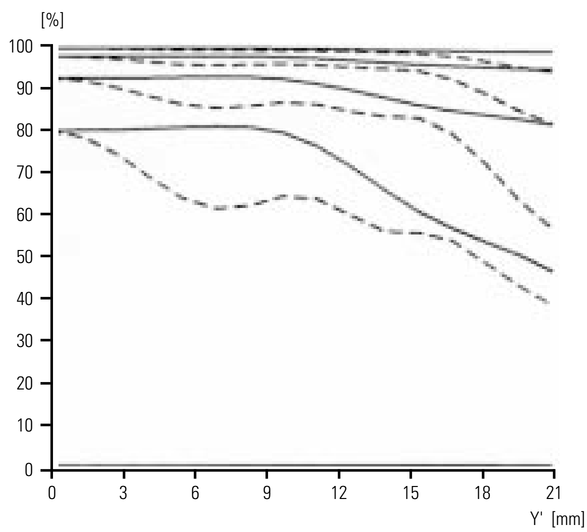
The new Summicron-M 1:2/28mm Asph. marks the top level of performance from wideangle lenses and is one of the best Leica M lenses.

It was introduced at photokina 2000.

Full Aperture

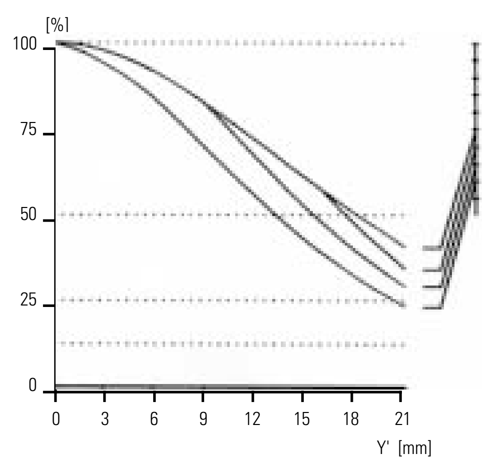


Optimum Aperture



Distortion

Vignetting



35 mm lenses

The direct comparison between the first 35 mm f/1.4 Summilux-M and the most recent one with one aspherical surface (1994) shows progress on two different levels. The immediately visible progress is a very marked improvement of image quality. The more subtle and far-reaching innovation is a radical departure from a classical Gaussian design. The original Summicron and Summilux designs are variants of the Double Gauss concept, pioneered a long time ago. During the design stage it became clear that the desired image quality could not be achieved with the use of aspherical surfaces alone. The design goal was a much-improved correction of the marginal zonal areas. As I mentioned in the introduction, we should approach image quality in a more integral way. All light energy that streams through the optical system is affected by a variety of aberrations. The lens designer, of course, will analyze the contribution of every single aberration to the overall performance in order to adjust and balance the corrections that are needed. Aberrations that affect marginal areas the most will invariably also play havoc with on-axis performance. Any successful optical design is a very carefully balanced trade-off between the many aberrations that stubbornly tend to degrade image quality.

It is not easy to correct an optical system with a wide aperture and a large field of view. The total energy flow (the luminous flux) through a high-aperture lens is much greater than it is through a lens with a smaller aperture and a smaller field of view. The effect of aberrations is also many times larger and more difficult to correct. Many aberrations increase at the rate of the square root or even the cube root when the field of view is widened.

The revolutionary idea behind the Summilux aspherical lens is the radical departure from the Double-Gauss design. The optical system consists of five groups with the first surface of the first element and the last surface of the last element having a concave shape. In the future, highly corrected, high-speed lenses for small format photography could be based on this concept. Production technology however has not yet advanced to a level that every conceivable optical design can be manufactured within required engineering tolerances and necessary commercial parameters.

35 mm f/1.4 Summilux

At full aperture, the 35 mm f/1.4 Summilux produces a low contrast image with fine details clearly visible in the center and rapidly softening in the field and corners.

Very fine details in the field are fuzzy but just discernible. At this aperture the lens shows a veiling glare and strong halos and double images around point light sources

At f/2.0 the overall performance improves and at one stop smaller (f/2,8) contrast now is quite high and very fine details become considerably more crisp, showing quite a high edge contrast. In the center, extremely fine details emerge, but in the field very fine details remain soft. Optimum aperture is reached at f/8. This pattern is typical of older generation lenses where stopping down improves contrast and the rendition of fine details, the latter only to a fair level. However a number of aberrations are not affected by the reduction of the aperture and continue to degrade the image quality.

35 mm f/2 Summicron-M

The 35 mm f/2 Summicron-M is inherently corrected to a higher level. At full aperture, contrast in the center is high and very fine details are rendered crisply. Extremely fine details are slightly soft at the edges with a visible contrast reduction in small adjacent areas of different illumination. This fine performance is not sustained in the field where rendition of very fine details is progressively lost in aberration noise. At f/2.8 the excellent center performance now extends over most of the field, only the corners still lag behind. At f/8 the optimal aperture has been reached and here we encounter a very high level of image quality. High overall contrast and high micro-contrast of extremely fine details over most of the image field bring a performance level that is difficult to exploit without appropriate types of emulsions.

From f/2.8 both the Summilux and the Summicron have a very similar optical 'fingerprint'. Indeed the performance is so similar at medium apertures that one is inclined to assume that the Summilux is a Summicron design opened up just one stop too far. The higher inherent flare level of the Summilux reduces the rendition of very small details in the field more than the Summicron does.

The performance of the Summicron-M is excellent and would be called outstanding if the aspherical version did not exist. In the course of these reviews I have to address a somewhat sensitive topic. Many older and recent Leica lenses are held in high esteem by users all over the world. Fortunately the standards of performance have advanced and Leica designers are willing and able to push these standards a few notches higher. Many Leica lenses that have been described by users, by the press and in factory brochures as 'outstanding', get lower marks in my reviews. Any evaluation is relative to the state-of-the-art available at the time of that evaluation.

35 mm f/1.4 Summilux-M ASPH

At full aperture the 35 mm Summilux ASPH delivers a high contrast image with excellent micro-contrast and a crisp rendition of very fine details in the center and over a large part of the field. Extremely fine details are clearly visible but they show soft edges, which reduces this lens' ability to record smoothly graded illumination differences. Light fall-off is noticeable, but restricted to a very small zone. Flatness of field is outstanding and distortion just noticeable. Centering proved to be perfect.

At f/2 the overall image quality improves with slightly higher contrast for the fine details over most of the image area. The finest details are recorded very cleanly with crisp edges. At f/2.8 there is a small improvement over the whole image field and at f/4 the performance peaks at a very high level.

All the virtues of the design are now clearly visible. Extremely fine details from center to corner, very smooth color hues in small object areas, crisp rendition of object outlines, both large and small, very good suppression of flare around strong points of light (sun reflections in water droplets) are the fingerprint of this lens.

In addition to these characteristics the new generation of Leica lenses, of which this Summilux ASPH is a prime example, has the almost unique property of image clarity that is the result of a very highly corrected optical system. Remember that in the introduction I discussed the effect of residual aberrations. These image-degrading aberrations can be compared to dust in an airtight room. This "dust" produces a thin fog that reduces the clarity of the view. This "dust" cannot be removed but only redistributed in such a way that it will no longer fog our vision. Leica designers are able, by studying the 'soul' of a design, to minimize this amount of "dust". Their designs ease the light energy through the many glass elements with minimal bending and disruption of the light rays. Small patches of light with a very high concentration of energy in the core are the result.

After f/5,6 performance drops a diffraction begins to affect the straight passage of light rays. This drop is relative, of course and up to f/11 image quality is of a very high order indeed. When using these apertures or smaller ones be prepared to accept an image that is slightly softer overall. To provide some comparative remarks: the 35 mm f/1.4 Summilux ASPH reaches its optimum at f/4.0, with the f/2.8 aperture just behind. One will note that the aspherical version reaches its optimum two to three aperture stops earlier than the predecessor does. And at f/4,0 the aspherical version has higher image quality than the original Summilux at f/8.

35mm f/2 Summicron-M ASPH

The Summicron-M ASPH 35 mm at full aperture gives quite comparable performance to the Summilux ASPH at f/2.0, with a very high contrast image over a large part of the picture field. The finest details are rendered a fraction softer at the edges and with somewhat lower micro contrast. The Summilux-M ASPH at f/2.0 is slightly ahead of the Summicron according to the MTF graphs in the outer zones. The better flare suppression of the Summicron produces a slightly tighter overall image. I would prefer to call it a difference in fingerprint or characteristic of image rendering. The Summicron-M ASPH shows a pattern of extremely high quality on axis, becoming less so when going outwards to the corners. The difference between the available image quality on axis and in the field is quite gradual. The Summilux-M ASPH at its full aperture of f/1.4 has the same pattern, but stopped down to f/2.0 shows very even coverage over most of the field. That is remarkable after only one stop. The non-aspherical Summicron/Summilux 35 mm versions follow the classical much more pronounced fall-off in quality between on-axis and the field or zonal areas. Evidently the Summicron-M ASPH at f/2.0 is better than the Summilux-M ASPH 35 mm at f/1.4. The differences between the ASPH versions of Summilux and Summicron are much smaller that those between the Summilux and Summicron predecessors.

Close-up performance of both lenses

Close up performance (±1 meter) is good for both ASPH lenses. At full aperture the Summilux-M ASPH 35 mm however shows curvature of field and vignetting. Here I would not go into a detailed comparison. Both are very competent in this area, with the Summicron-M ASPH 35 mm slightly ahead.

Flare of both lenses.

At f/2,0 flare and stray light are extremely well repressed in the Summicron-M ASPH 35 mm, it delivers excellent separation of highlight details, virtually flarefree images and fine details are clearly defined with very good gradation and color nuances. It also exhibits a very crisp image of brilliant clarity. The image of Summilux-M

ASPH 35 mm at this aperture is more flare prone at least in this situation. The larger front lens element element just captures more oblique rays of light that can soften the image a bit.

Interestingly at f/1.4 Summilux-M ASPH 35 mm is better than at f/2,0, as the diaphragm blades do not reflect some of the light that pass through the lens at this wide opening. At f/2,0 the diaphragm is closed a little more and now present an obstacle to the light rays and some of them are reflected into the lens.

In another situation (portraits taken with very strong backlighting, but no internal reflections or flare) both versions of the ASPH could take advantage of the better micro contrast and produced images with slightly better retention of fine details in the highlights. At this level he differences are however small.

Performance at infinity

Some Leica users question the ability of modern wide-angle lenses to be critically 'sharp' at infinity.

'Sharpness' is not a measurable concept. We do have a visual sharpness impression that is based on the edge contrast of the larger object outlines (also referred to as acutance). A Japanese drawing looks very sharp because its black contour lines that define the shapes of larger object details stand out with high contrast from the background. If you take a picture of trees silhouetted against the sky the sharpness impression is quite high. Take another picture at the same distance from a building with very fine architectural details and we are led to assume that sharpness is less because the overall contrast is lower. Careful tests show that both ASPH lenses at infinity record very fine details with high contrast. Here however the expression that the weakest link is responsible for the strength of the chain is true. The tripod must be a heavy one. The film must be extremely fine grained with excellent acutance, and the slightest over-exposure will destroy the image quality. Tests show that a half stop overexposure (as referenced by the optimum exposure) will degrade the image. Any nature photographer can tell you the additional precautions that are necessary to ensure a stable platform.

At smaller apertures of f/4,0 and less all four 35 mm lenses perform admirably. Theoretically the better micro-contrast of the ASPH lenses should become visible in the definition of the fine details. But handheld shooting and the grain limit of the films mostly used will diminish this possible advantage.

Conclusion:

The Summilux-M at the wider apertures is a bit overstretched in its capabilities. Stopped down it is a good performer, but that is not the reason you will buy a 1,4 design.

The Summicron-M was and is an excellent lens. It is a tribute to the designers of that lens that it took Leica 20 years and the most modern design- and production technology to bring optical quality to a higher level.

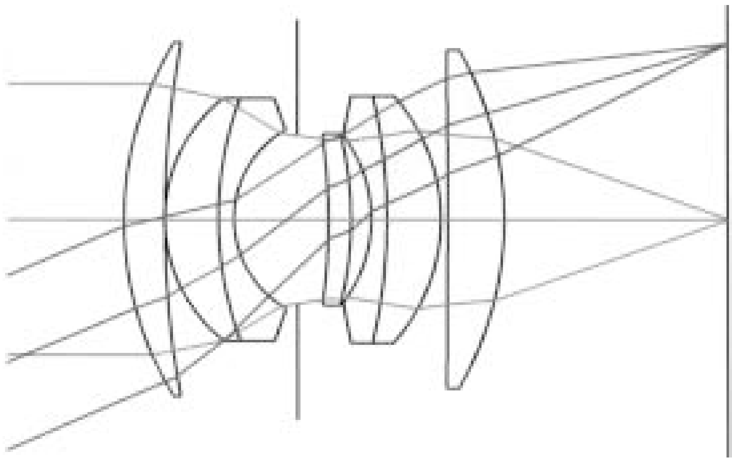
Summicron-M ASPH and Summilux-M ASPH are the more modern designs and are capable of higher image quality than the Summilux-M and the Summicron-M. The differences are visible, but you need to compare the images side by side to see it convincingly. The Summicron-M ASPH is a superb general-purpose lens with a very even and excellent performance. The Summilux-M ASPH is a lens that brings Summicron quality into a f/1.4 design. The Summicron-M ASPH and the Summilux-M ASPH have a different fingerprint and photographic capabilities and therefore a different audience. If you need the best performance available at f/1.4 there is no alternative. The 1,4 design is more susceptible to flare and has less flatness of field. If f/2.0 is enough for you the flavor of Summicron-M ASPH and its price/volume are very attractive. In performance it and its sibling Summilux-M ASPH are in the same league.

The photographer willing to exploit the superior qualities of the ASPH lenses, however must be willing to upgrade his technique also.

The current Summilux-M ASPH from 1994 (with one aspherical surface) has been preceded by the Summilux-M Aspherical with two aspherical surfaces (from 1990).

The performance of this first version is almost identical to the second version. The MTF graphs show small differences that should not be studied too closely. In the center the first version shows slightly higher contrast, but in the field the second version has an advantage. I doubt if these theoretical differences are perceptible.

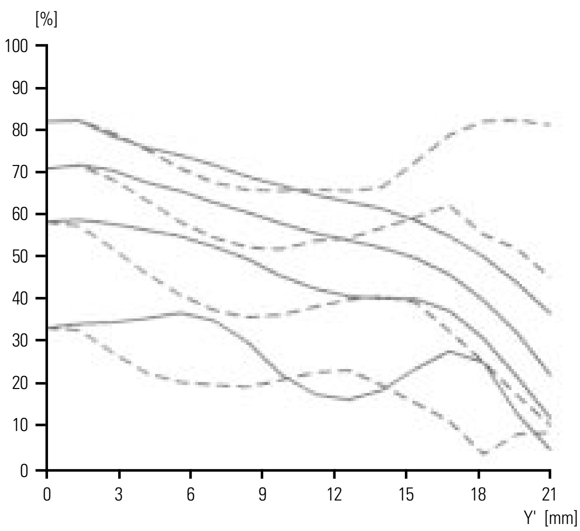
35mm f/1,4 Summilux-M



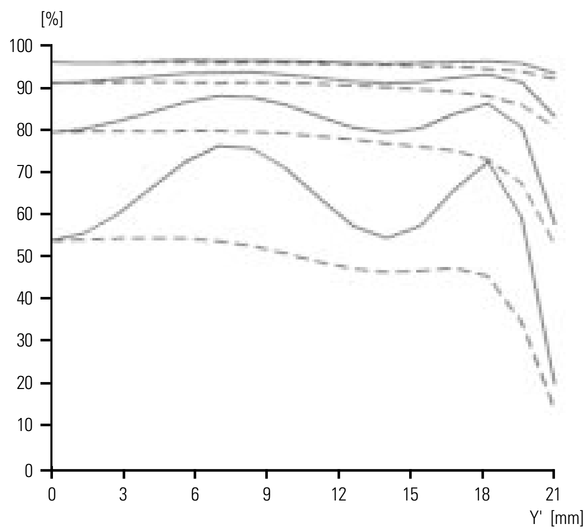
Summary

At full aperture this lens has low overall contrast with a modest definition of fine details and subject outlines. Stopping down, the improvement is commendable, becoming excellent around f/8. The overall performance characteristic should be put in the context of its age and small volume.

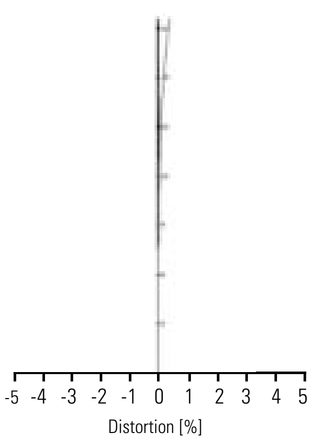
Full Aperture [1,4]



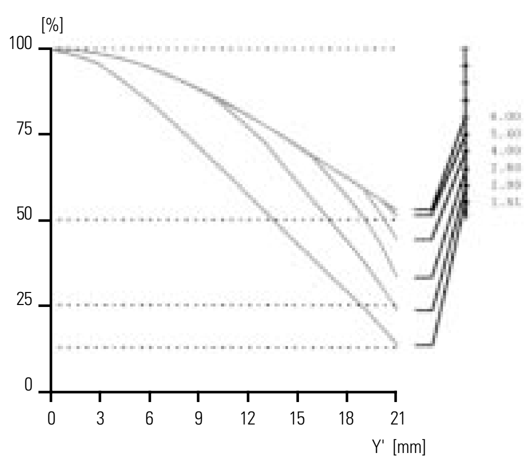
Optimum Aperture [8,0]



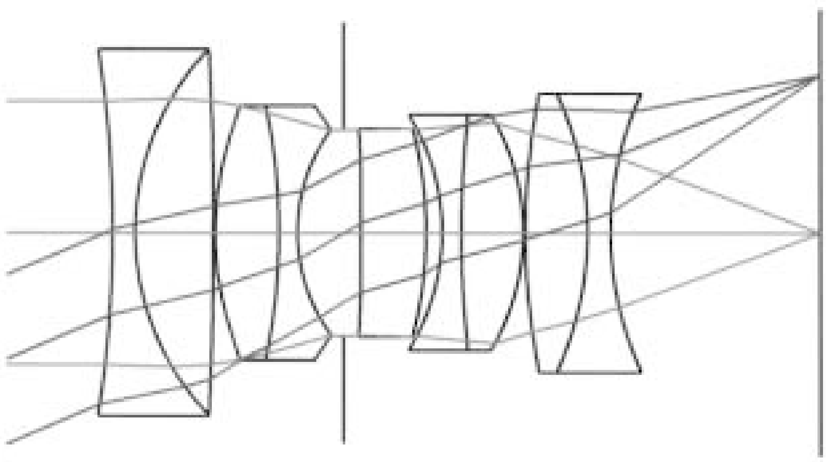
Distortion



Vignetting



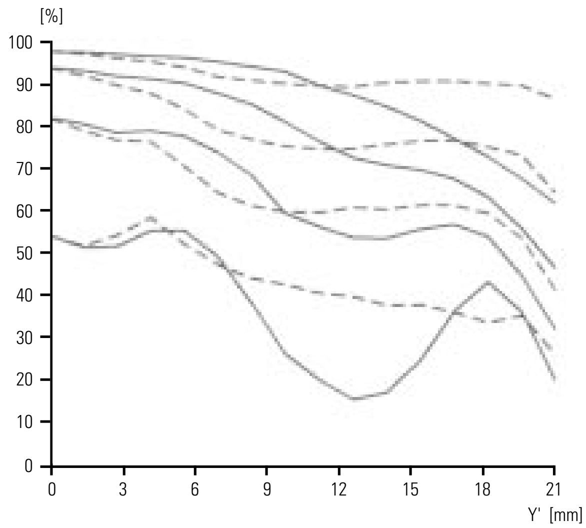
35mm f/1,4 Summilux-M (aspherical)



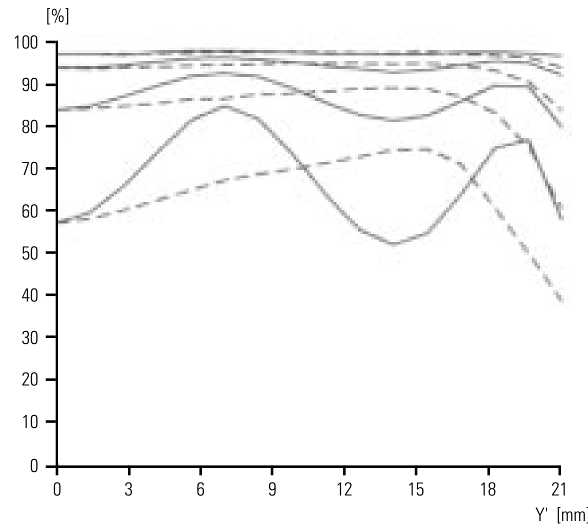
Summary

This design is a milestone in optical construction, because of its negative front and rear surface and the two aspherical surfaces. Its full aperture performance is superb with a high contrast image and a clear definition of extremely fine details.

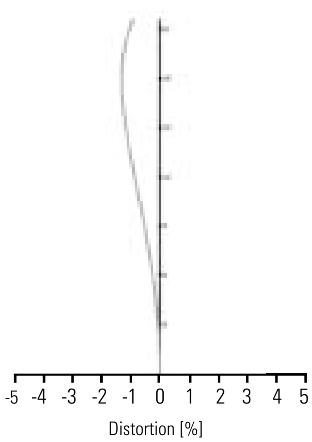
Full Aperture [1,4]



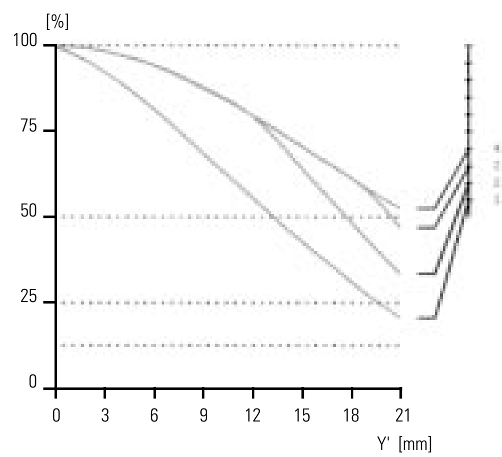
Optimum Aperture [4,0]



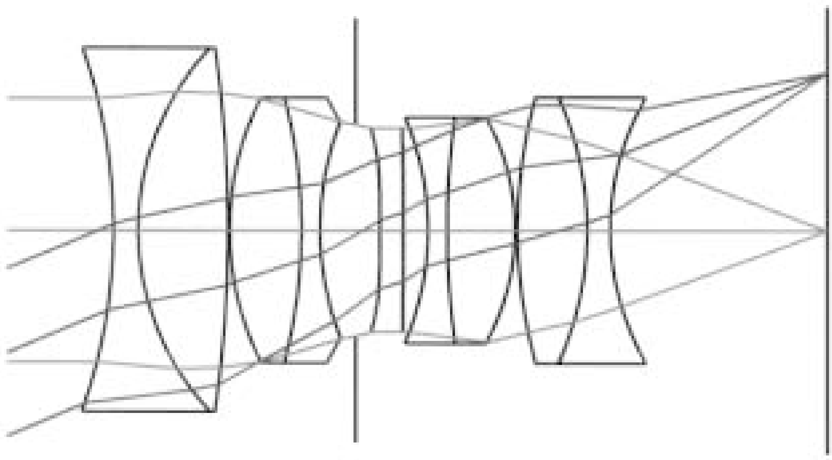
Distortion



Vignetting



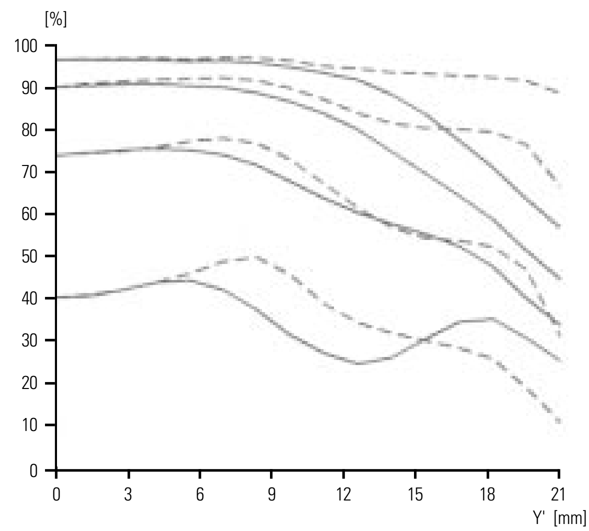
35mm f/1,4 Summilux-M ASPH



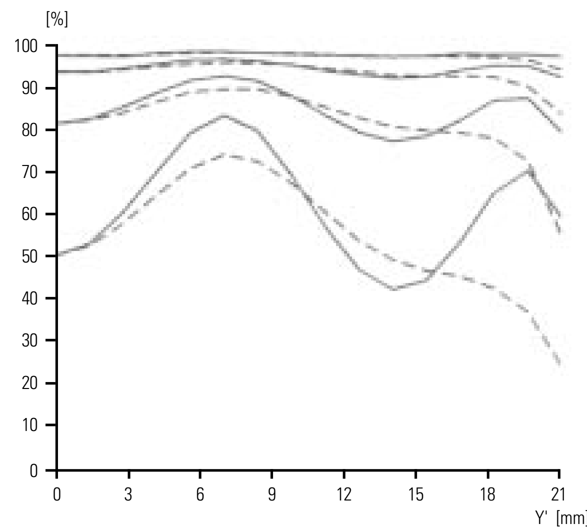
Summary

The redesign with one precision pressformed aspherical surface can be produced more economically. Superior imaging at full aperture, with a slightly different fingerprint than predecessor. At f/1.4 it is a close match to the performance of the Summicron 50mm at f/2.0.

Full Aperture [1,4]



Optimum Aperture [4,0]



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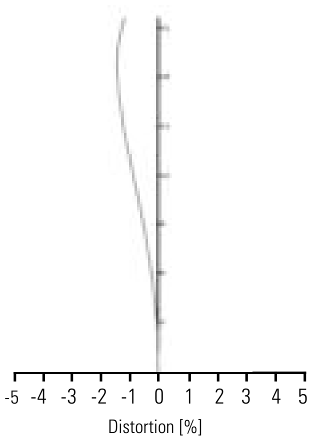
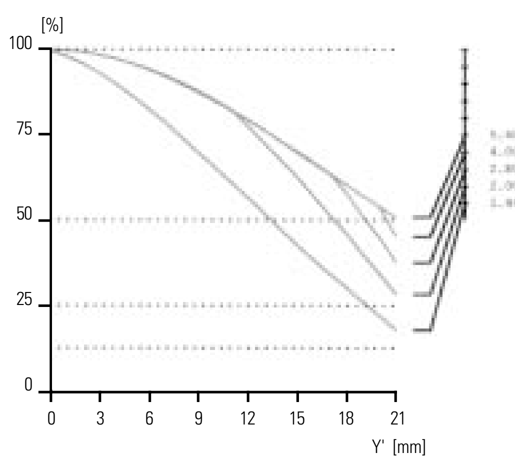
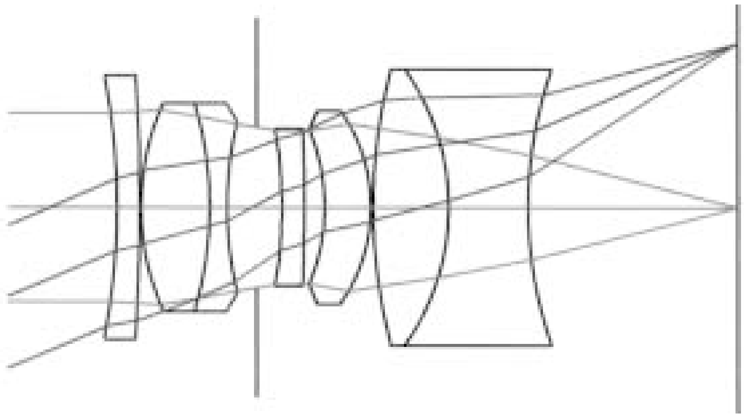


Vignetting



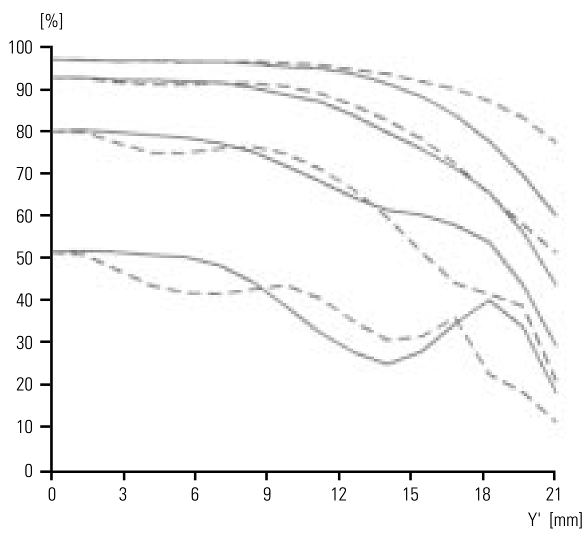
35mm f/2 Summicron-M ASPH



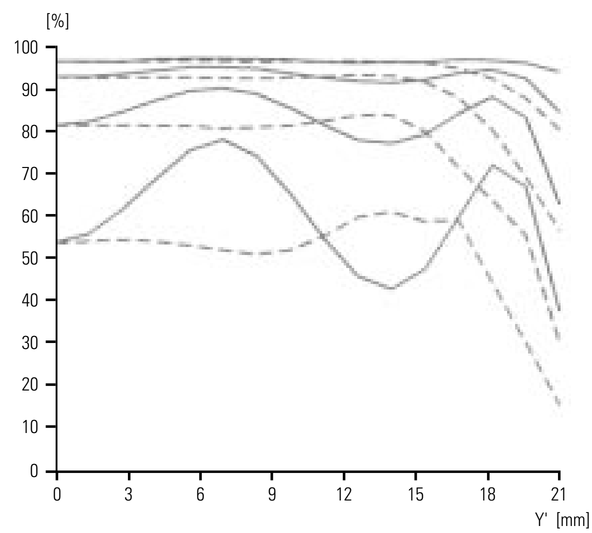
Summary

Outstanding image quality at full aperture and over most of the picture area are its prominent characteristics. This lens, with its very low propensity for flare, combined with its crisp rendition of extremely fine textural details, is suitable for both the fine-art photographer and the documentary photojournalist.

Full Aperture [2,0]



Optimum Aperture [4,0]



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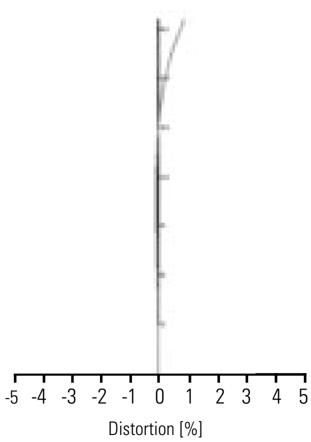
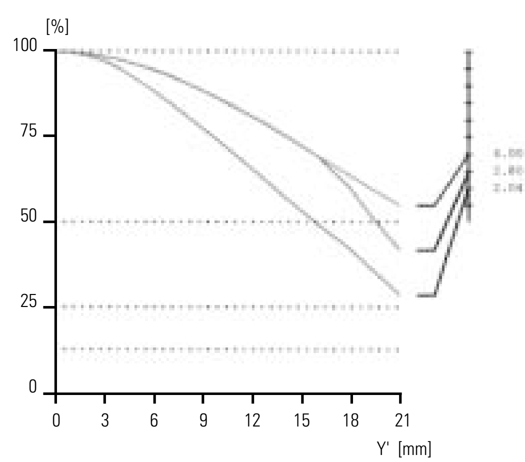
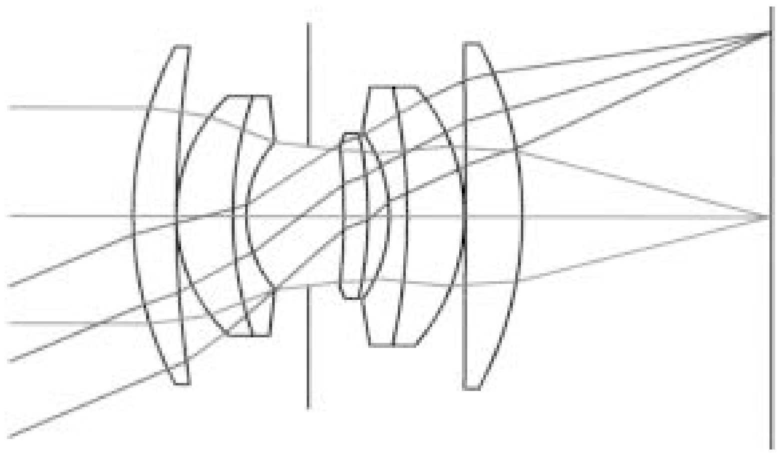


Vignetting



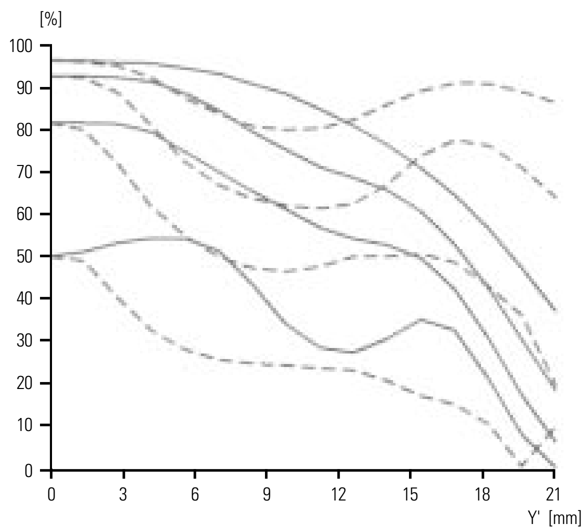
35mm f/2 Summicron-M



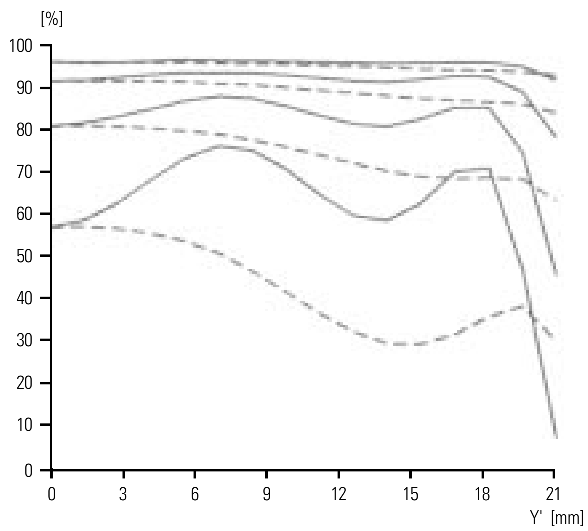
Summary

This lens type has been the epitome of Leica photography for more than 40 years. It is the prime choice of many users because of its small volume and excellent performance. At full aperture the image quality on axis is front-rank, but it drops visibly in the field.

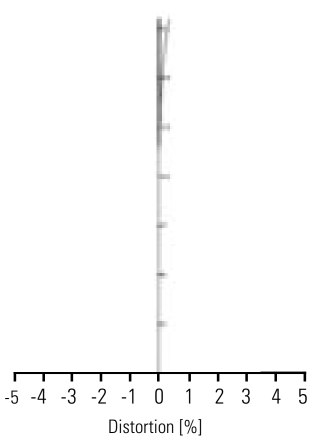
Full Aperture [2,0]



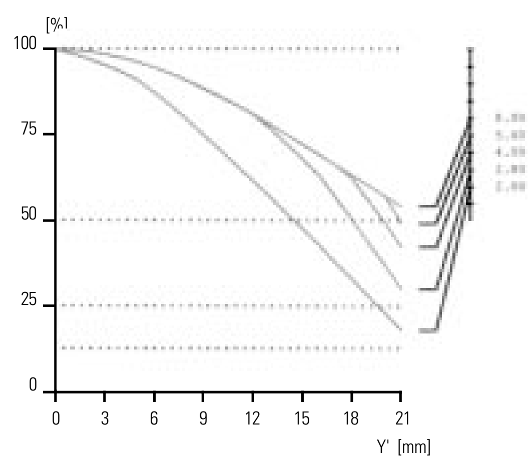
Optimum Aperture [8,0]



Distortion



Vignetting



50 mm lenses

The first lens used for the Ur-Leica had a focal length of 42mm. Commercial models (from 1925) were fitted with the Anastigmat/Elmax f/3,5/50mm. This design had 5 elements, presumably to avoid patent conflicts with the Zeiss company. There is much speculation why Barnack/Berek had chosen this particular focal length. The most popular explanation is the alleged correspondence between the angle of view of human vision and that of the 50/52 mm focal length: ± 46º. Now the human eye has several angles of view, depending on several criteria. They range from 6º to 150º and there is no compelling argument that the eye favors the 46º angle. The binocular field of vision is 130º. Let us stay on safer ground. There is a sound optical reason for the choice of the 50mm focal length.

It so happens that the 50mm focal length is a solid base for excellent performance. Adopting this focal length will ensure very good optical corrections, so dearly needed for the success of the original Leica.

50mm f/2.8 Elmar

The Elmar f/2,8/50mm was introduced in 1957, almost 33 years after the Elmar f/3,5/50mm. In its day, the Elmar f/2,8 was famous for its very good image quality in the center. It was also slightly ahead of perennial competitor Zeiss with the Tessar. The different position of the aperture (between the first and second element) was the main advantage of the Elmar. On test the Elmar performs acceptably, at full aperture with a low overall contrast and clearly rendered fine details with smooth (more accurately: soft) edges. Fine details are visible in the center but become fuzzy in the field. Stopping down to f/4.0 markedly improves overall contrast and brings in the corners. Very fine details now become more crisp and a small amount of extremely fine details is detectable in the center. At f/5,6 optimum performance is reached.

The Summicron f/2,0 (7 element version) at full aperture has much better center performance than the Elmar at f/2,8. Only in the outer zones of the field the Elmar shows better imagery. Overall the original Elmar at apertures of f/5,6 and smaller is a good performer. Image quality at the wider apertures is a bit below the aura bestowed on it by benign collectors and users.

50mm f/2,8 Elmar-M

The redesigned Elmar-M f/2.8 at full aperture provides a medium to high contrast image with very fine details very crisply rendered over most of the field. Generally the new one is a stop or two ahead of the predecessor. More important for the overall image quality is a much-improved micro contrast that adds to the very fine textural details a sparkling clarity. At f/5,6 the Elmar-M is close to the performance of the current Summicron-M f/2.0/50mm. Close-up performance of the Elmar-M is excellent at full aperture. The four elements of the Elmar give less latitude for aberration-correction than the six of the Summicron. The lesser number of elements on the other hand produce a very pleasing, almost brittle rendition of very fine details.

At f/2,8 the Elmar-M has the same fingerprint as the current Summicron-M at full aperture (f/2.0), be it with slightly less overall contrast.

50m f/2 Summicron-M (current)

The aperture of f/2.0 has been the workhorse of 35 mm snapshot/reportage photography since the early thirties. The earliest version for the M-series was the 50mm f/2.0 Summicron with 7 elements. This lens was the first to benefit from advanced glass research and improved computations. The design proved to be sensitive to production tolerances. Medium to high contrast in the center with fine details clearly resolved was combined with a relatively sharp drop of performance in the field and outer zones. The higher level of aberrations in the field had its negative effects on the overall image quality. At full aperture this lens is prone to flare in not very severe lighting situations. Stopped down to f/4.0 this lens performs very well with a high contrast image over most of the field and a slightly soft rendition of edges of very fine details. Compared to the current 50mm f/2.0

Summicron-M at the same aperture of f/4.0 we note a very different fingerprint. The current Summicron-M renders exceedingly fine details with sparkling clarity. Subtle color shades are cleanly and smoothly differentiated in both shadow details and highlight details. Within specular highlights minuscule details are still visible, a proof that flare and veiling glare are very well controlled.

At f/4.0 the Summicron-M performs at its optimum. It is a characteristic of modern lenses that the gap between the image quality at full aperture and at the optimum aperture is moderately small. At full aperture the current Summicron-M is at a different performance level compared to the first Summicron seven-element lens, that performs quite commendably. With a high contrast image over most of the field and extremely fine details clearly and crisply rendered in the center this aperture can be used for all but the most exacting demands. Stopped down to f/2,8 this performance extends over most of the field and exceedingly fine details are now crisply rendered with good clarity.

At f/5.6 the contrast of very fine details begins to drop, a characteristic that should be discernible in very critical work. The full aperture performance of the f/2.0 Summicron-M is difficult to equal, let alone to surpass. The new 90mm f/2 Apo-Summicron-M ASPH gives an improved imagery at full aperture (the clarity and edge contrast of outlines and finest textural details), but one must remind oneself that with 27°, the angle of field is much less.

Close-up performance of the Summicron-M is on the same level as the performance at infinity setting (actually infinity is that distance where the incoming light rays are parallel to the optical axis. For most lenses this condition is satisfied at about 100 times the focal length).

50mm f/2 Summicron-M (previous)

The 1969 version of the Summicron 50mm lens has about the same center performance as the current (1979) version. In the field however, the 1969 design has quite low edge contrast. On stopping down the field does not improve much. Extremely fine details are markedly lacking over most of the field.

Center performance however is about equal to that of the current version, albeit with a bit lower overall contrast. This fingerprint of the Summicron version of 1969 at full aperture and performance when stopping down has initiated the impression that Leica M lenses are deliberately optimized for center 'sharpness' with a certain neglect of the field. It has been suggested that this behavior has been designed specifically for the rangefinder camera, as focusing and composing is done mostly in the center part of the field. The reportage style of M photography should also benefit from these characteristics.

I would be a bit hesitant to support these propositions. A higher amount of spherical aberration in the 1969 version is mostly responsible for its optical behavior. The designers in those days could not reduce the aberration without resorting to a bigger or more expensive design.

50mm f/1.4 Summilux

The first 50mm Summilux design (1959) closely resembles the performance characteristics of the Summilux 35 mm. A low contrast lens at full aperture with fine details just resolved, this design closely resembles the 50mm f/1.5 Summarit in construction and performance. Stopping down to f/2,0 improves the center performance to a level just above the Summicron (7-element version) but not yet to the level of the second generation 50mm f/1.5 Summicron.

50mm f/1.4 Summilux-M

The current Summilux-M version was introduced in 1962, making the predecessor one of the shortest lived lenses in the Leica history. At full aperture we note a high contrast image on axis with a fairly quick drop of contrast in the field. Fine details are clearly visible, but the edges are very soft.

On stopping down the overall contrast improves rapidly. Very fine details are rendered crisply in the center only, and rendition in the field is quite dull, if not fuzzy You need to stop down to f/8 to get very good image quality over the whole field. The fingerprint of this lens is identical to the one of the second generation Summicron. Excellent center performance already at full aperture, with a rapid drop off axis from about 6mm image height. Close-up performance shows crisp rendering of fine details from f/2.8. Close-ups at full aperture are to be avoided if very good imagery is required. Night pictures with bright small light spots produce a faint halo around these point sources. Oblique light rays however generate a veiling glare and an overall softening in the rendition of details.

The 35mm f/1.4 Summilux ASPH is to be preferred when state-of-the-art full aperture performance is needed. Aperture for aperture the 35mm Summilux ASPH shows improved image quality in comparison to the 50mm Summilux-M.

Performance in the outer zones is a bit low at all apertures, which are noted easily as the center is of such excellent quality.

Flare

When I discuss flare (secondary reflections and flare spots) and veiling glare, I refer to the way specular highlights are recorded (with or without reflections in the small details). When veiling glare is present, one will notice that the shadow details are gray because of unfocused stray light through the whole lens and the way strong light sources just outside or in the far corners dilute the saturation of colors and wash out fine textural details.

The commonly used method of shooting straight into the sun or a light source will quite often produce secondary reflections of the primary source. In these cases the observer should look at preservation of image details in heavily overexposed areas. One of the best methods to study inherent flare tendencies of a lens is to take pictures of trees with many branches against a bright sky. The way the light spills over into the dark silhouetted branches is a good indication of sensitivity to flare.

Optical character

There is much speculation in the Leica community whether the different optical characteristics noted sometimes (high image quality in the center and lower performance in the field versus somewhat lower performance in the center but even coverage over the whole image field) are deliberately designed to support certain types or styles of photography.

I cannot support this position. Any designer needs to balance aberrations to get the image quality that is required. As soon as advances can be made, high image quality over the whole field is the prime requirement. See for example the 35mm f/1.4 Summilux ASPH or the 90mm f/2.0 Apo-Summicron ASPH.

Noctilux design considerations

One of the curses of high-speed lenses based on the double Gauss design is the stubborn presence of an overcorrecting oblique spherical aberration. This aberration is particularly problematic as it affects the whole image area at full aperture and it is still busy deviating rays when it is stopped down. One of the design possibilities is splitting the single last meniscus lens element. That is the classical Summilux design (seven lens elements), that we also have in the 50mm f/1.0 Noctilux-M.

Still, sagittal oblique spherical aberration cannot be avoided. Add this characteristic to the lower performance of the Summilux in the field and we see some of the arguments for the emergence of the Noctilux f/1.2/50mm. The demand from the market to produce an even wider aperture than f/1.4 seems a bit strange nowadays. But the emulsion technology then was not as advanced as it is now. In these days reportage style photography in the darkest corners of the human living space was quite popular. The ubiquitous fill-in flash we are used to now, was not available in those days or pictorially speaking, anathema.

50mm f/1.2 Noctilux

The Noctilux design with two aspherical surfaces (front surface of first element and back surface of last element) aimed at reducing spherical aberration and enhancing image quality in the field. Both design aims could be met. At full aperture this lens has medium to high contrast with fine details visibly resolved with slightly fuzzy edges. Very fine details are just resolved, but its micro-contrast is quite low. On coarse-grained film this level of rendition of details will be lost in the noise level of the grain clumps. With modern fine grain B&W films these details are visible but quite fuzzy. Stopping down to f/1.4 improves overall contrast to medium/high. Fine details hardly improve in micro-contrast. At f/2.8 we have a high contrast image with crisply resolved very fine details in the center. The field is still lagging behind. These areas improve after stopping down to f/5.6 and f/8. Compared to the Summilux f/1.4, the Noctilux f/1.2 is not as good as the Summilux at f/1.4 and f/2.0. At f/2.8 both lenses are comparable and from f/4 the Noctilux is ahead by a small margin.

The Noctilux f/1.2 is very sensitive to the correct distance from lens flange to film plane. All Leica lenses are calibrated and adjusted to a maximum contrast transfer at 20 lp/mm. The performance of the Noctilux f/1.2 drops quickly when the distance is not within a 0.02 mm maximum tolerance. That is the reason behind the recommendation that the Noctilux f/1.2 should be individually paired to a body.

The laborious production of the aspherical surfaces (only one specially constructed grinding machine was available and it had to be operated manually), the high level of out-of -tolerance surfaces and the realization that this design did not solve all problems of ultra-high-speed lenses are arguments for the next player in high speed designs: the 50mm f/1 Noctilux-M.

50mm f/1 Noctilux-M

At full aperture (f/1) this lens has low to medium overall contrast with fine details clearly visible, but with soft edges. Very fine details are just visible on axis and barely visible in the field. Meridional and sagittal structures are equally well recorded, a sign of a high level of aberration correction. Looking at overall contrast one dimensionally the previous version of the Noctilux has a higher contrast at f/1.2, but then that is a half stop smaller. The better correction of aberrations in the sagittal plane gives the current Noctilux a small performance edge.

At f/1.4 the current Noctilux has the same high contrast as the predecessor. The micro-contrast of very fine details are also much improved. Still in the marginal zones the previous Noctilux still has an advantage. Compared to the Summilux f/1.4 at its full aperture, the Noctilux has lower contrast but a more even coverage.

At f/2 the Noctilux improves again with a marked crispening of the fine details on axis over an image circle of ±14mm. Compared to the current 50mm Summicron, the image quality of the latter is in a different league. Where the Summicron has the ability to record exceedingly fine details with clarity and smooth internal gradation over a large part of the image area, the Noctilux is able to record fine details with very smooth internal gradation, but fuzzy edges.

At f/4.0 and f/5,6 the Noctilux is an outstanding performer and is comparable to the Summicron at f/2.8 and f/4. The very wide aperture however gives rise to aberrations that cannot be as rigorously corrected as in the Summicron design. This will be visible in the different fingerprint of this lens. One could say that the Summicron draws with a very sharply pointed pen and the Noctilux with a slanted pen to produce broader and smoother strokes.

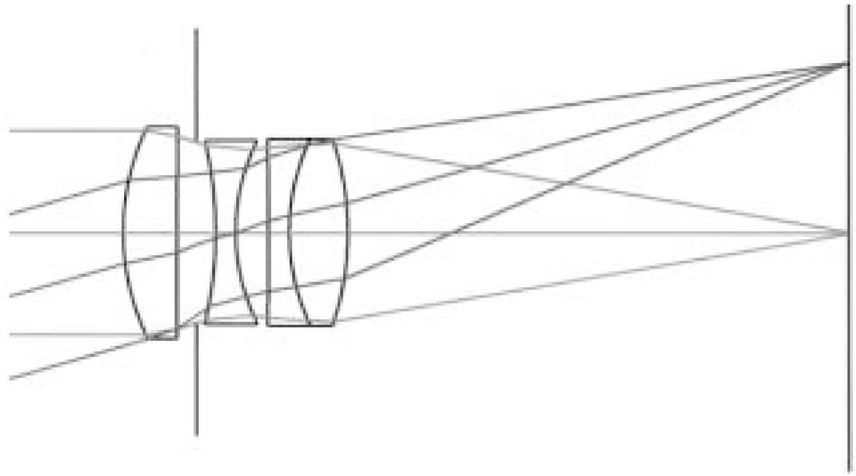
The finely reproduced internal gradation of small textural details in combination with medium overall contrast produces images with a special character.

The Noctilux-M is a lens that defies a simple characterization. At full aperture the blur circles of the light patches are quite large. It is difficult to detect small object details with crisply rendered outlines. This lens should be employed in quite demanding low level light situations to record larger object shapes with finely graded internal textures. Here its capabilities can be advantageously exploited. At all apertures from 1,0 to 2,0 overall contrast is lower and the recording of very fine details more fuzzy than that provided by its companion lenses (Summilux and Summicron). A special characteristic of the Noctilux is its shape preservation in out-of-focus- areas, bringing a remarkable depth of vision.

From f/4 the Noctilux can be used without hesitation for quite demanding photographic tasks. The severe vignetting at full aperture might be a problem when used for evenly and brightly lit objects. The Noctilux then excels in situations of very low light levels and/or vast brightness differences to record the feeling and ambiance of the scene. Its flare reduction is second to none and even better than that of the Summicron. Its penetrating power in ‘unavailable’ light produces stunning images that show finely graded details in lowly lit areas of the scene. Daylight pictures in the night, one would dare to remark. Close-up pictures (±1 meter pr 3’3”) at full aperture should be considered carefully, as the very shallow depth of field will produce a razor thin sharpness plane with very fuzzy out of focus planes.

There is no need to worry about the rangefinder accuracy in combination with the reduced depth of field of the f/1.0 aperture even at larger distances.

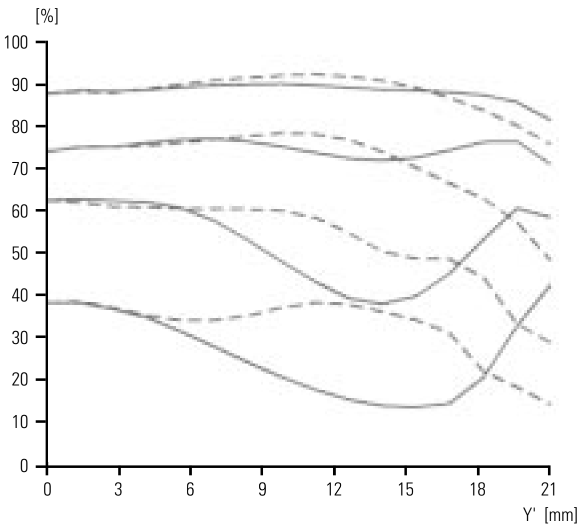
50mm f/2.8 Elmar



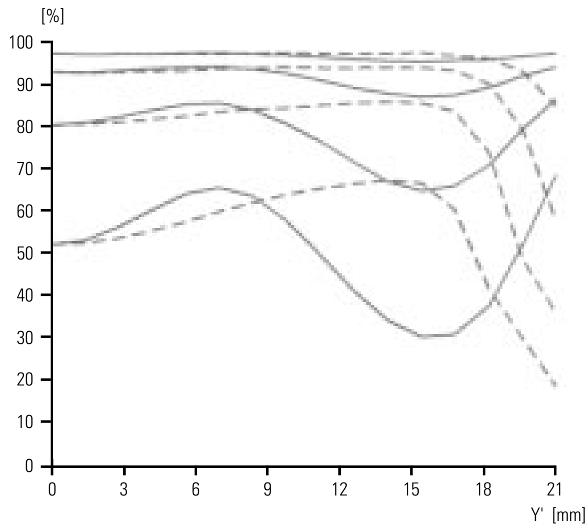
Summary

At full aperture the low to medium contrast of this lens produces a slightly dull image and fine details in the field are recorded with blurred edges. At f/4 the image markedly crispens and the on-axis performance is excellent, with the outer zones trailing behind in image quality.

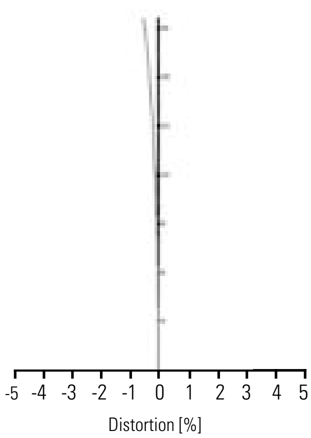
Full Aperture [2,8]



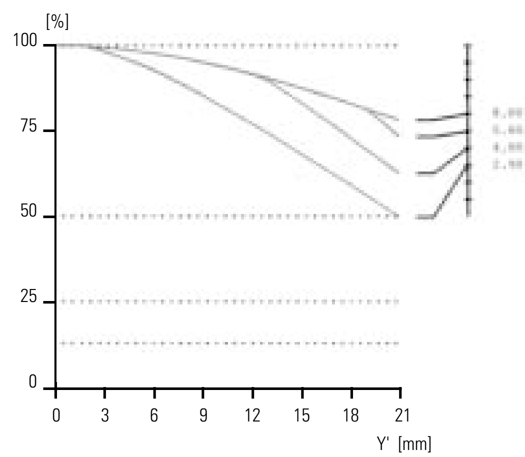
Optimum Aperture [5,6]



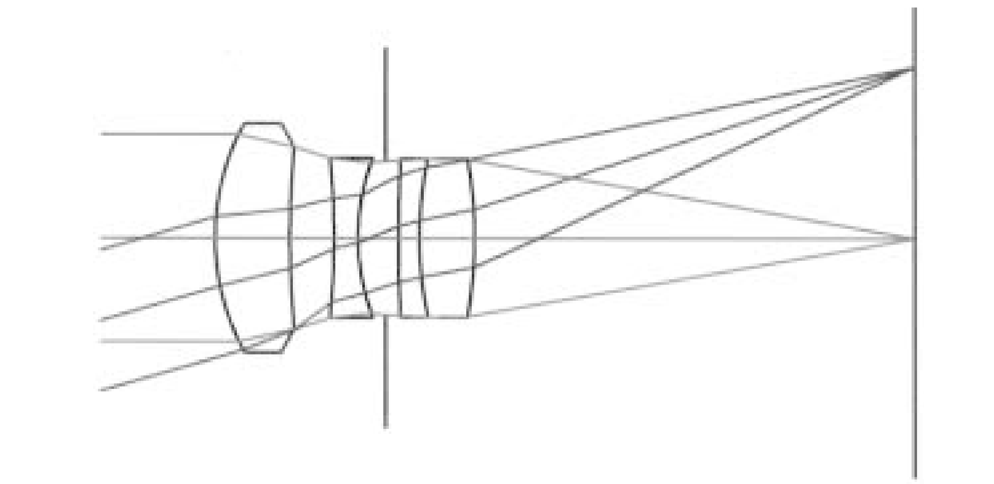
Distortion



Vignetting



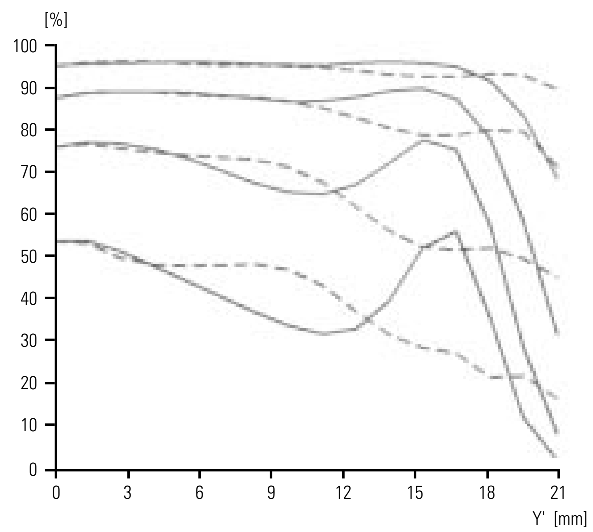
50mm f/2.8 Elmar-M



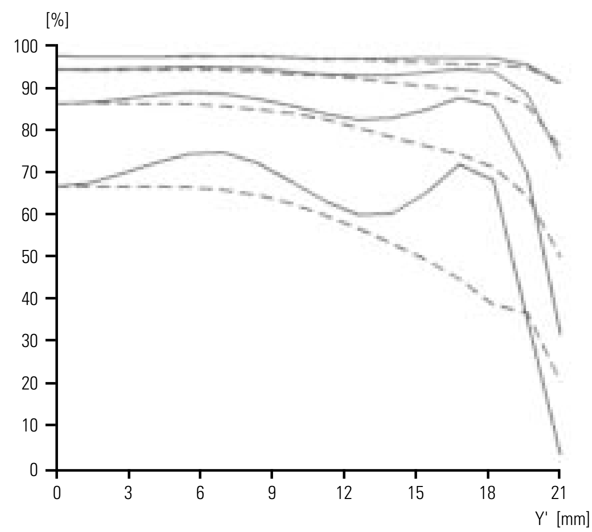
Summary

This redesign has been significantly improved. At full aperture very fine details are recorded with very crisp edges and good clarity. This compact (collapsible) lens is a front-rank design for very high requirements.

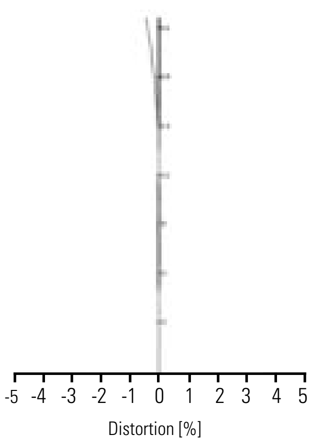
Full Aperture [2,8]



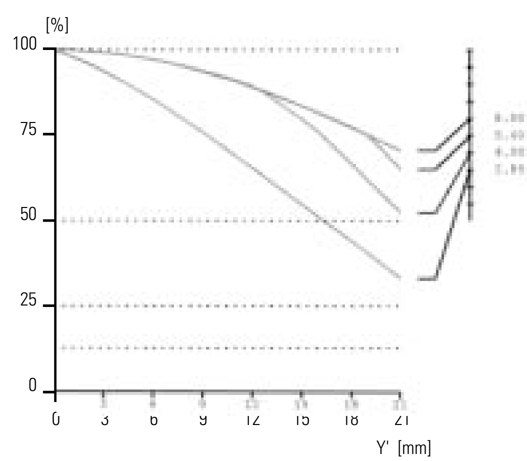
Optimum Aperture [5,6]



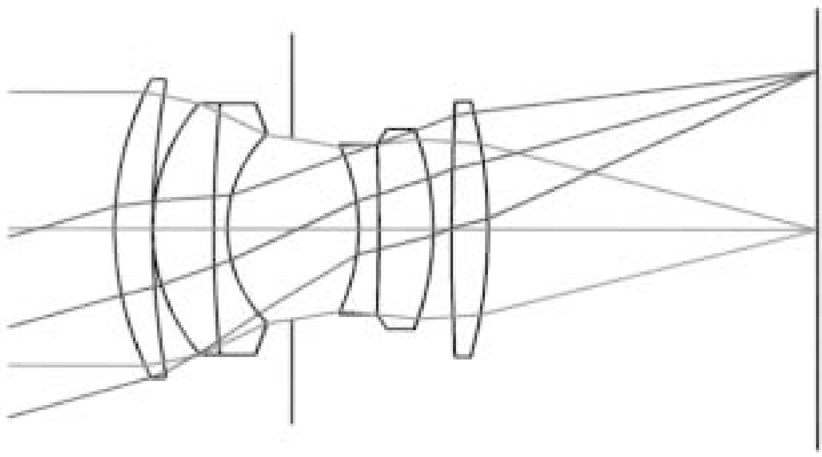
Distortion



Vignetting



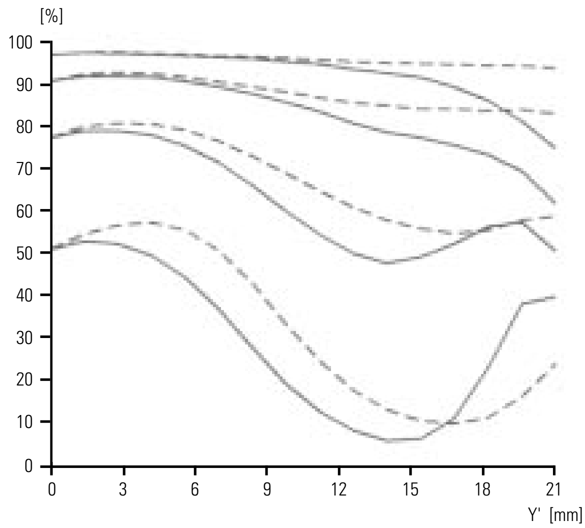
50mm f/2 Summicron-M



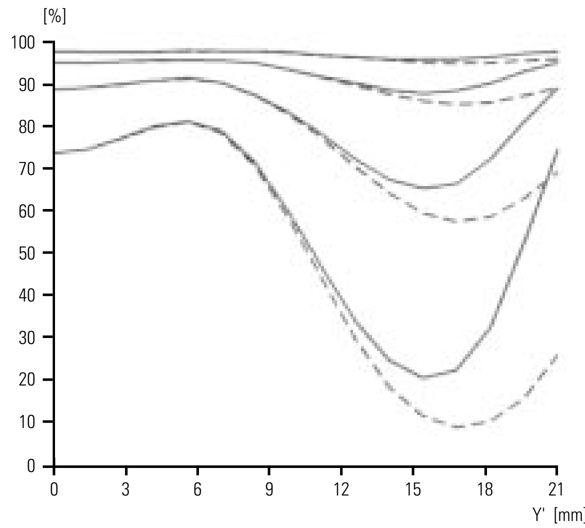
Summary

At full aperture this lens exhibits high contrast and very small image details are defined with excellent clarity. In the field and in the outer zones the image quality drops a little. Stopping down leads to a significant improvement in the center of the picture area, with the outer zones trailing behind.

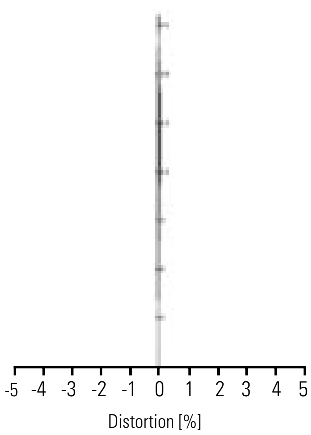
Full Aperture [2,0]



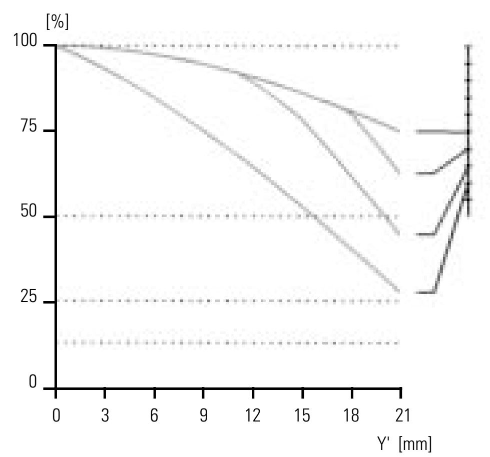
Optimum Aperture [5,6]



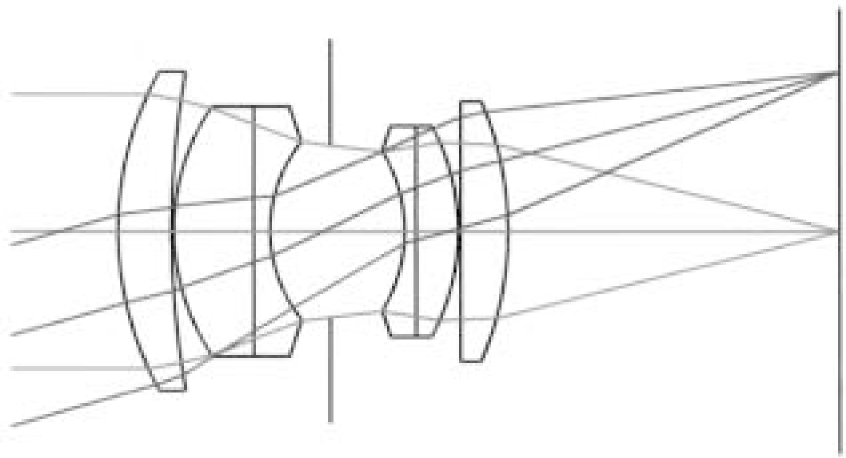
Distortion



Vignetting



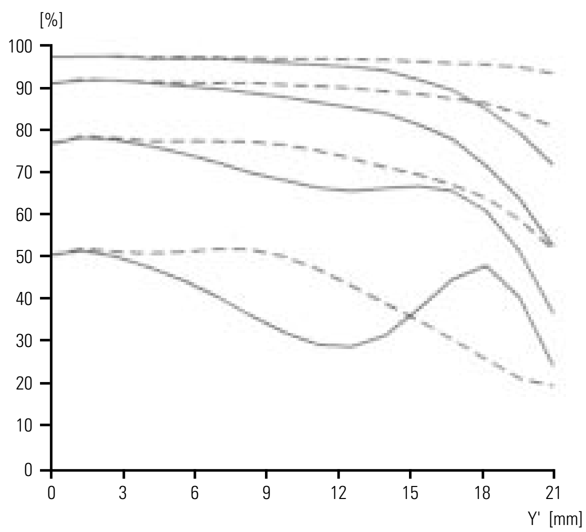
50mm f/2 Summicron-M (current)



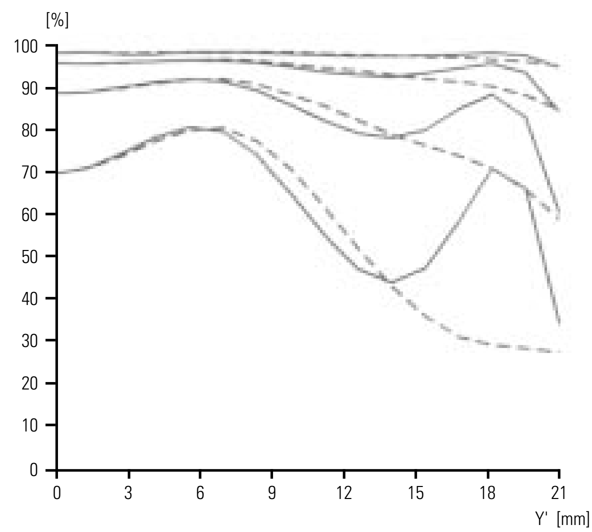
Summary

The classical double Gauss design, stretched to the limit, delivers image quality of a very high order. High contrast, very clean and crisp definition of tiny details, clear subject outlines at full aperture are the hallmarks of this lens that only needs to be stopped down one or two stops for cutting-edge image quality.

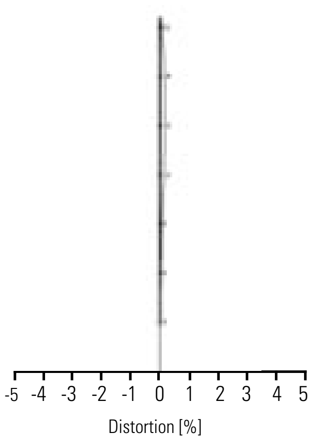
Full Aperture [2,0]



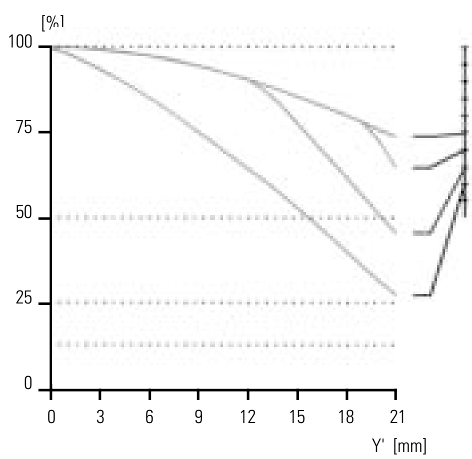
Optimum Aperture [4,0]



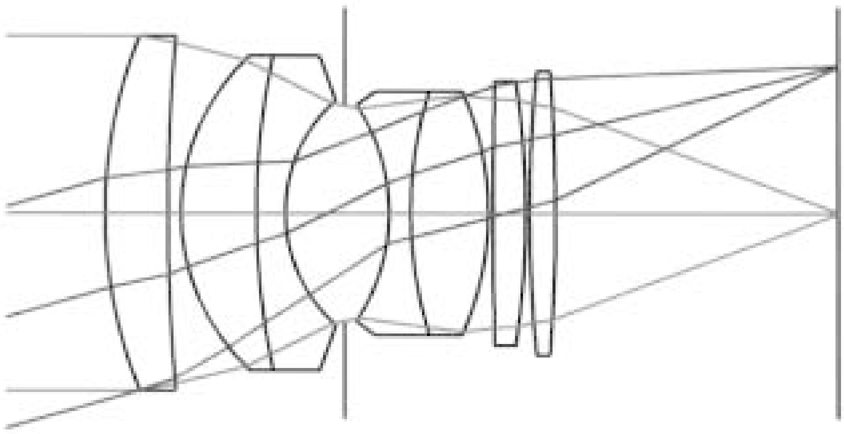
Distortion



Vignetting



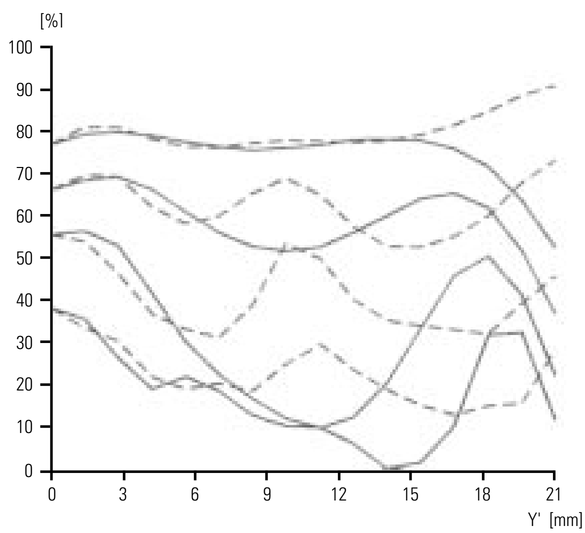
50mm f/1.4 Summilux-M



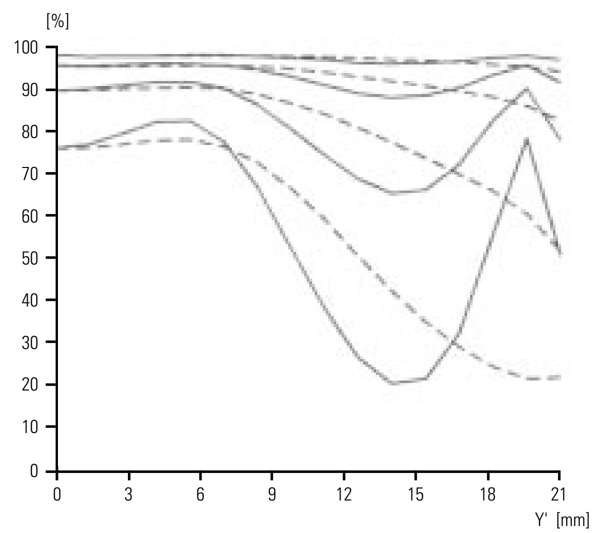
Summary

With quite low contrast at full aperture, this lens can record subject outlines and small details with good visibility. Stopping down two stops markedly improves the on-axis performance, with the outer zones lagging behind significantly. Even in its day it did not set a record performance.

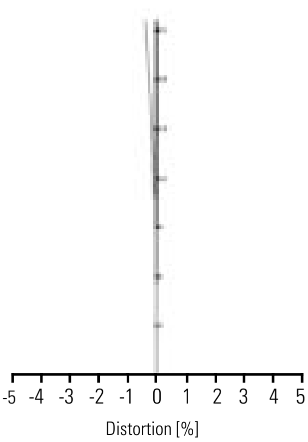
Full Aperture [2,0]



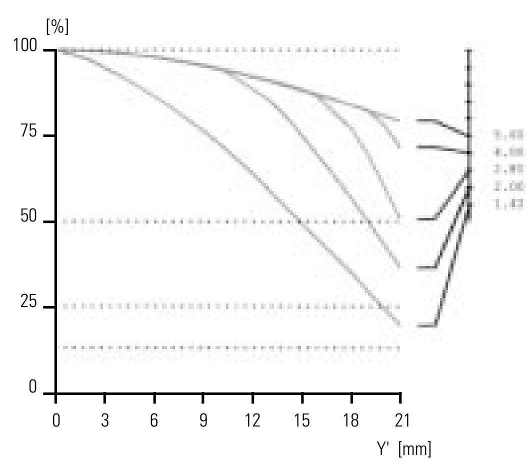
Optimum Aperture [5,6]



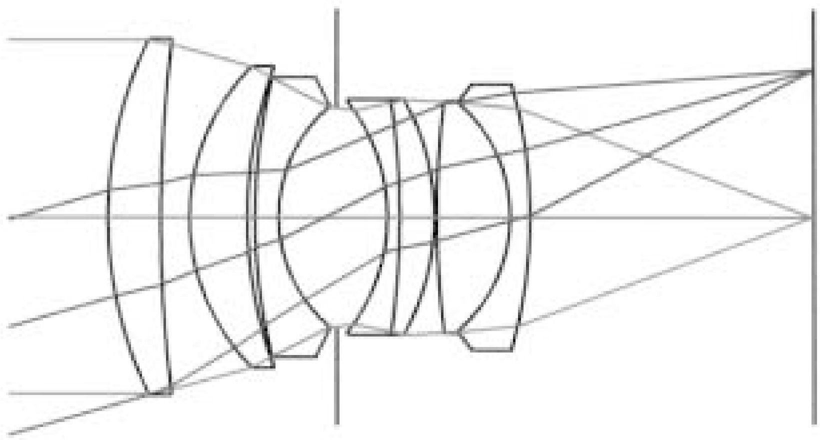
Distortion



Vignetting



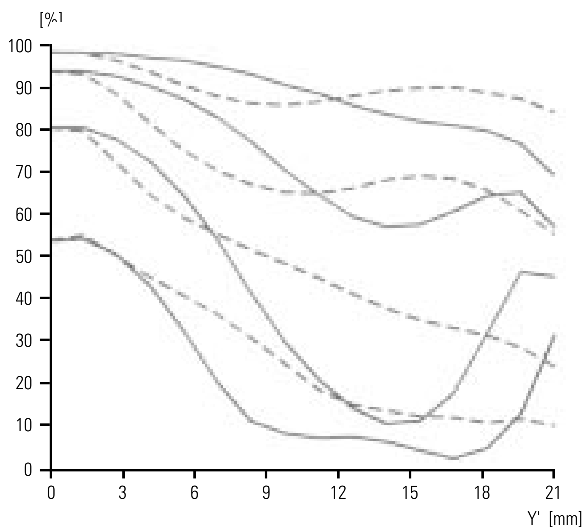
50mm f/1.4 Summilux-M (current)



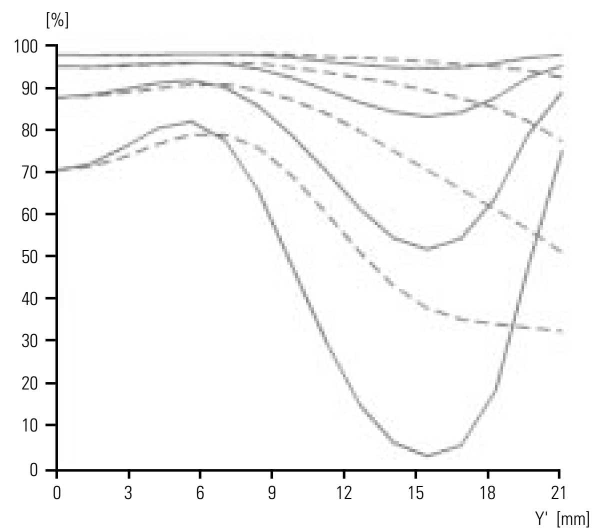
Summary

This redesign shows the image character of the classical high-speed lens: high contrast, excellent center performance that drops markedly when approaching the outer zones of the picture area. The image quality becomes outstanding when stopped down to f/8. This lens is clearly challenged by more recent designs.

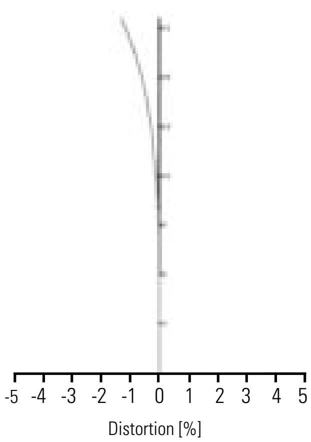
Full Aperture [2,0]



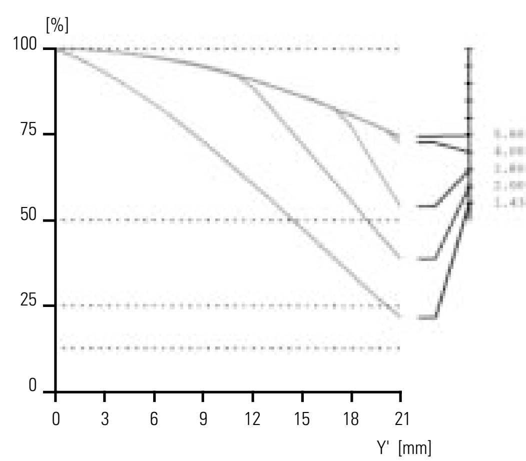
Optimum Aperture [5,6]



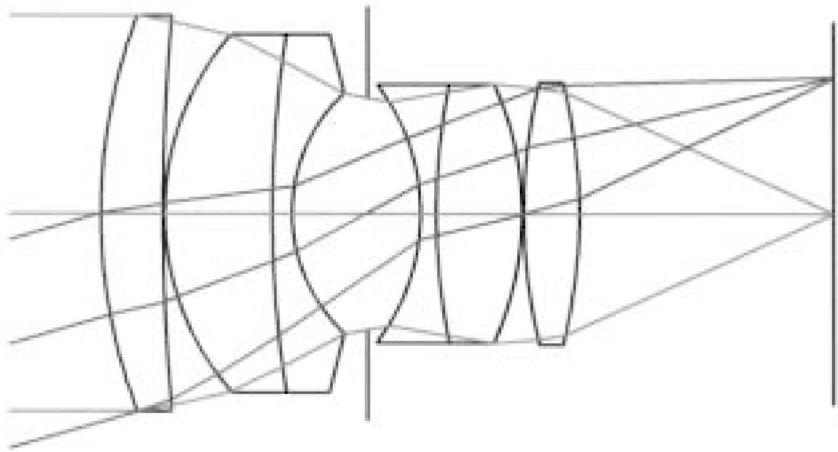
Distortion



Vignetting



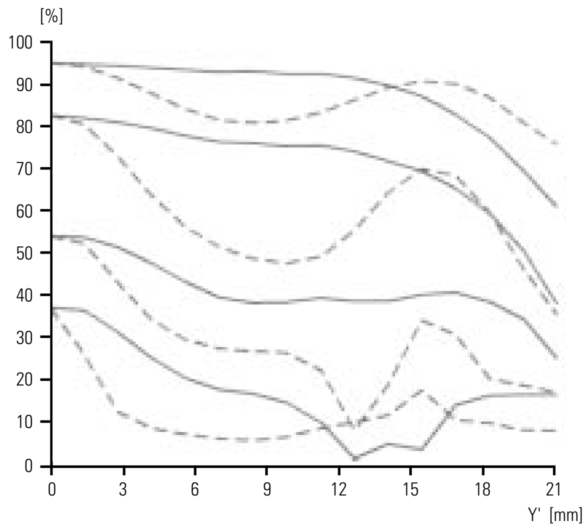
50mm f/1.2 Noctilux-M



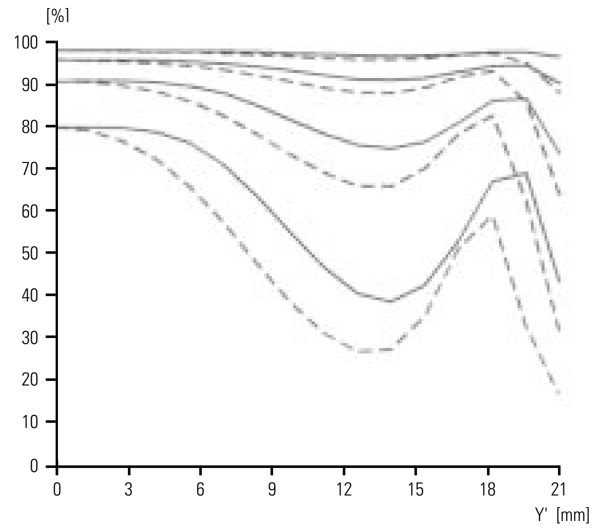
Summary

Arguably the most famous of all high-speed lenses, its design incorporated two aspherical surfaces. Wide open it recorded subject outlines with good clarity and its effective flare suppression helped the definition of fine details. The lens improves by stopping down and the on-axis performance at f/2.8 is superb.

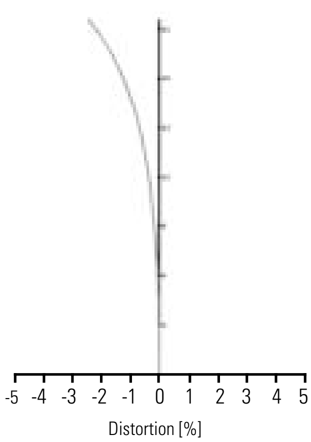
Full Aperture [1,2]



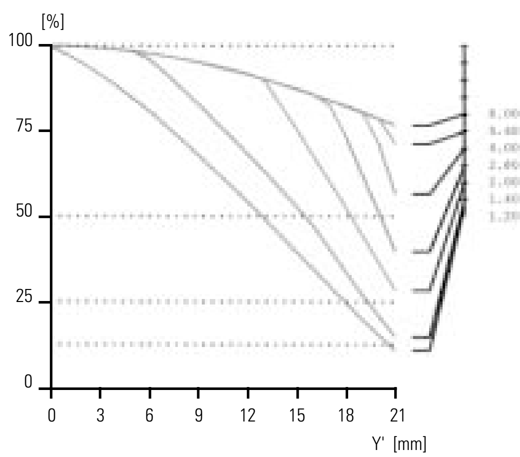
Optimum Aperture [5,6]



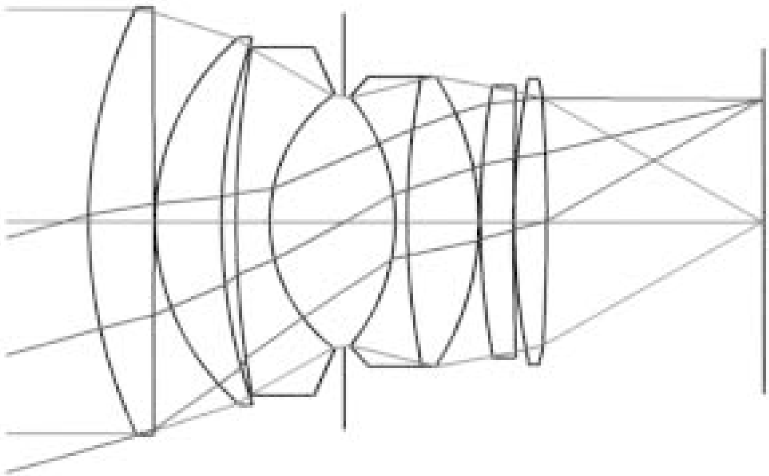
Distortion



Vignetting



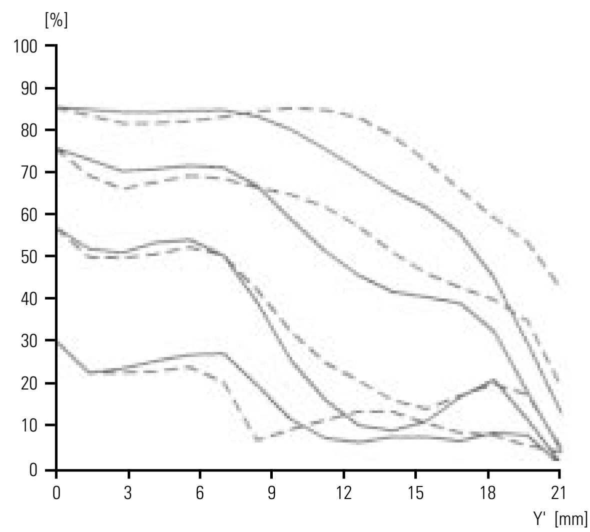
50mm f/1.0 Noctilux-M



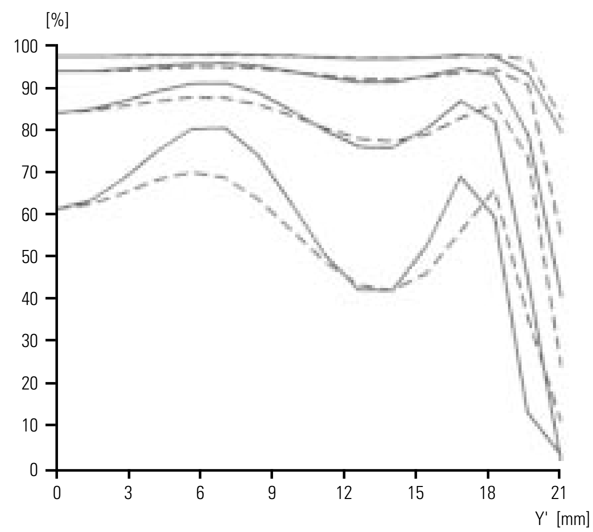
Summary

The fingerprint of this lens is unique. At full aperture it shows superior flare suppression, a medium overall contrast and a clean rendition of the finer textures in subject details in shadows and highlights. This is a lens for the connoisseur, and not a substitute for the 50mm f/2 Summicron.

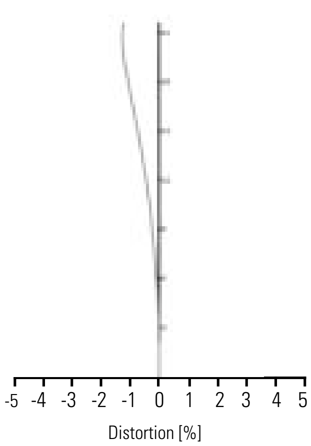
Full Aperture [1,0]



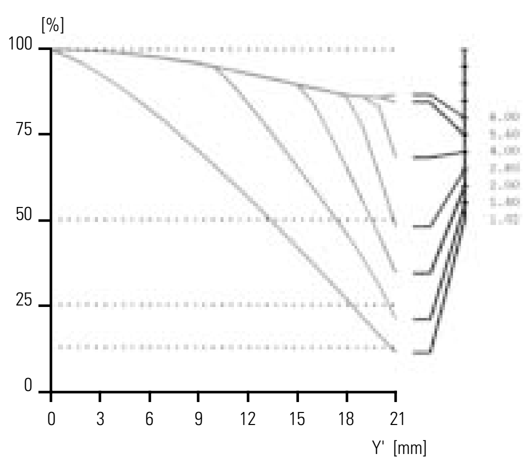
Optimum Aperture [5,6]



Distortion



Vignetting



TRI-ELMAR-M

This lens is very important in several ways. Its three focal length (28-35-50) selection brings zooming convenience to the M-rangefinder line-up. It takes a while to become accustomed to its three ring handling (aperture selection-distance selection and focal length selection). The focal length selection ring is close to the distance setting ring and when in a hurry it is easy to mix things up. After some use (it took me a day) your fingers 'know' the right locations intuitively. The convenience of having three focal lengths at swift disposal would be useless for the critical Leica M user if the optical performance were below par.

General optical performance

I tested the Tri-Elmar-M in comparison with the 28mm Elmarit-M current and third generation, the 35mm ASPH and last non-ASPH version and the current 50mm Summicron. As I always use the same test method I can easily refer to the older generations as well. First surprise: the Tri-Elmar-M hardly improves on stopping down and this statement is true for all three focal lengths. This behavior is only possible in a very well corrected optical system.

It also means that the Tri-Elmar-M exhibits excellent optical performance at its full aperture. Admittedly not as wide as its fixed focal length brothers and sisters, but we will take up this issue at the end of this section.

How excellent is the performance?

Not every person will like the conclusion, but the Tri-Elmar-M is clearly superior in all optical parameters to many Leica lenses of the 28, 35 and 50mm focal lengths. With the exception of the aforementioned 5 lenses (28 current and 3rd generation, 35 ASPH and immediate predecessor: (the 7 element Summicron) and the current 50mm Summicron) the Tri-Elmar-M will outclass any other Leica lens of the 28, 35 and 50 focal length of previous generations by a large margin. Second surprise: in many picture-taking situations its performance is equal to that of current Leica lenses of 28, 35 and 50mm focal length. There are obvious and visible differences between the Tri-Elmar-M and its current fixed focal length companion lenses. To appreciate the relative importance of these differences I would like to draw a distinction between two types of Leica M use. Note that this a distinction between styles of use and not between users. The same person in one situation will demand superior optical performance and in another situation this person will be more concerned with capturing the fleeting moments of passion and life. Leica M users are fortunate that their equipment supports both styles eminently.

The performance of the Tri-Elmar-M at 50mm: the lens gives a high contrast image with fine and very fine details rendered crisply. Extremely fine details have somewhat softer edges, but are still quite visible. This performance extends over a circular image area with a diameter of 12mm (the center area). In the outer zones (the image circle from 9 to 16mm from the midpoint) the contrast drops a little and the very fine details become slightly softer. Some astigmatism lowers the contrast here. The extreme outer area and corners are soft with fine details just visible. Stopping down to f/5.6 brings somewhat more contrast and better definition of extremely fine details.

This performance level continues until after f/11 where diffraction softens the details and lowers the contrast. Close-up capabilities (1.2 meter) are very good with a contrast image showing crisply rendered fine details over the whole image field. At 35 mm: at full aperture the contrast now is a bit lower and very fine details are a bit softer.

Extremely fine details are just visible in the center, but in the outer zone barely so. The corners are on the same level as they are in the 50 mm setting. Quite remarkable here is the uniform performance over the total image field. The close-up performance again shows a high contrast image with excellent rendition of details over the whole image field. At 28mm: Leica states that the 50 position of the Tri-Elmar-M gives the best performance, and a slightly lower performance at the 28 setting. Indeed distortion is a bit greater than it is at the 35 and 50 settings. When photographing flat objects like walls, some barrel distortion is clearly noticeable. When picturing architectural objects with depth, this effect mostly vanishes. At full aperture fine details are rendered with medium to high contrast in the center and contrast is a little lower in the outer zone. Very fine details are clearly visible and become somewhat softer in the outer zones. At close-up distances the image is of the same high contrast and uniformity of field as it is at the other settings. Here, as with the 35 and 50 settings, stopping down increases contrast but the correction of aberrations is already of such a high level that image details and textural details only improve a little.

Comparison to the fixed focal lengths.

These lenses excel of course with excellent to outstanding performance at the wide apertures of 2.0 and 2.8. At f/4.0 they are at thier optimum and then they are comparable to the Tri-Elmar-M at nearby its optimum. For all focal lengths we can give this conclusion, based on the f/4,0 performance.

The fixed focal lenses perform a little better than the Tri-Elmar-M in the image quality at the level of extremely fine details and the performance in the outer zones and far corners. The overall contrast of the fixed focal lenses too is a shade better, giving the pictures slightly more clarity.

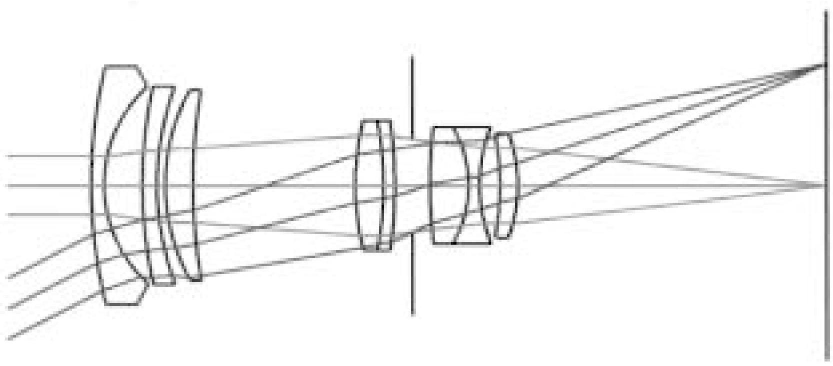
Very careful comparison of the pictures (low speed slide film at 30 x) taken with the Tri-Elmar-M and its companions shows these performance differentials in contrast and the quality at the level of extremely fine details. The Tri-Elmar-M shows remarkable suppression of flare and night shots taken on the 28 position give very good clarity of highlights and shadows with good rendition of details and only faintly visible coma in the extreme outer zone.

For most users, who will shoot casually or who do not demand the utmost of enlargements or projection distances, the performance differences are immaterial and will not be of any importance. The very demanding user might note the differences but it is a matter of personal preference how to rate these quality differences.

Conclusion.

Is the Tri-Elmar-M a replacement for three top class fixed focal length lenses? The answer is obviously not easy. Its full aperture of f/4.0 has its limitations. Especially when using low speed films. Its compact design constitutes an attractive alternative to three popular focal lengths and in this respect it performs outstandingly well. The smooth and quick changing of focal length brings many picture-taking opportunities that would be lost if you had to change several lenses. And the critical Leica user can use these new possibilities in the secure knowledge that the resulting pictures will show all the qualities for which Leica lenses are famous. And it may even captivate the most critical users of older generations of Leica lenses in the 28 to 50mm focal length group. Weighing only 330 grams (less than 12 ounces), it is a very convenient lens with excellent performance that the older lenses simply cannot match. The modern and current generations are able but hard-pressed to surpass this level of performance at f/4 and smaller. The Leica user who needs outstanding performance at apertures wider than f/4,0 and/or big enlargements showing the smallest image details with great clarity and contrast needs to change lenses and after many years might wear out the bayonet flange.

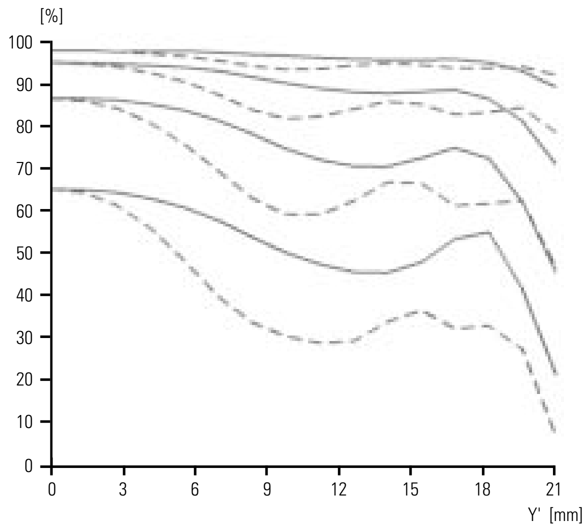
28mm f/4 Tri-Elmar-M ASPH.



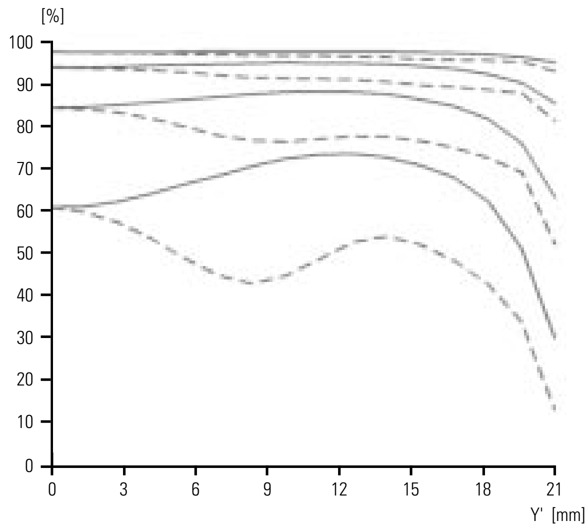
Summary

One of the very best lenses available for the M, its image quality at all three focal lengths is impeccable at full aperture. The maximum aperture at f/4 is sufficient for many situations and the smooth and easy change of focal length helps capturing elusive picture opportunities.

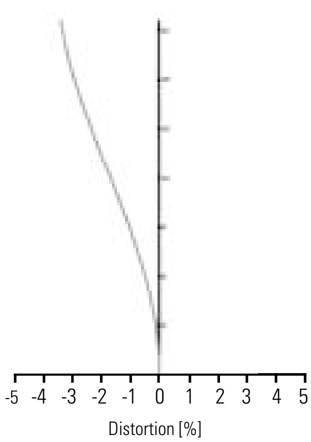
Full Aperture [4,0]



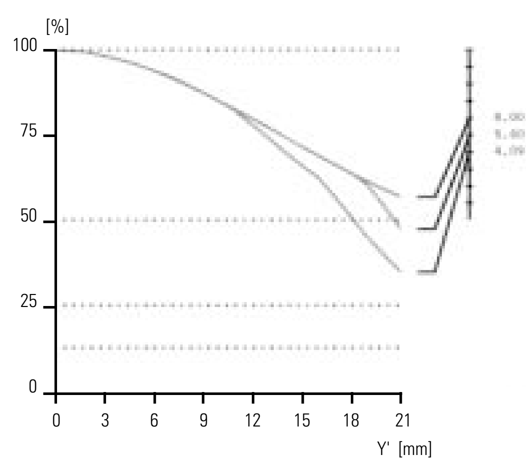
Optimum Aperture [5,6]



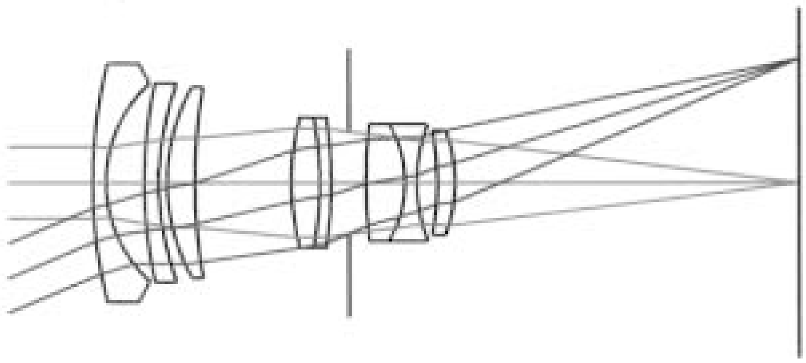
Distortion



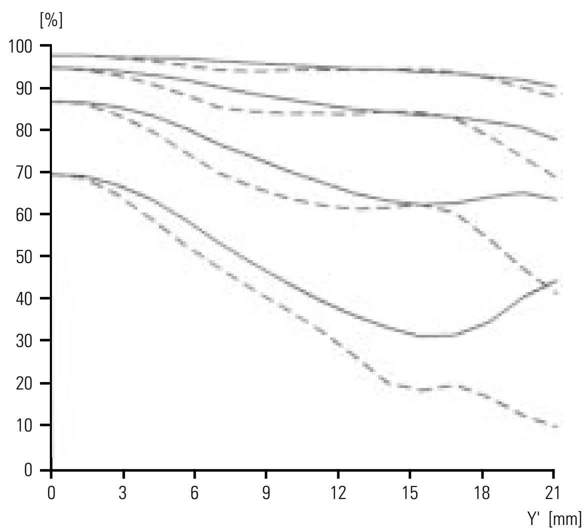
Vignetting



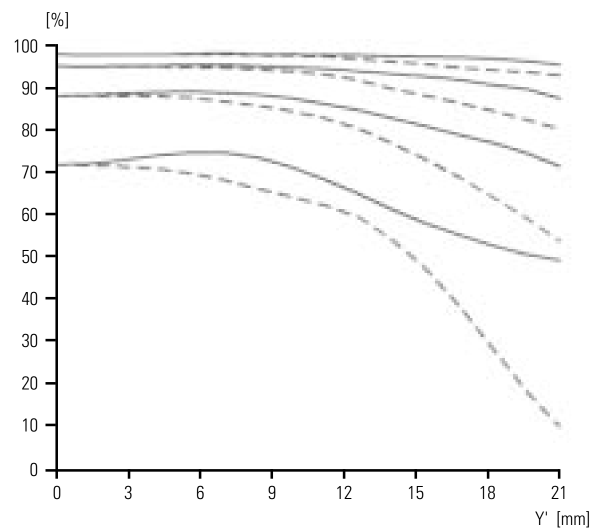
35mm f/4 Tri-Elmar-M ASPH.



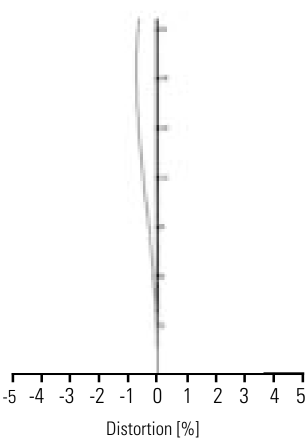
Full Aperture [4,0]



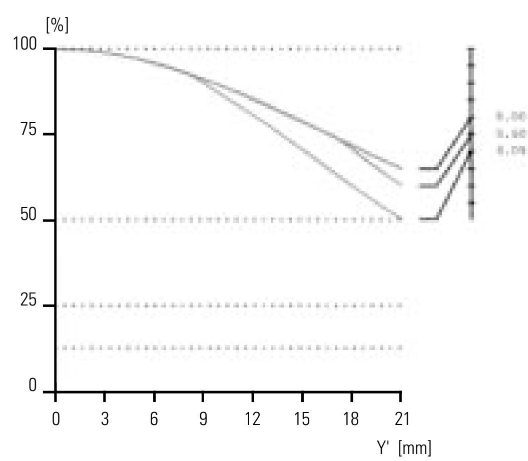
Optimum Aperture [5,6]



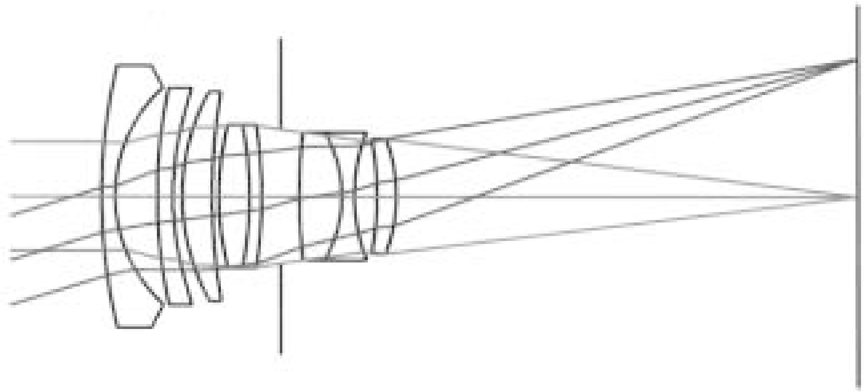
Distortion



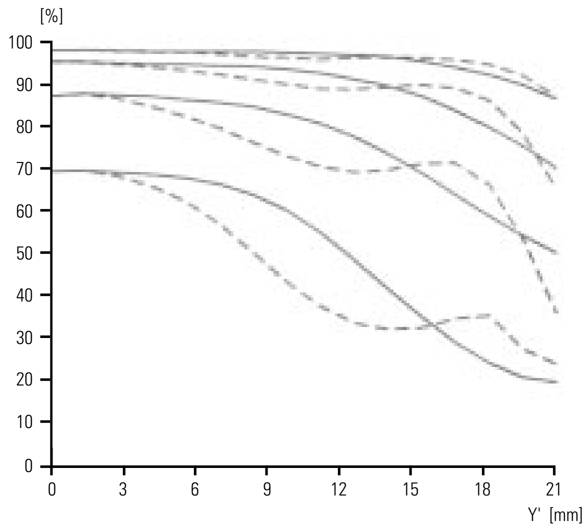
Vignetting



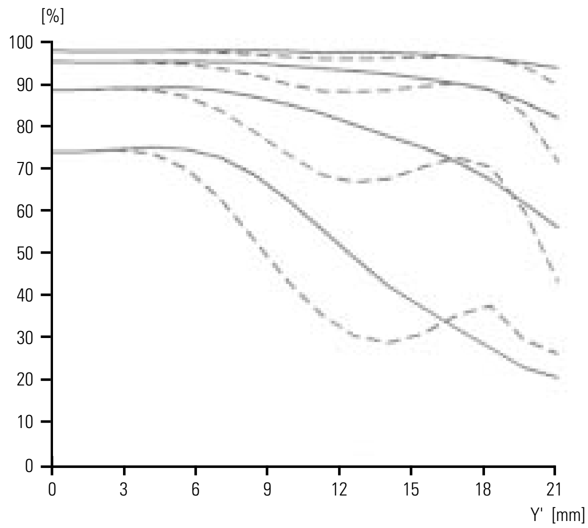
50mm f/4 Tri-Elmar-M ASPH.



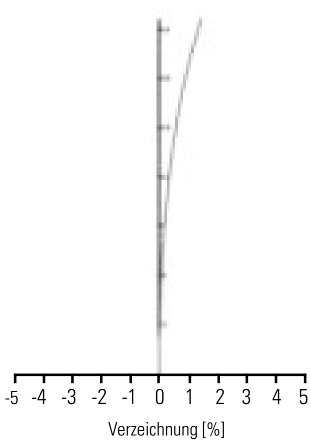
Full Aperture [4,0]



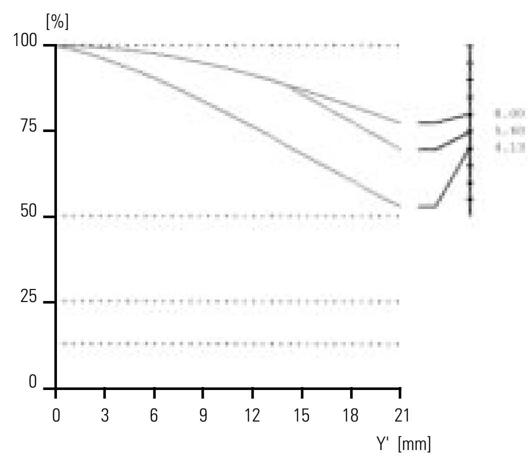
Optimum Aperture [5,6]

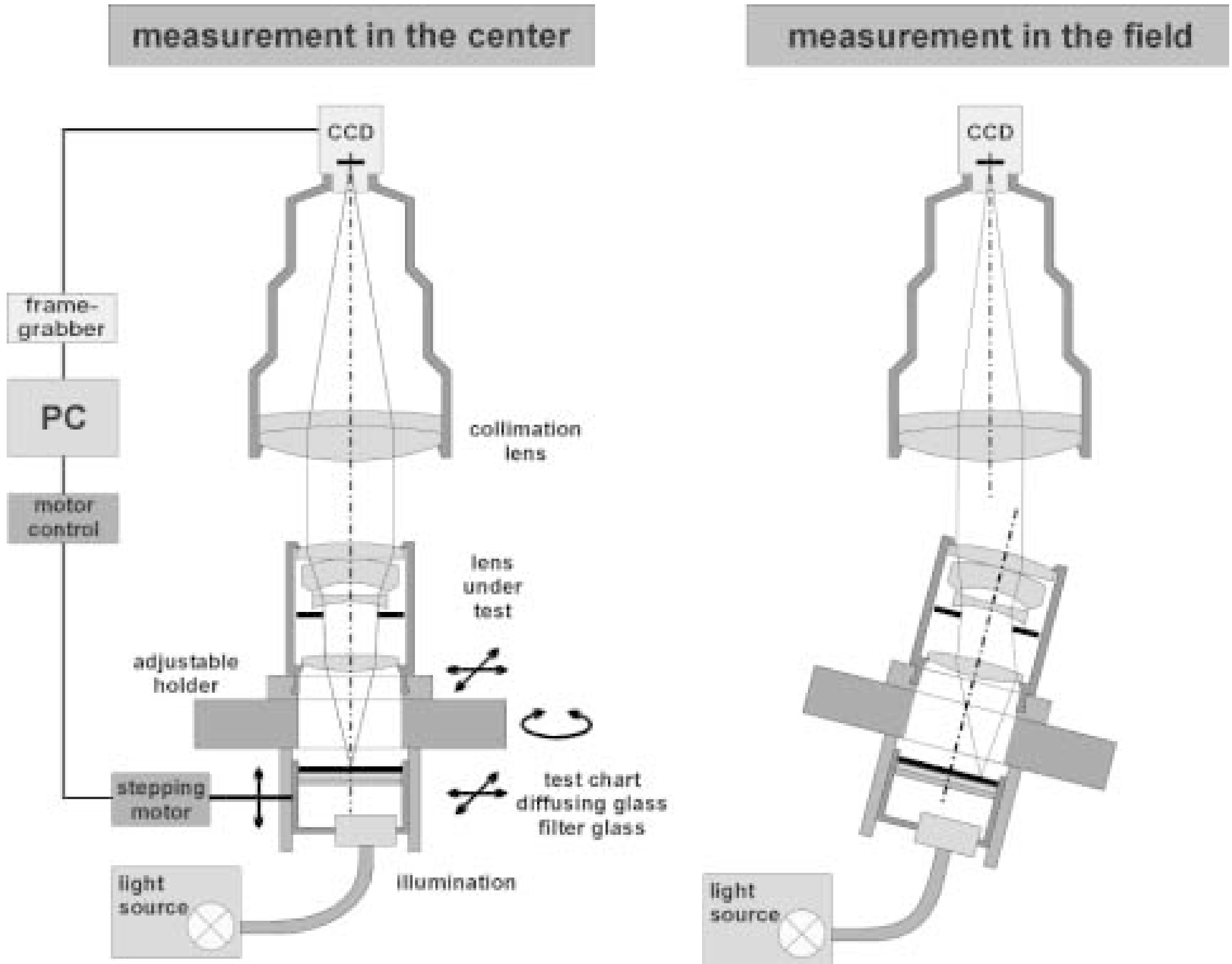


Distortion



Vignetting





MTF-measuring instrument to obtain MTF data

75 mm lenses

At first sight one might ask if a focal length of 75mm has added value, as it seems quite close to the 50mm and 90mm lenses. The angles of field are 45 degrees, 33 degrees and 27 degrees, respectively. If we take a look at history we note that Leitz offered a 73mm f/1.9 Hektor (from 1931 - 1946) and a 85mm f/1.5 Summarex (from 1943 - 1960). Both offered the widest aperture on the market at its time.

Leitz introduced the Summilux 75 as the new incarnation of the time-honored high-speed lens for candid photography and non-posed portrait photography. The maximum aperture of f/1.4 posed some constraints on weight and volume and so the focal length of 75mm was adopted.

The 75mm Summilux was designed in 1980 as were the 90mm f/2 Summicron-M, the 35mm f/2 Summicron-M and the 21mm f/2.8 Elmarit-M and they may be considered to be the last designs of the classical period. This series of lenses accompanied the introduction of the M4-P, the P standing for Professional, indicating quite clearly the role of the new M-model as the dedicated tool for candid work in preciously little available light.

From 1980 to 1993 no new designs were developed for the M-series. Since 1993 the 21, 35 and 90mm have been completely overhauled, with new designs incorporating Leica’s expertise of aspherical technology. It is a tribute to the excellence of the Summilux design that, when shifting production from Canada to Germany, only a redesign of the lensmount (lighter by 40grams) was deemed necessary. The weight reduction is much appreciated, as the earlier versions were a bit on the heavy side after a few hours continuous use.

75mm f/1.4 Summilux-M

At full aperture the lens exhibits a medium to high overall contrast, with extremely fine details quite visibly recorded. Very fine details are clearly resolved with some softness at the edges. Some astigmatism is visible in the outer zones, which softens the finest possible textural details. This performance holds over most of the image field, with a detectable reduction in the outermost zone. The corners, although much softer, still record very fine details with good visibility. Stopping down to f/2.0 achieves the high overall contrast needed to record extremely fine details with clarity and crispness. Higher contrast generally gives the fine details more clarity and sharper edges. The outer zones now also improve and only the extreme corners lag a bit beyond this performance.

At f/2.8 the contrast is slightly higher yet and now the micro contrast is at its top, allowing the clear and crisp rendition of exceedingly small details. Now a tripod is most needed to record the finest possible details. We are talking about small details with a diameter of about 0.3mm in the image, photographed at a distance of 7.5 meters! You need to view the real object at really close distances to see what the lens/film combination can record. This performance level is maintained from f/2 and f/2.8 to f/8 and the choice of aperture needs only to be justified on depth-of-field arguments. Stopping down to f/11 slightly lowers the overall contrast and the definition of very fine details also loses a bit of its crispness. At f/16 a marked reduction of contrast occurs.

Flare is very well suppressed but the use of the built-in shade is mandatory! When taking pictures against strong lightsources (for instance when recording fashion shows) the fine light rays through smoke and dust hovering around lamps are rendered with subtle gradations.

The rendition of highlight details is uncommonly good: highlights hold their internal gradations and separation of fine luminance differences is also very good. The objects (including catch lights) are rendered very life-like and the extreme sharpness gives a special tactility to every object. The very shallow depth of field at large apertures/medium distances (at 2 meters distances we have ±6cm) requires careful focusing at the limit of the mechanical/optical precision of the M6-rangefinder. But candid portraits and full figures are clearly isolated from the background.

Historical comparison between the Summilux-M and the Summarex f/1.5/85mm.

At full aperture the Summarex has a low to very low overall contrast, with fine details rendered quite soft. Outlines of larger subject details show fuzzy edges. This performance holds over the whole image field from center to the outer zonal regions. The extreme corners are very soft.

Stopping down to f/2.0 brings a very marked jump in overall contrast and on axis performance now is of surprisingly high level with very fine details rendered with good clarity. In the field however the recording of fine details might be described as close to sharp.

At f/2.8 the central performance now extends over a large portion of the image field. Stopping down to f/4.0 brings in very fine details with good visibility, but without the crispness and sparkling clarity we are accustomed to see in current designs.

Performance improves up to f/8 after which the inevitable drop (diffraction) softens the whole image that by now has a very even coverage.

The time span between the Summilux and the Summarex covers more than 30 years of optical progress, which is most evident in the imagery with wider apertures. The inherently higher aberration content is visible in the somewhat flat and dull rendition of fine details at smaller apertures. At the wider apertures the fine details show quite fuzzy edges and overall contrast is low. Flare is copiously present in adverse situations.

Comparing the 75 mm Summilux-M to the 90mm Summicron-M (of the same generation).

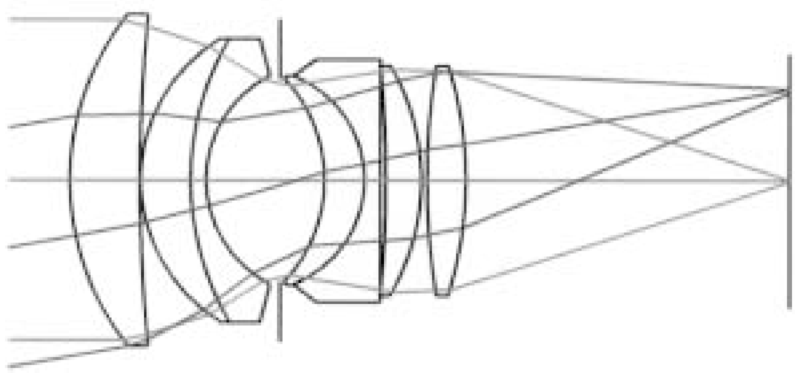
The Summilux-M 75 stopped down to f/2 has a higher contrast image with a clean and crisp rendition of extremely fine details over the larger part of the image field (excepting the outermost zones and the corners) than the companion 90mm f/2 Summicron-M at its full aperture (f/2). But the Summilux at aperture f/1.4 is not as good overall as the Summicron-M at f/2. This behavior illustrates the general rule when comparing the f/1.4 and f/2 pair of lenses or the f/2 and f/2.8 pair of lenses (of same focal length of course). The f/2 (f/2.8) provides higher image quality at maximum aperture than the f/1.4 (f/2) version, but stopped down one stop the higher aperture lens improves to a level generally above the quality of the smaller aperture version.

There are finer differences to be noted when comparing the full aperture performance of the Summilux at f/1.4 and the Summicron at f/2. The Summilux stays on the same quality level from center to corner, with only a very gradual reduction. The Summicron on the other hand drops quite a bit in the zonal area starting about 7mm from the center, but improves in the corners. When taking a portrait or a human-interest scene (camera horizontal) and placing the face/person in the middle, the weaker zone of the Summicron coincides with the out-of-focus zone. The behavior of the out-of -focus image is then both influenced by the inherent image quality in this zone and the out-of-focus-blur because of the sharpness plane located at the face/person. Shooting the same scene with the 75mm f/1.4 Summilux will produce a different out-of-focus impression, again because of the different definition and the larger out-of-focus blur size. The wider aperture and the shorter focal length will compensate here a bit, but still the fuzzy background will be quite different in character.

There is a long and fruitless debate in the Leica community as to which lens more closely represents the natural viewing angle (and perspective) of the eye. The 35 mm and 50mm were both appointed as candidates. Some very strong arguments have been given for the 90mm as providing the most natural perspective. Whatever the truth (if it can be found in this case), the 75mm perspective is very pleasing for close-range portraits and medium-range candid shots. Using a 90mm or a 50mm and just stepping back or forward, will give the same magnification of course. But the foreground-background relation (in depth of space) will change quite conspicuously and the visual effect is also altered. The perspective relation between the 75mm and 90mm is closely related with the 21mm and 24mm.

The Summilux 75mm has its specific strengths when used in the photographic domain for which it has been designed. If you need the maximum aperture of f/1.4 and/or the pictorial effects and special style of imagery possible with the 75mm Summilux-M, this lens should be in your tool kit. Stopped down to f/5,6 the Summilux equals the performance of the 90mm f/2 Apo-Summicron-M ASPH at this same aperture, which is some act.

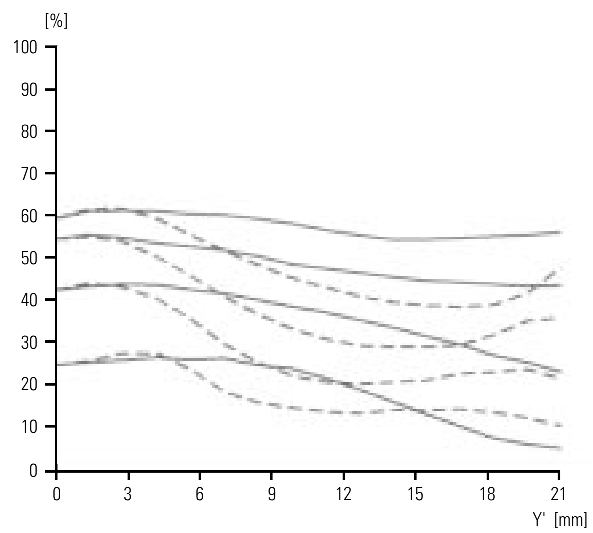
85mm f/1.5 Summarex M



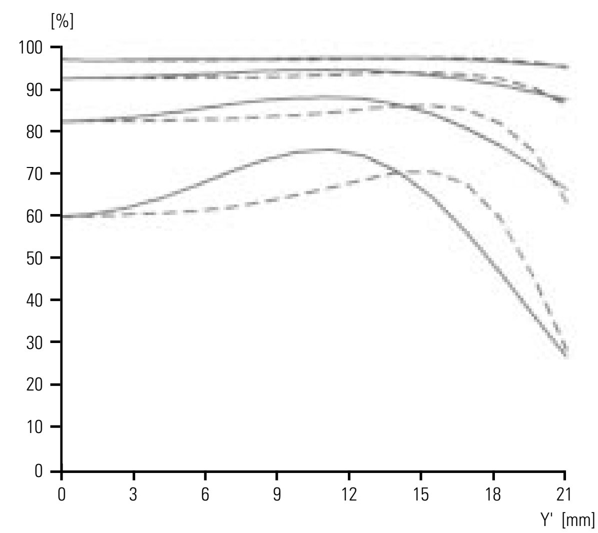
Summary

Stopped down to medium apertures, this lens from 1943-1960 performs remarkably well. At full aperture the contrast is very low and subject outlines are rendered with good visibility. A significant improvement can be seen when stopping down to f/2. Now of only historical interest, it clearly shows the optical advances made in the last two decades.

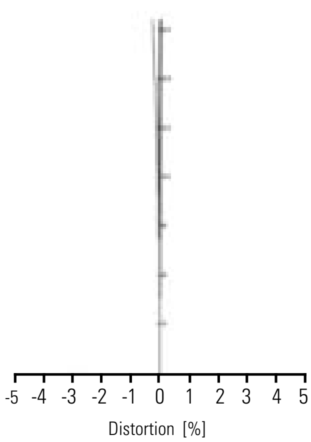
Full Aperture [1,5]



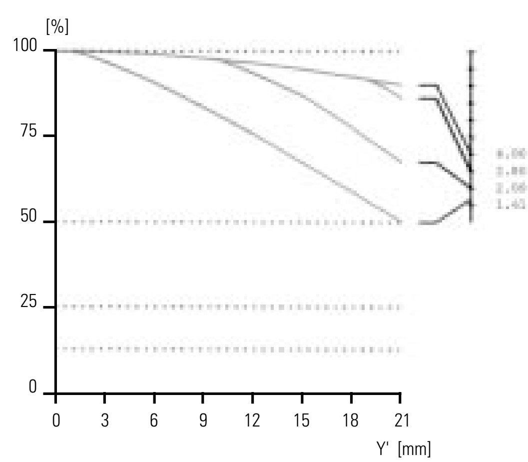
Optimum Aperture [8,0]



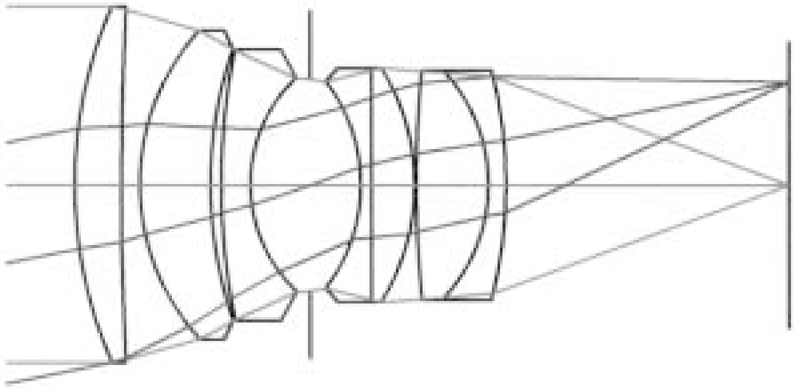
Distortion



Vignetting



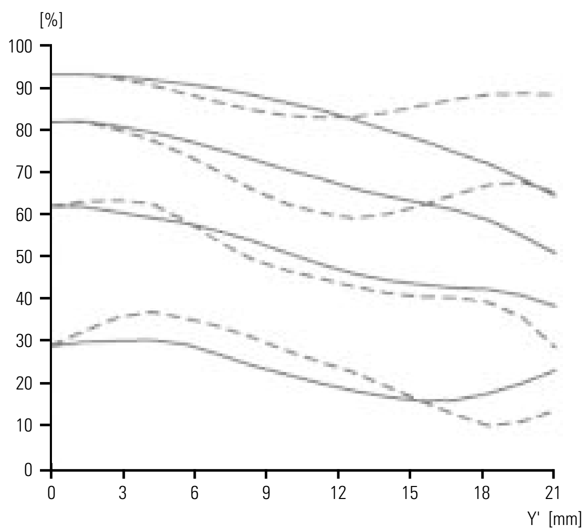
75mm f/1.4 Summilux M



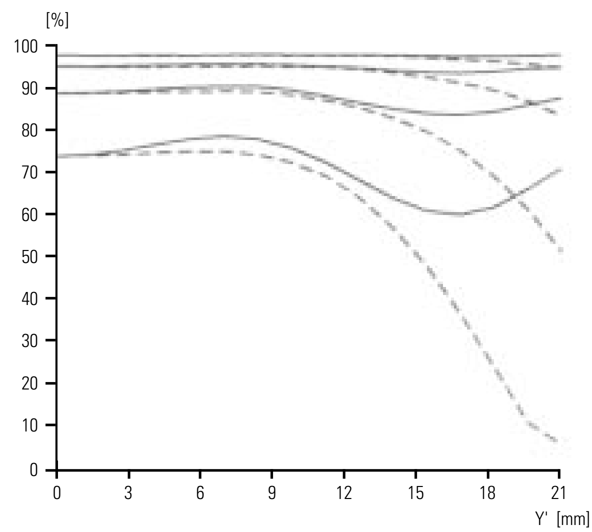
Summary

An outstanding lens for distinctive location portraiture and human-interest photography. At full aperture the lens has a medium/high overall contrast and renders fine details crisply and with good clarity of subject outlines. Stopped down to f/2 brings in very fine details with considerably higher contrast.

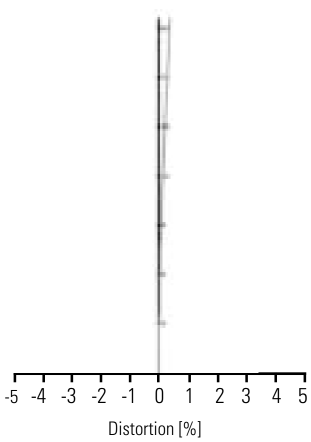
Full Aperture [1,4]



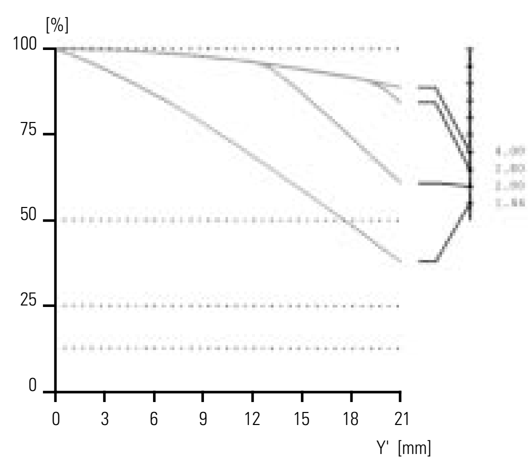
Optimum Aperture [5,6]



Distortion



Vignetting



90 mm lenses

If we would add the several types of the Elmar 90, the Thambar 90, the Elmarit 90and Tele-Elmarit 90 versions and the Summicron 90, we count 14 different designs, signifying the importance of this focal length for the rangefinder Leica.

The first 90mm, the 9mm f/4 Elmar was announced in 1931 and stayed in production till 1964, spanning the development of the Leica from the beginnings till the landmark design of the M3. Before 1930 the only emulsion available for the Leica was the Perutz 'Feinkorn-Spezial-Fliegerfilm'. It had an acceptable grain structure, but big enlargements were not possible. The basic premise that the small Leica negative should be enlarged 3 times (to compete with the popular rollfilm print of 6 x 9 cm), might be influenced too by the limited potential for enlargement of the emulsion. The well-known Circle of Confusion of 0.033mm is also based on this enlargement factor of 3. This measure of 0.033 mm is hopelessly inadequate for current demands, but no one wishes to change the calculations. Anyway, after 1930, improved emulsions with anti-halo backing and improved sharpness became available. Still, the amount of details that could be recorded and made visible after enlargement was quite modest. The argument for a focal length larger than the 50mm standard lens was the ability to get larger details on film, assuming the same picture-taking distance. The 90mm focal length did not start its life as a portrait lens, but as a lens to capture details too small for the emulsion to record. Significantly the 105 and 135 mm focal lengths were introduced at about the same time.

As noted in the 50mm review, the 46º angle of view has no special relation to the characteristics of the eye. The most used camera, the 6x9cm rollfilm had a lens with a 53º angle of view and as this camera was the natural competition for the Leica, it would seem natural to adopt this angle too. The restriction to 46º was made on optical arguments (less aberrations to correct in the field).

The human field of view is an ellipse about 150º high and 210º wide. The extent of binocular overlap is about 130º, the field of view that seems to do the binocular processing is about 40º, and the extent of eye movement without a compensating head movement is about 20º.

The 27º angle of view is a most natural one for many objects, as the field of view can be viewed without head movement. The popularity of the 90mm is based on the flexibility of use. In effect, one could shoot many photographic assignments with only this focal length. The concentration on the main topic is quite demanding for a good composition and requires a careful selection of which elements to include in the picture. The M-rangefinder gives the 90mm frame within a larger environment. Anticipating the moment that all pieces fall into a meaningful pattern is easier than it is with a SLR, where the viewfinder isolates the photographer from the scene. The Leica M and a 90mm lens form a very fine partnership. The rangefinder accuracy is much higher than is needed for the exact location of the sharpness plane, even at a distance of 20 meters, where depth of field will cover the occasional focus error anyway. Still there is one and only one plane of best sharpness and the use of the hyperfocal distance setting is not recommended.

90mm f/2,8 Elmarit-M

This, the current version of the 90mm with a 2.8 aperture, was introduced in 1995 for the M-line. Its design closely resembles the one used in the 90mm f/2,8 Elmarit-R, introduced in 1983.

The optical performance of the Elmarit-M at full aperture is outstanding. The overall contrast is high to very high. On axis, over a circular area of about 12mm diameter (radius 6mm from center) extremely fine details are rendered crisply. In the field (the outer zones) there is some softening because of curvature of field and some astigmatism. The lower contrast reduces the ability to record the finest structures of textural details and stopping down to f/4 is required to bring in this level of details. The overall rendition crispens visibly, with only the outer zones lagging a bit behind. As this area will be unsharp in most cases because it is in the background, it will only be noticeable by a most critical observer when studying an extended object filling the whole frame. The optimum aperture is reached by stopping down to f/5.6 and now the frame is covered with exceedingly fine details from center to corners.

At this aperture and with proper technique (correct exposure, proper vibration control and accurate focus) the Elmarit-M will outperform the capabilities of almost any film on the market.

Very critical study of the performance details of this lens, compared to the predecessors (the 90mm f/2.8 Elmarit of 1959, and the 90mm f/2.8 Tele-Elmarit of 1964 and the Tele-Elmarit-M of 1974) proves two points: the performance improves almost linearly over the period, with the 'Tele' versions producing a slightly flatter image, a bit dull perhaps. The second point is the relation emulsion performance and optical performance. On the same film only the current Elmarit-M can record the finest textural details, only visible when enlarging more than 30 times. The other lenses do not show this level of rendition of details when recording the identical object. The film is not the limiting factor in most cases. It is the lens. In the sixties however the (Tele)-Elmarit lenses would have been better than the film emulsions that were available at that time, with some exceptions.

Vignetting is hardly visible, but more important is its absence of flare. Flare is one of the worst image degrading factors. It is most visible when strong light sources are present in the object area, but, contrary to common sense, will also operate when a large area of high luminance (as an overcast sky) is part of or close to the object.. The mechanical construction needs to be tuned to reduce the stray light within the lens when the light energy passes through the lens elements. The particular clarity and crispness of very fine details of the Elmarit-M is a tribute to its optical and mechanical design.

Close-up performance at full aperture is already excellent and can be used even for critical demands.

The natural companion lens for the 90mm Elmarit-M is the Tri-Elmar. With only two lenses, the Leica M user gets a high performance package of great flexibility (covering 28 to 90mm) and at a very modest weight.

90mm f/2.8 Tele-Elmarit-M

This lens is a Canadian design of 1974 (the current Elmarit is a Leitz Germany design) and it utilizes four separate lens elements, as does the current one, but in a different configuration. The outward appearance of the Tele-Elmarit-M has much in common with the Elmar-C (1973) for the Leica CL. It is clearly designed as a very compact lens and with a weight of only 225 grams (less than 8 ounces) – the Elmarit-M weighs 380 grams (just over 13 ounces) - it can be carried in a pocket. There is a Leica maxim that states that optical performance requires volume. Reduce the volume below a certain threshold and performance starts to suffer. Relatively speaking, of course, as the design goals of the Leica optical department are located at Olympic heights.

At full aperture the contrast of the Tele-Elmarit-M is medium. Very fine details are rendered with slightly soft edges over most of the image field. At the edges and corners the image is quite soft, and fine details, while visible, have fuzzy outlines.

Stopping down brings a very marked improvement, the edges of very fine details improve noticeably and now cover most of the image field. For the casual viewer, the performance approaches the value of the Elmarit-M. Still, a side by side comparison reveals the differences: the Tele-Elmarit-M gives a flatter, more dull image, due to a lower contrast and the softness of the very fine textural details, which give a picture its sparkle and clarity. Stopped down to f/8 the Tele-Elmarit equals the image quality of the Elmarit-M.

Close-up performance is good, but for exacting demands an aperture of f/5,6 might be preferable.

When ease of travel and compactness are of overriding importance, this lens is a good choice. Its fine overall image quality makes it suitable for many picture-taking situations. Stopped down to f/4 or f/5,6 it is an excellent performer.

90mm f/2 Summicron-M

The first 90mm Summicron (without the suffix -M) arrived on the scene in 1958, and with a weight of 680 grams and a length of 99mm from bayonet flange to front rim was a physical heavyweight. Its performance at full aperture was moderate and so the ever-creative sales people invented the notion of a portrait lens. The softness of the Summicron at full aperture would support the romantic portraiture of women, and the lower contrast would help taking reportage style pictures in high contrast lightning situations.

These notions are still en vogue today and the full aperture of the Summicron 90mm lenses is mostly described in this context.

The 90mm f/2 Summicron-M was introduced in 1980 in a mount that lost much weight (460 grams) and with 5 lens elements (6 for the predecessor). Two lens surfaces are plane, which reduces cost, but you also loose possibilities for additional optical correction. At full aperture the 90mm Summicron-M has medium-high overall contrast and very fine details are registered with fuzzy edges over most of the image area. This behavior has been described as 'smooth sharpness' (an oxymoron like 'military intelligence'). Stopping down to f/2.8 brings a very marked improvement of contrast of the subject outlines and a crispening of the edges of very fine details. In its overall impression, it is now comparable to the 90mm f/2.8 Elmarit-M at full aperture. The Elmarit however is able to record exceedingly fine detail structures that are beyond the capabilities of the Summicron. At f/4 the Summicron improves markedly again and now the rendition of the very finest details is brought into the picture. Compared to the Elmarit-M, the higher flare level of the 90 mm Summicron softens the edges a bit, but at this aperture the Summicron gives an excellent performance over most of the image field. The edges of the image (the zonal area covering the outermost 4 to 5 millimeters in the horizontal direction) lag a bit behind the rest of the image. But in most pictures this part is automatically covered by the unsharpness of the out-of-focus zone.

At f/5.6 the Summicron-M reaches its optimum with outstanding performance on axis and slightly lower performance in the outer zones of the field. At f/8 these outer zones become slightly crisper and the whole picture area is now covered with a high contrast image and a crisp rendition of extremely fine details.

Close-up performance is much improved, when compared to the first version of the Summicron, which had to be stopped down to f/5,6 to get decent quality. At smaller apertures the Summicron 90mm is a very strong performer. Its full aperture quality is acceptable. The best test for a wide aperture lens is a picture of a night scene with lots of street lamps and neon light advertising. Flare, veiling glare, halos around bright spots, contrast in the darker parts of the scene and the clear separation of closely spaced highlights are easily spotted. The Summicron-M performs commendably in this type of scenery, but its image quality is not fully convincing. Choosing the Summicron and not the Elmarit would be justified by the performance at full aperture f/2. In many cases you might consider the 75mm f/1.4 Summilux.

90mm f/2 APO-Summicron-M ASPH.

Many people underestimate the growth of aberration content when the designer has to open up a lens one more stop. The step from f/2.8 to f/2 seems a small one. In fact some aberrations increase by a factor of nine and that amount of aberration is not easy to control and correct.

The designer needs to accept a reduced image quality or if possible he has to aim for a higher level of correction. Leica designers have been well aware of the absolute and relative performance of the 90mm Summicron and its production life of almost 20 years shows that a better correction had to wait for new tools.

When designing lenses for the M camera, the designer has a few additional parameters to give attention to. Weight and volume are the obvious limiting factors. If volume and weight were not an issue, the designer could use heavy special glass and more glass elements for correctional purposes.

With 500 grams, the APO-Summicron ASPH is a fraction heavier than its predecessor, but dimensionally the two are almost equal.

The creativity and expertise of the designer can be assessed by looking at the specifications in relation to the performance. One quite complex aspherical surface and two special glass types were used to achieve the required apochromatic correction from the core of a highly evolved optical system.

At full aperture (2.0) the lens exhibits a high contrast image with extremely fine details rendered with excellent clarity and contrast. On axis (center) and in the field (outer zones) and extending to the very corners, minuscule details are recorded impeccably. The faintest trace of softness at the edges of very fine details can be detected. Outlines of image details have superb edge contrast. At f/2,8 the contrast improves a bit and the whole image becomes somewhat more crisp, bringing exceptionally fine details above the threshold of visibility. From f/2.8 to f/5.6 we find an enhanced capacity for recording the finest possible details with the crystal-clear clarity and excellent edge contrast that is the hallmark of the New Design Principles set forth by Mr. Kölsch.

Perfect centering, only the faintest trace of astigmatism and no curvature of field added by painstaking engineering make this lens the one to use.

Stopping down after 2.8 only improves depth of field. After f/16 we notice a slight softening of edges and a drop in overall contrast as diffraction effects become visible.

Gone are the days when one had to excuse the quality at wide open aperture with the argument that image degradation had to be expected. The APO-Summicron-M ASPH is one of the very few 90mm lenses to offer stunning quality already at f/2,0. Most high speed lenses loose a bit of punch when stopping down due to focus shift, caused by residual zonal spherical aberration. Again this lens has a very good correction of this aberration and after stopping down, image degradation is very slight, if at all perceptible.

Close up performance at full aperture delivers very crisp pictures over the whole image field. The very high level of correction of this lens brings a rapid drop to the unsharpness area, where outlines of objects are preserved. Details however are washed out. This behavior in the sharpness-unsharpness gradient, a very rapid and abrupt change from the plane of focus to the unsharpness zone, is typical of the current Leica M lenses.

The APO-Summicron-M ASPH is very flare resistant. One should have no illusions here. It is always possible to force bright patches and secondary (ghost) images into a lens. The APO-Summicron-M ASPH is very stable, but not immune to these effects.

When taking pictures that contain bright light sources, the use of filters is discouraged unless one can control the direction of the light reaching the lens to a high degree.

Users who upgrade from the previous Summicron-M 90 to the current one will notice the excellent suppression of veiling glare. The Apo version shows blacker shadows than the previous one. When using high speed lenses, quite often a certain amount of veiling glare will illuminate the shadow areas, producing an impression of shadow penetration. In fact what happens is a graying of the shadows by the stray light. No details will be visible in the shadows. It just looks as if the lens /film combination has a very high speed. The first pictures with the Apo version produce blacker shadows, and so the user is inclined to think that he has underexposed or that the lens does not give the true speed. The truth is that the user now has a better-corrected lens in his hands and a new learning experience is required. One has to adjust to the new characteristics.

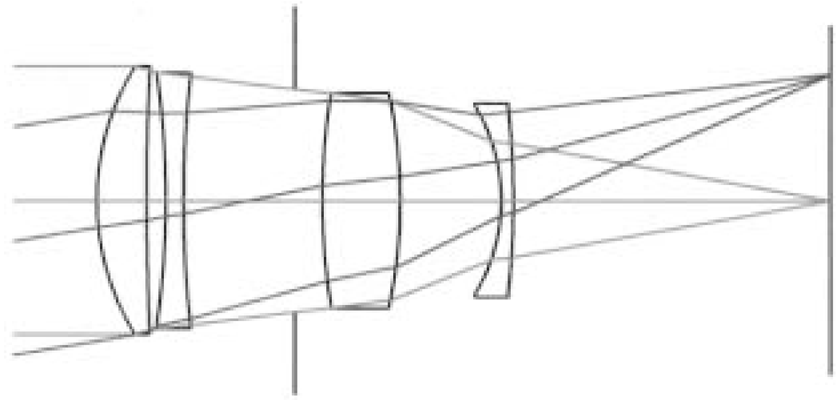
Conclusion

Both 90mm lenses, the Elmarit-M and the Apo-Summicron-M ASPH represent the current state-of-the-art of Leica lens design and define the limit of image quality at this focal length and apertures. The specification of the 90mm f/2.8 version is not a limiting case and the Elmarit-M can employ a computation from 1983 to present superb image quality that is difficult to surpass. The earlier versions of the Elmarit type are very good lenses too. The commitment of Leica to exceed the bounds of the feasible optical performance at any time is clearly documented in the case of the 90mm lenses. Five recomputations for the Elmarit between 1959 and 1983 document the relentless drive forward.

The Apo-Summicron-M ASPH, now in its third recomputation, defines the performance level for the next generation of Summicron design. It has stunning performance at all apertures, distances and over the whole image field.

The choice between both lenses is an economical one. The Elmarit-M is cheaper and has less volume, and its optical performance is only marginally surpassed by the Summicron version. The price-performance relation of the Apo-Summicron-M ASPH is tempting and if one wishes to enjoy breathtaking full aperture performance, this lens opens a new vista.

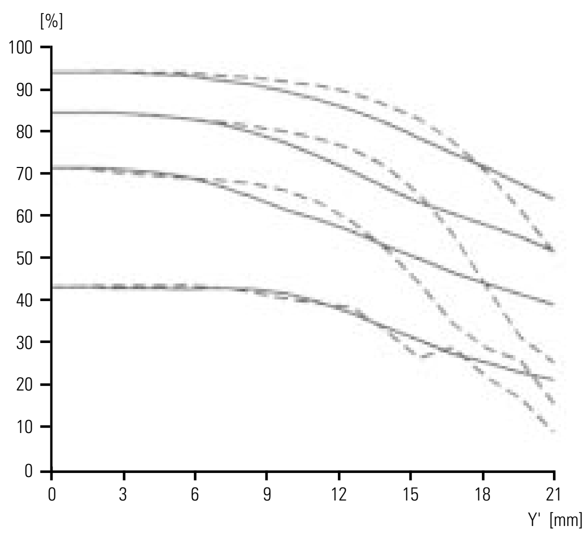
90mm f/2.8 Tele-Elmarit M



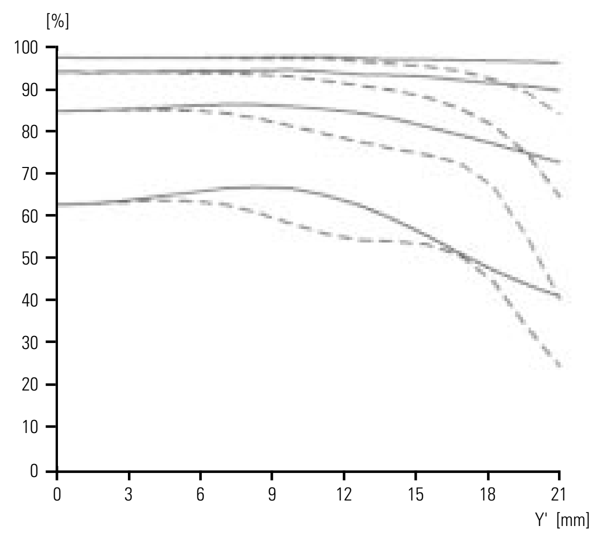
Summary

This very compact and lightweight lens delivers excellent imagery overall. Wide open the contrast is medium and the definition of very small picture details is slightly soft. Stop down two stops and the image quality over the whole picture area becomes of a very high order.

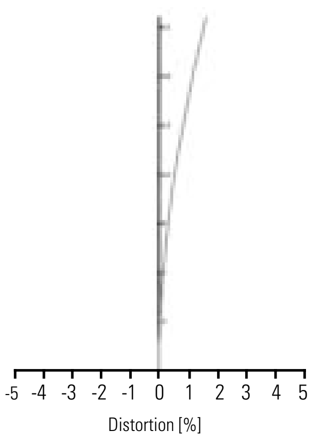
Full Aperture [2,8]



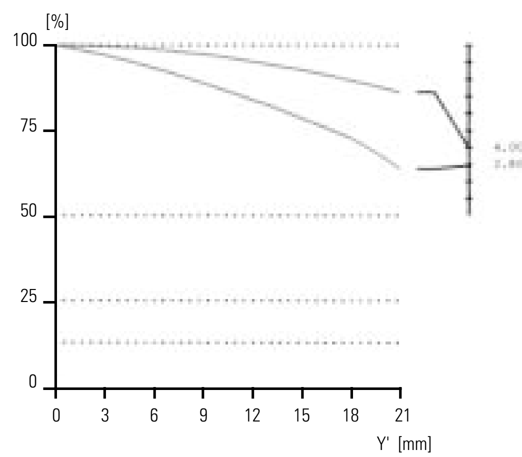
Optimum Aperture [5,6]



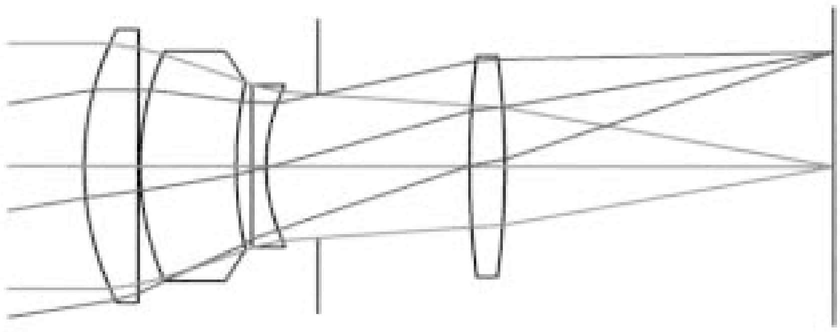
Distortion



Vignetting



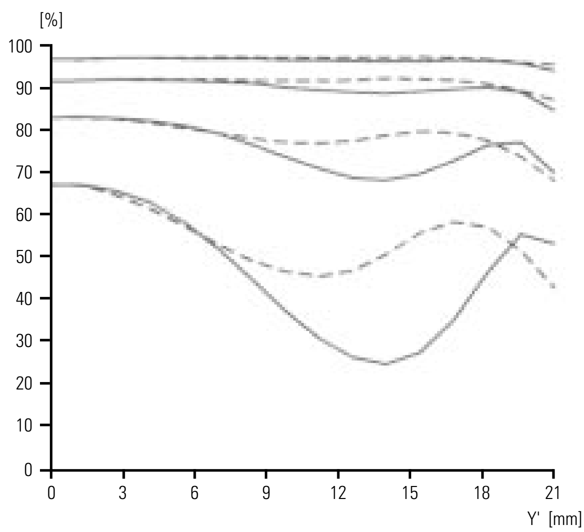
90mm f/2.8 Elmarit M



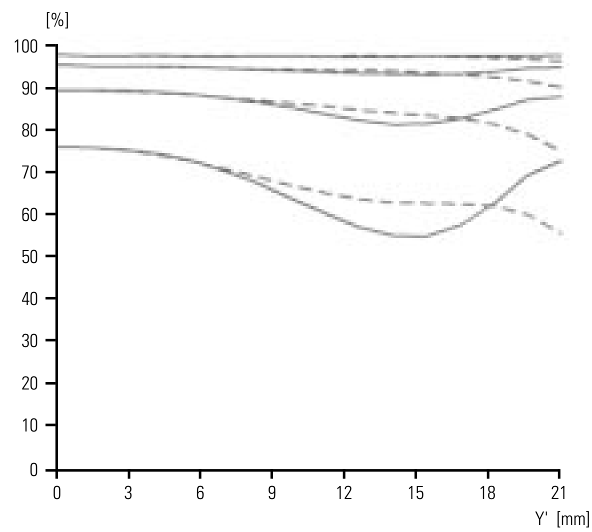
Summary

Before the arrival of the new 90mm f/2 Apo-Summicron ASPH this lens was the best medium telephoto lens ever designed for the M. At full aperture extremely fine textures and picture details are rendered with high fidelity and excellent clarity. Stopping down improves a bit on this marvelous performance.

Full Aperture [2,8]



Optimum Aperture [5,6]



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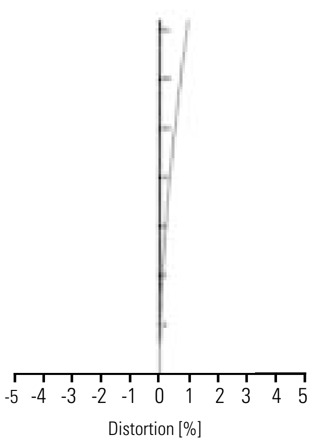
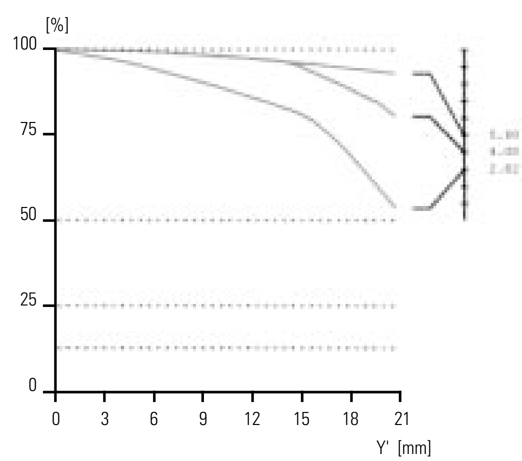
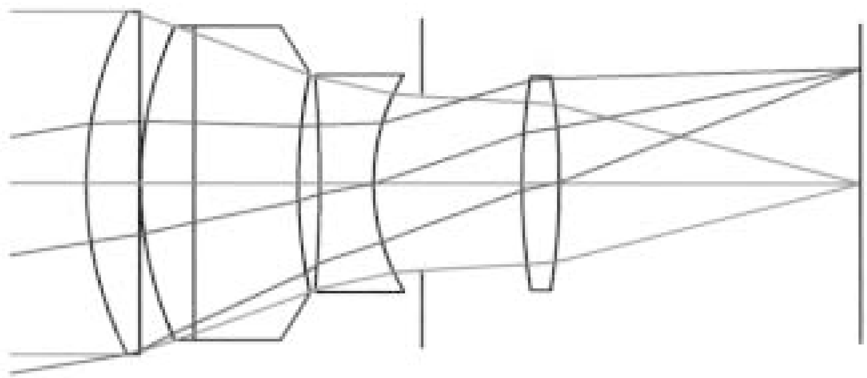


Vignetting



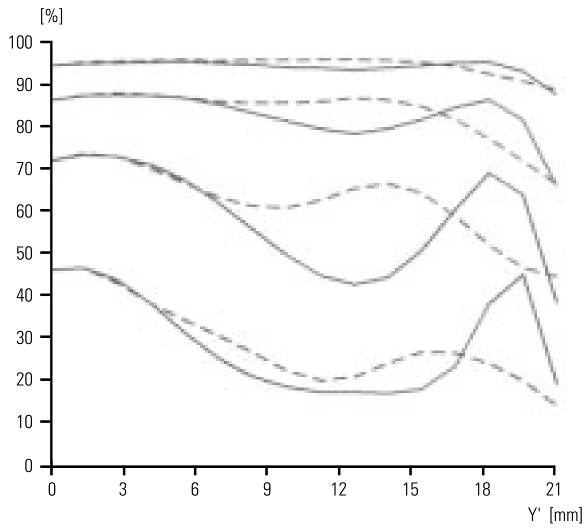
90mm f/2 Summicron M



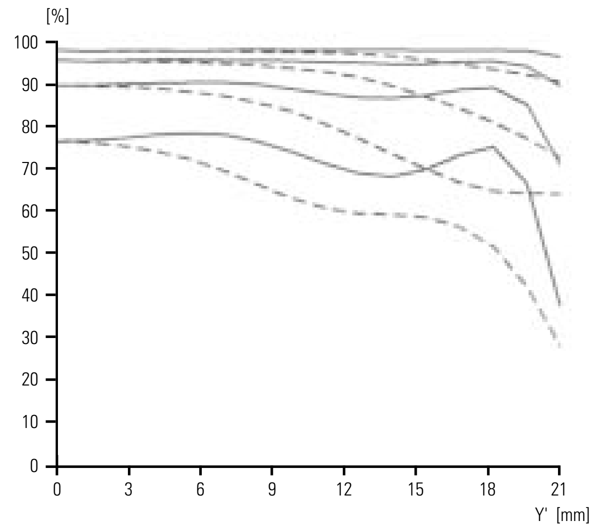
Summary

Stopped down to f/4 and smaller, this classical lens delivers a first-class performance. The full aperture performance that is characterized by medium contrast, somewhat fuzzy outlines of finer details, and a trace of veiling glare do indicate that the design is a bit overcharged.

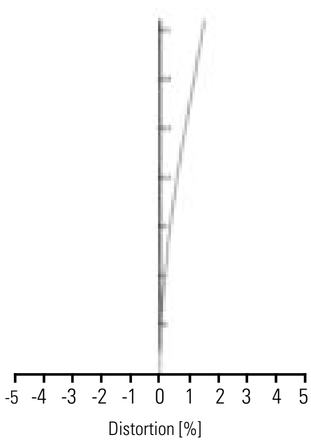
Full Aperture [2,0]



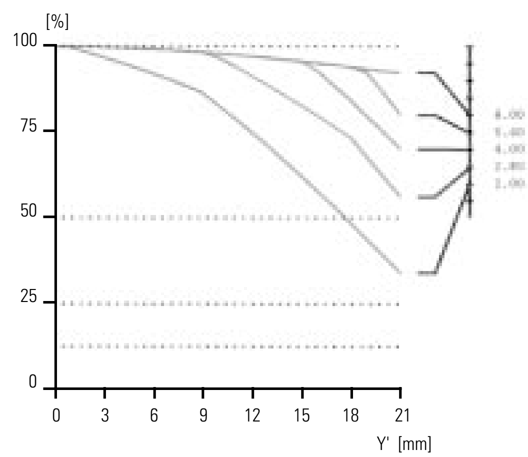
Optimum Aperture [5,6]



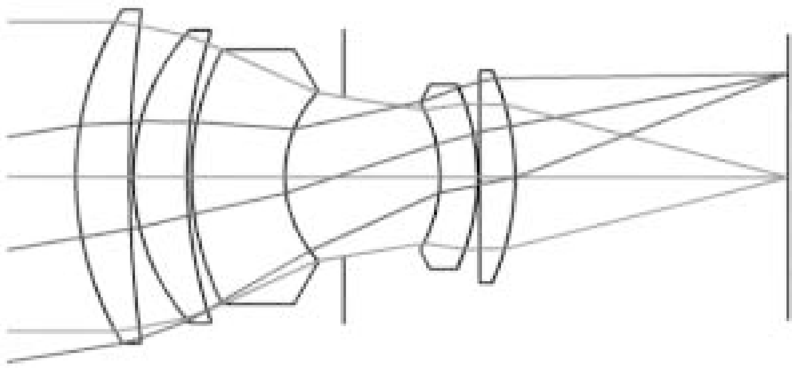
Distortion



Vignetting



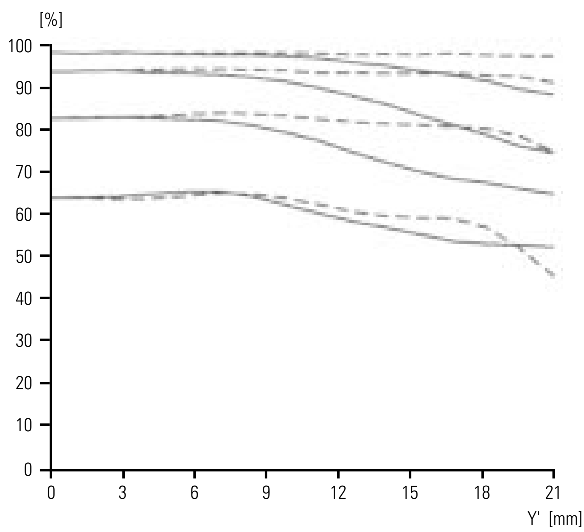
90mm f/2 APO Summicron-M ASPH



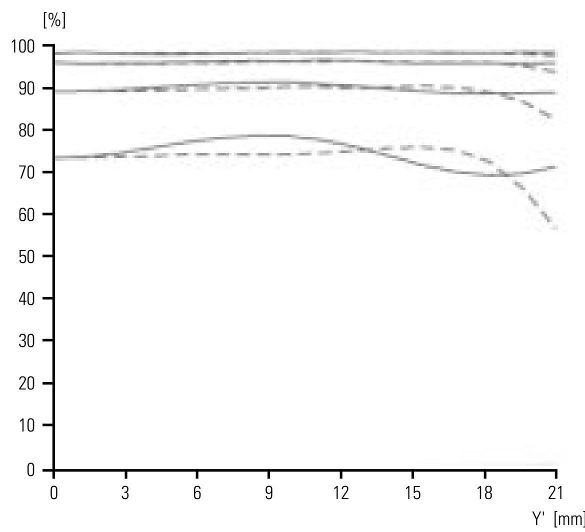
Summary

A masterful lens, setting a new standard of excellence, this one shows in what direction the Leica designers are thinking. At full aperture extremely small details are rendered with very good clarity over the whole image field. Flare is hardly detectable, as is vignetting. A superb lens.

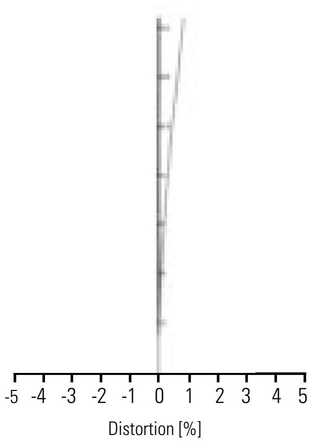
Full Aperture [2,0]



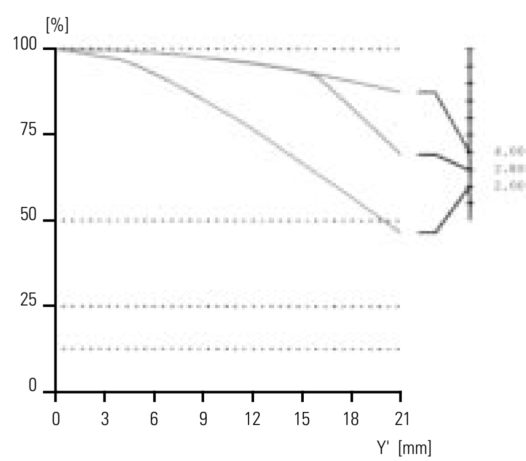
Optimum Aperture [4,0]



Distortion



Vignetting



135 mm lenses

Barnack had the vision and the engineering creativity to design his Leica with a coupled rangefinder to accommodate lenses of different focal length. The 135 mm focal length sets the mechanical limit for the M-rangefinder, not the accuracy limit. The M rangefinder is based on the principle of vernier acuity. This and the long base ensure that the required accuracy at all distances is within very tight tolerances. To explain the mechanical limit, consider the following. The movement of the rangefinder roller is about 2mm, which stays the same, irrespective of the lens coupled to the body. The 50mm lens moves 2mm when focusing from 1 meter to infinity. So the relation is 1:1. The 135 mm lens has a movement of about 18mm to focus from 1.5 meter to infinity. This 18mm has to be converted to the 2mm movement of the roller. That is a reduction of 1:9. Any small error in the mechanical coupling will therefore be ‘enlarged’ 9 times. The mechanism has to be built to a very high degree of precision to ensure that this ‘error’ stays within the required overall tolerance.

The frame of the 135 lens in the finder is small, but just big enough to allow framing. A tight composition however is not feasible. One should give some margins around the motive.

The 135mm f/2.8 Elmarit-M with spectacles tried to overcome the limit of the frame, but added a cumbersome device to the Leica body.

With the Tele-Elmar-M from 1965 the design reached the theoretical optimum attainable in these days and reigned unchallenged for more then 30 years. Indeed the optical performance of the Tele-Elmar-M in its various redesigned mounts (three times) stayed the same, as the computation was not changed.

Even today it delivers outstanding image quality. Its field of view and foreground-background relation can be used very advantageously for reportage photography and fine-art studies alike. It is a very versatile focal length with a long tradition of classical images. It is a pity that the 135 mm focal length does not get the attention it deserves pictorially. The new 135mm f/3.4 Apo-Telyt-M might change this undeserved Cinderella status.

135mm f/4 Tele-Elmar-M

The Tele-Elmar-M has an optical layout, consisting of 5 lenses in 3 groups. In comparison the Apo-Telyt also has five lenses, but now in four groups. The Tele-Elmar-M is optically unchanged since 1965 and has been given several facelifts. The optical performance is, even from today’s high standards, outstanding.

At full aperture the whole image field from center to the outermost corners gives a high contrast image. Extremely fine details are rendered crisply over most of the image field and they soften a little in the outer zones. .

The subject outlines are sharply delineated and give the image a high sharpness impression. Stopped down to 5.6 the contrast improves somewhat, but the outer zones still lag behind. After f/8,0 the contrast of the very fine object details diminish a bit. Stopping down further softens the edges of fine details slightly more. This performance holds from infinity to about 3 meters.

For close-up pictures at its closest distance (1.5 meter) one should stop down to get the optimum performance.

Centering is perfect for the older version I tested, and some curvature of field and a trace of astigmatism can be noted on the bench. This lens is at its top at f/5.6 and by stopping down further, overall contrast and edge contrast of very fine details are reduced a fraction. The overall performance is of a very high standing. This lens is also commendably flare-free. When using it at the limit of its performance, one should use a tripod at least once to really appreciate its image quality.

135mm f/2.8 Elmarit-M

This lens has been introduced in 1963. It weighs more than 700 grams, and it is a bit bulky. Its assigned task is photojournalism in available light, that is i.e. at low light levels. Its usefulness however is much broader, as it can be used in all situations where accurate framing is required.

At full aperture the lens produces an image of low to medium contrast. The object outlines are recorded with slightly soft edges with very fine details clearly visible over the whole image field. Its wide-open performance suggests that is a bit overstretched optically. Stopped down to f/4 image quality improves strikingly and approaches the performance level of the Tele-Elmar-M. At f/5.6 and smaller apertures the Elmarit-M inches towards the image quality of the Tele-Elmar-M, without rivaling that level.

135mm f/3.4 APO-Telyt-M

Lenses with a focal length larger than the 50mm standard lens enlarge the subject details, when the picture is taken from the same position of course. But enlarging the object has a nasty drawback. The aberrations are also enlarged. Especially lateral and longitudinal chromatic aberrations will degrade the image quality as fine details and outlines alike are recorded with color fringes. The designer will opt for an apochromatic correction to reduce the secondary spectrum. But optics is optics and behind the secondary spectrum looms the tertiary spectrum. So perfect imagery is not yet attained. The Apo-Telyt-M is a very fine example of a design that combines the special demands of the M series (lightweight and small volume) with that other characteristic of the M lenses: impeccable optical performance. With only five lens elements (to reduce weight) the designer has computed a masterpiece, supported by the engineers of the production department.

The Apo-Telyt at full aperture (f/3.4) produces a high contrast image with exceptionally fine details very crisply rendered over the whole image field from center to corners. Stopped down to f/4.0 the Apo-Telyt improves visibly on the Tele-Elmar-M on its ability to render the finest possible details with excellent contrast and clarity. Stopping down this level of performance holds to the aperture f/8, and stopping down further only very small losses in edge contrast can be detected.

This APO-Telyt -M shifts the performance level of M-lenses to a higher plateau. It represents current thinking about optical performance as implemented by Leica. At wider apertures and closer distances the unsharpness area sets in abruptly and the shapes of objects rapidly lose its details. For me personally this behavior is excellent, but bokeh aficionados might be less happy.

The distinctive characteristic of the Apo-Telyt is its superior clarity of exceedingly fine details that give the Apo-Telyt images a new look. While for some purposes the Tele-Elmar-M gives adequate performance, the Apo-Telyt offers a lucidity of fine color hues and almost lifelike rendition of very small subject details. In direct comparison the rendering of the same fine details by the Tele-Elmar-M is dull, or when going to the edge soft or washed out. When reproducing still smaller details the Tele-Elmar-M produces noise where the Apo-Telyt still records these details with authority.

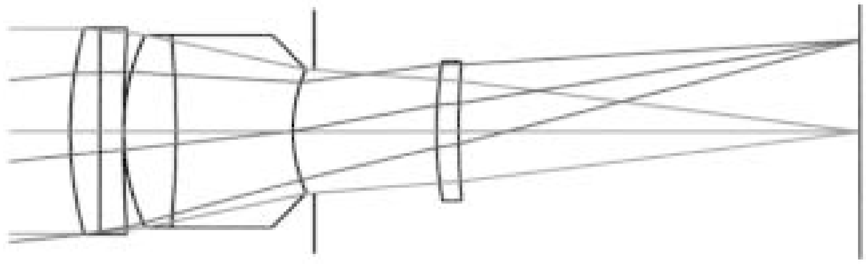
This level of optical performance is very sensitive to manufacturing tolerances. Computer diagrams show the loss of performance when focus is shifted away from its optimum position. Lavish, some would say excessive attention to production tolerances is indeed needed here.

Conclusion.

We may note that Leica M users are very well served in the medium telephoto lens field and now can produce images that are the envy of R-users, who long had the advantage in this field.

The Apo-Telyt is a truly superb lens. Its optimum performance is on a level that requires users who are willing and able to exploit it to the fullest their technique

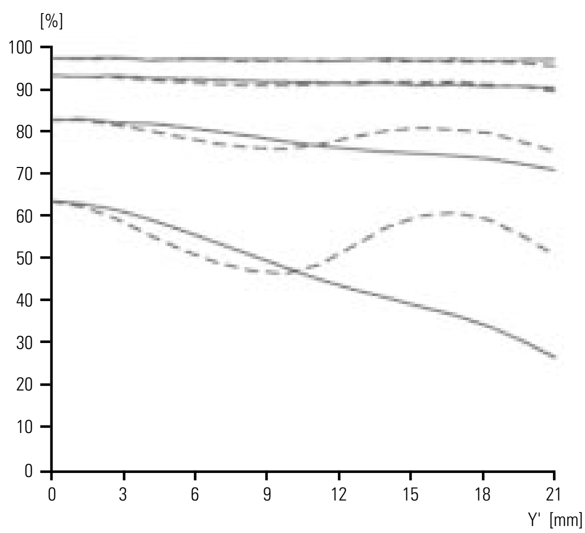
135mm f/4 Elmar M



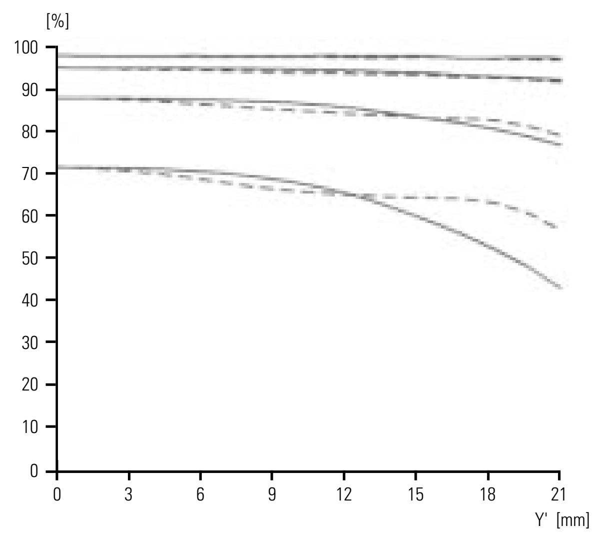
Summary

This 1965 design from will outperform many current comparable lenses. It delivers outstanding performance at all apertures and at f/5.6 it might be called superb. This focal length is very useful for the reflective type of picture-taking.

Full Aperture [4,0]



Optimum Aperture [5,6]



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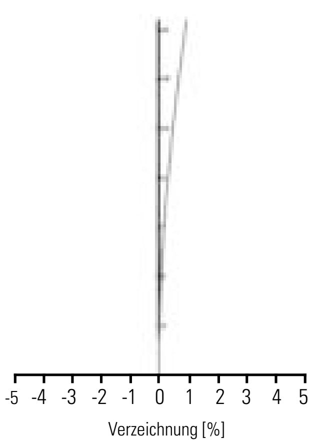
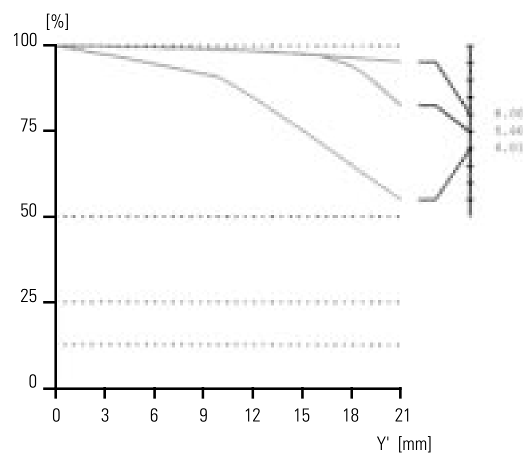
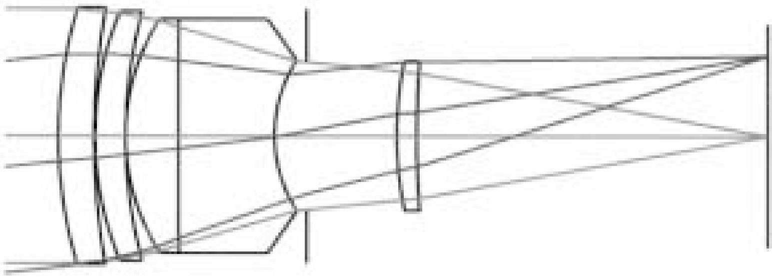


Vignetting



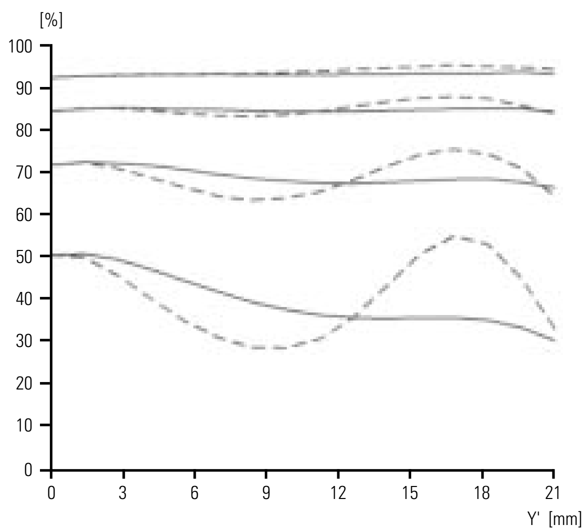
135mm f/2.8 Elmarit M



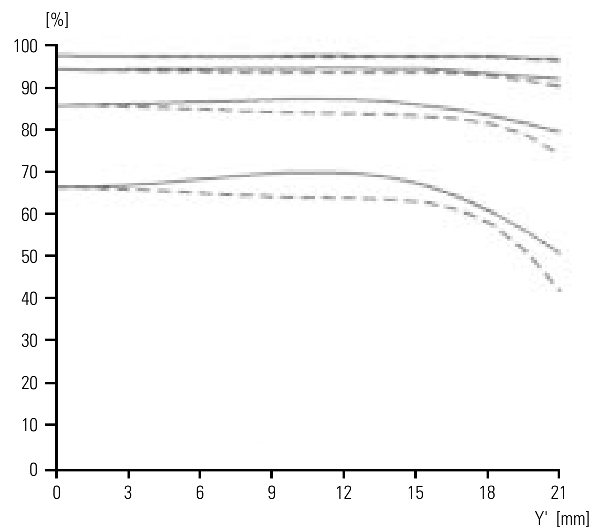
Summary

Wide open this design exhibits medium overall contrast that softens fine details a bit. Stopped down to f/5.6 it delivers very good image quality. The detachable spectacle viewfinder helps the framing of the image.

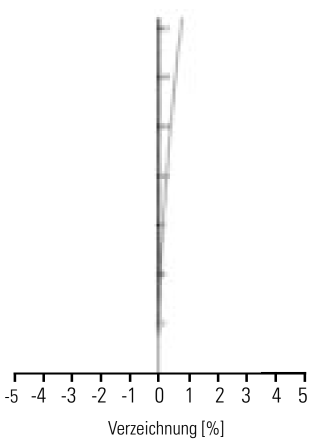
Full Aperture [2,8]



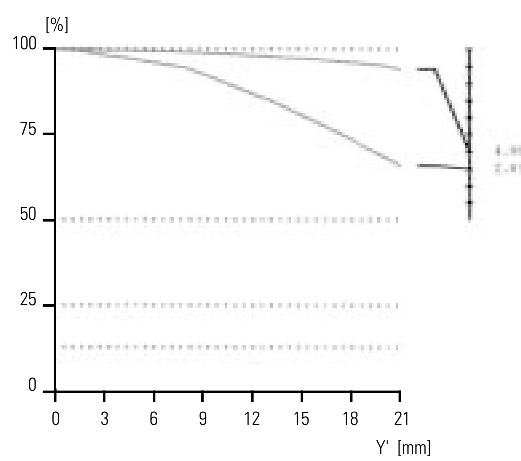
Optimum Aperture [5,6]



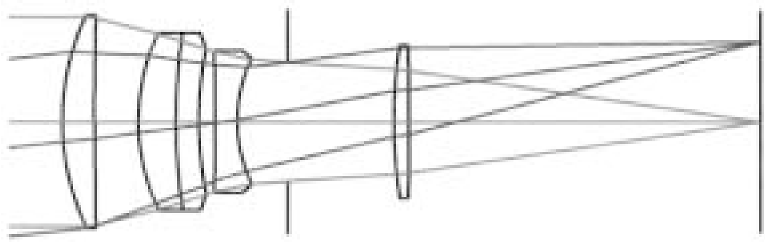
Distortion



Vignetting



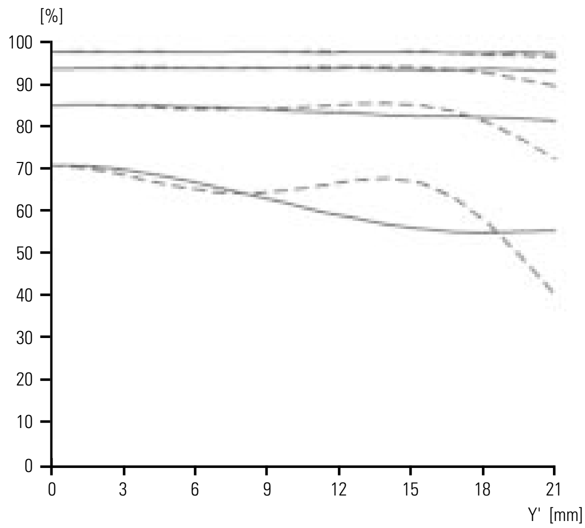
135mm f/3.4 Apo Telyt M



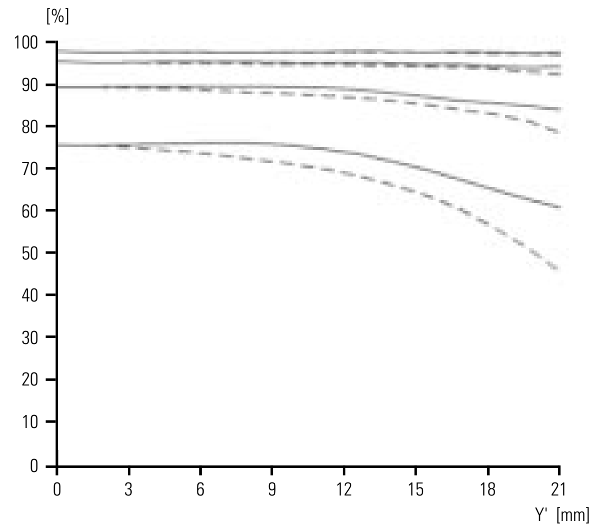
Summary

High overall contrast, outstanding clarity of small picture details, very clean colors and subject outlines with high edge contrast are the trademark of apochromatic correction as practiced by Leica. At full aperture the Apo-Telyt extends the picture possibilities of the M body with an image quality that is unrivaled.

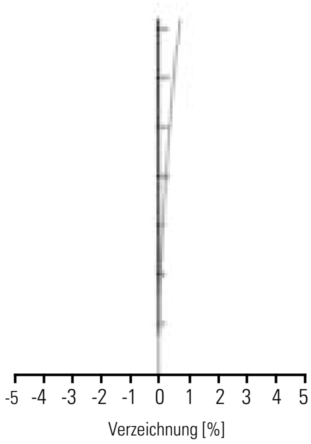
Full Aperture [3,4]



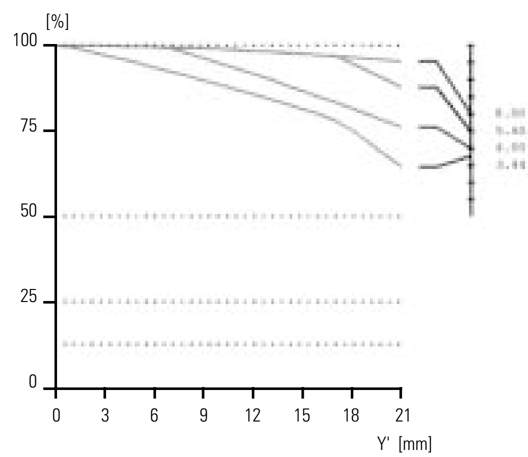
Optimum Aperture [5,6]



Distortion



Vignetting



Professor Dr. Max Berek

When discussing the origins of the Leica, the credit should go to Oskar Barnack, who designed the Ur-Leica and Ernst Leitz, who decided to start the commercial production in 1924. He made this decision on his own, as all his advisers were against the production. The risks were quite large indeed, because the microscope firm had no experience with photographic cameras. If we search for the reasons for the success of the Leica, we need to look at Leica lenses. The first lens for the commercial version of the Leica was designed by Max Berek. So in a certain sense he is responsible for the worldwide success of the Leica.

Max Berek was born on August 16, 1886 in the small town Ratibor as son of a millworker. Like so many of his contemporaries in the late part of the 19th century, when Germany experienced a cultural and scientific explosion, he attended the university to expand his knowledge. He began his study in mathematics and mineralogy in Berlin in 1907 and finished there in 1911 with a famous crystallographic research.

In 1912 Ernst Leitz invited him to become the first scientist employed by the Leica company. We should admire Leitz' uncanny ability to select top talent for his firm. Berek stayed with Leitz till his death on October 15, 1949.

Berek's area of research focused on microscopy, especially polarization-microscopy. In this area he reached world fame and his inventions (the Berek compensator and the formula to compute depth of field of microscopic vision) are still used today. He wrote several books on the principles of microscope technology.

He was able to use this background and knowledge, when Ernst Leitz asked him to design a photographic lens for "Barnack's camera". The lens was a f/.3,5/50mm triplet with the last three lenses cemented into one unit. It is known as the Leitz Anastigmat and later the Elmax, presumably a concatenation from ErnstLeitzMaxBerek. The 5 elements helped to give this lens an outstanding performance and today an MTF measurement would deliver very high marks.

In an interview in 1940 Berek noted that the choice for the aperture of 3.5 was quite deliberate. A wider aperture, he remarked, would have been easy from the designer's point of view. The Leica camera however, was a new product and should succeed in the market. Therefore the quality of the Leica images was of paramount importance. The aperture of 3.5 gave excellent optical performance and more importantly, it had an extended depth of field. So even if the Leica user misjudged the distance a bit, he was assured of high quality images. Berek rightfully assumed that the user of this new instrument needed to gain experience with the wide aperture and the focusing. He should not be disappointed with the results, even while experimenting and learning.

The optical correction of the Elmax departed from the older generations of anastigmats. These were corrected for the green to purple part of the spectrum, because emulsions of those days were sensitive to this part of the spectrum. Again Berek assumed that the user would need a lens corrected for the whole spectrum, so he computed a lens where the red part of the spectrum was also corrected. He noticed that any lens that is well corrected for panchromatic emulsions is also suitable for color film. But panchromatic film needs to be corrected for every wavelength in the visible spectrum, because any wavelength can produce unsharpness effects. For color film the sensitivity of the eye enters into the equation and so the lens should be best corrected for the yellow part of the spectrum (the middle part, that is).

These kinds of considerations indicate a very sensitive mind to the needs and demands of the Leica user and a firm understanding of the core elements of the Leica camera and the Leica philosophy. Berek designed 23 lenses for the Leica. The last one of which was the 85mm f/1.5 Summarex from 1940. He received a personal Grand Prix in 1937 at the Paris World Fair for his accomplishments. Up to now Leica has produced about 65 different lenses for the rangefinder system. Berek alone accounts for more than 35% of all Leica rf-lenses and his design considerations still can be noted in today's designs.

In the 1940 interview Berek remarks that a high quality image is less an issue if the optical performance than of the technical expertise of the user. This perception is still true today. His ideas about designing lenses were published in a book called "Grundlagen der praktischen Optik" (subtitle "Analyse und Synthese optischer Systeme") or "Fundamentals of practical optics (subtitle: Analysis and Synthesis of optical systems). It was published in 1930 and many reprints were made until 1986, when the last version was printed. The book is still very interesting for its approach and contents. The handbook by M. von Rohr 'Die Bilderzeugung in optischen Instrumenten vom Standpunkt der geometrischen Optik' (The geometrical investigation of formation of images in optical systems), published in 1920 was the reference in the world of optics. Berek improved on the theory of geometrical optics with his book. He and Merté (from Zeiss) engaged in a small scientific battle about the 'principles of geometrical optics'. This scientific debate had its parallel in the Zeiss and Leitz lenses for the two coupled rangefinder systems of the thirties: Contax II and Leica III.

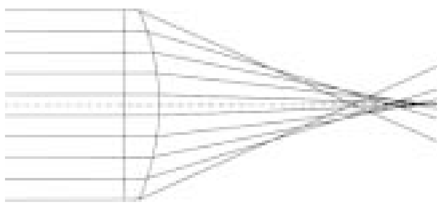
Berek loved to work at night when everything was quiet. He would retreat to his room with a pot of tea, his slide rule and, smoking cigars, would trace difficult rays to compute the corrections he needed. He was very well versed in the flute and played in many chamber music sessions. Given the close relationship between optical and sound waves, his accomplishments in both areas are not surprising.

Glossary of abberations

The spherical lens is the fundamental building block of optical systems. Its two most important properties are its index of refraction and the curvature of its two surfaces. It is a known fact that the direction of a light ray changes as it passes from one medium (like air) into another medium (like glass). The extent of this change is governed by a number: the index of refraction. Because this index depends on the wavelength (λ) of the light ray, one can define a glass with a series of numbers. This variation of indices of refraction is called dispersion. Visible light has a spectral range of 400 nm to 780 nm (nm = nanometers). The index refraction is greater at 400 nm (for example: Schott glass BK7: 1.53026) than it is at 700 nm (1.512894). This change in the index of refraction is different for each type of glass and the amount of change can be greater than 4%. A standardized number for the magnitude of dispersion is provided by the Abbe Number. A large (small) number indicates low (large) dispersion. Glass with an Abbe Number greater than 50 is classified as flint glass and glass with an Abbe number lower than 50 is called crown glass. There are exceptions, however. Glass manufacturers divide their catalogs into three sections: Preferred glass (in stock), Standard glass (produced at regular intervals) and Special glass (produced upon demand, provided the quantities are sufficient).

When a spherical lens images a point source of light (object) on the plane of focus, one would expect a point-shaped image. The law of refraction states that the path of a light ray that strikes the glass surface at a given angle of incidence is altered by an angular amount that is a function of the angle of incidence. If that angle is changed, the amount of deviation (=Refraction) will also change. A curved lens surface means that the angles of incidence for parallel incoming rays will be greater at the rim than they are at the center of the lens, so that rays that come in near the edge are bent (=refracted) more strongly.

The illustration below shows that the refracted rays do not intersect the optical axis at a single image point, but at various points along that axis. This error is the basic spherical error, called

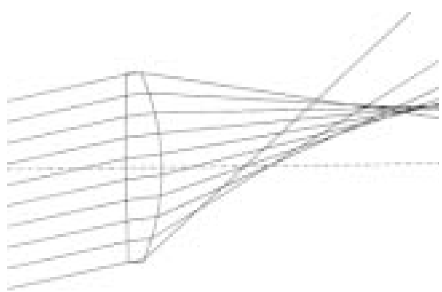


spherical aberration. It is a monochromatic error, and in this case this means that the rays of each wavelength that come in at a distance from the optical axis form an image point on the axis that is located ahead of the image point formed by rays that come in near the axis. Instead of a point, a patch of diffused light (circle of confusion) is formed on the image plane. The rays coming in near the optical axis come to a focus on a plane that is called the Gaussian plane. The point image has a bright core surrounded by a halo .

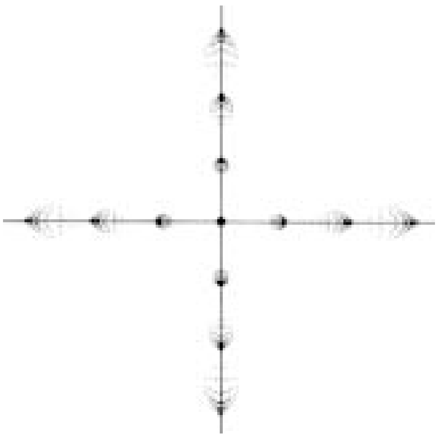
When the lens is stopped down, the rays that come in at a distance from the axis are blocked and the position of the image point will change, as will its form. The core will become larger and the surrounding halo will become smaller. This change in the position of the image is called focus shift. Because one always focuses [R-lenses only] wide open, it makes sense to select a plane of focus on which the contrast is best at full aperture. High contrast occurs when the halo is small, even when the bright core point is slightly larger than it was on the Gaussian image plane. In practice, this involves displacements by very small amounts, and their order of magnitude is the domain of the optical designer's expertise. If we imagine an image core on the Gaussian image plane with a diameter of 0.02 mm and a flare rim of 0.08 mm, the core on the ideal focusing plane will be slightly larger, namely 0.025 mm and the flare diameter will be reduced to 0.04 mm.

It is obvious that such an image point has less flare and better contrast. Theoretical resolution is reduced by a small fraction because the image core is a little larger. In practice this resolution cannot be achieved anyway, because stray light diminishes contrast and the entire picture will have a flat appearance. This example shows exactly where the optical designer has to apply his or hers skills in order to optimize a system and it also shows how tight the manufacturing tolerances have to be.

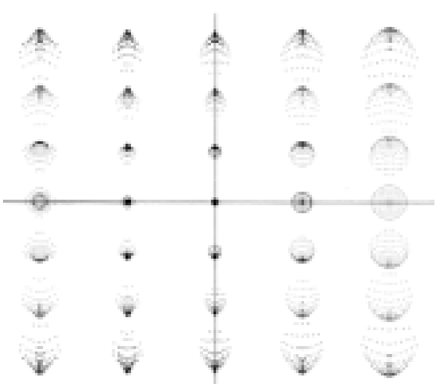
Spherical aberration affects the imaging of points that are located on or close to the optical axis (for all light rays traveling parallel to that axis). If the object point that is being imaged is further away from the optical axis, the bundle of rays coming from that object becomes skewed and asymmetrical. The second monochromatic error is the asymmetrical error, also called coma.



This aberration is also caused by the differences in the refraction of light rays in relation to the different angles of incidence of the rays that strike the curved glass surface. The illustration above shows that the rays coming in from below are bent more strongly then the upper rays. Spherical aberration involves a small bright core that is surrounded by circles of diffuse light , all of them having the same center (the axis). With coma, we observe the same structures (core and rings or zones of diffuse light), but now the asymmetry causes every ring to have a different form and to occupy a different position on the image plane. The image point is drawn out on one side and takes the form of a point with a bright core and a triangular blur zone, looking much like a comet.



One can think of the bundle of rays as a cone whose point is positioned precisely on the image plane. That creates a point at that location, a point that is surrounded by zones of diffuse light. If this cone impinges on the image plane at an angle, as shown in the illustration of coma, the image will no longer have the shape of a point. The oblique cone of light will be intersected by the curvature of the surface of the lens. If you look at a circular lens from the front, you will see s full circle. If you now rotate the lens in a vertical direction, it will become an ellipse, like a cat's eye. It is clear that rays entering the lens in the vertical direction, the longer one, will have different angles of inclination than rays entering in the horizontal (the shorter direction). This aberration is called astigmatism.). The bundle of rays



in the horizontal plane focus at a different location than do the rays in the vertical plane. They do not form a point of light, but a line, one lying in front of the other and mutually perpendicular. All object points that have a horizontal focus, are located on a tangential plane, which is not flat but has the shape of a parabola or ellipsoid. In the same pattern, we also have a vertical plane, which is curved as well. At the optical axis, these surfaces coincide, but they diverge quite significantly in the outer zones, Between both extremes, we will find a position where the point has the least unsharpness.Astigmatism is difficult to visualize if one doesn't consider a fourth aberration at the same time.

Because of the spherical shape of the lens surface, the object is also imaged on a curved plane. But the film plane is flat, and that creates another problem. This (monochromatic) imaging error is called field curvature. When this aberration is present, sharpness gradually decreases towards the edges of the image. The image is dish-shaped because of the spherical forms of the lens. That is also the case with astigmatism. If both aberrations are present, we will have two separate curved fields (dishes). If astigmatism has been eliminated, there is still curvature of field to be dealt with. These three dishes are usually curved in the same (forward) direction. The difference in the positions of the three dishes is on the order of 2% of the focal length. An optical designer is capable of eliminating astigmatism, but he or she can also over-correct it in the opposite direction and thereby compensate for curvature of field. Then there will only be a residue of less than 0.04% if the focal length (to cite a numerical example).

All of these aberrations are sharpness errors that diminish the sharpness of the image. But there are other aberrations that only affect the shape of the image, even if the image points were absolutely sharp. This, the fifth aberration is called distortion. An optical system always depicts an object in a specific size. A 50 mm lens focused at 10 meters (32'10") reduces every object by a factor of 200. But one can expect that the reduced image is geometrically accurate and that the ratio of reduction remains constant across the entire image. This is called scale fidelity. Unfortunately this is not the case with most lenses, because the reduction scale varies within the image area. When the scale increases as the distance from the center of the image increases, the result is pincushion distortion. When the scale is reduced towards he edges of the image, we get barrel-shaped distortion.

These five aberrations are called monochromatic aberrations because they act on a single wavelength. Because light diffraction (color dispersion) is not the same for blue light as that for red light, these colors are refracted differently. Blue, for instance, is bent more sharply than red light and they converge on different focal points. If we place the image plane in the middle between these two focal points, we will see a green (or yellow) core with a purple fringe (red plus blue). If we shift the image plane, the color of the fringe will change from blue to red or vice-versa. This imaging error is called longitudinal chromatic aberration and just like spherical aberration, it causes the image to appear flat because it reduces contrast. With this chromatic error the image plane will be in a different place for each wavelength. The dispersion of the glass will also cause a change in the size of the color image in each wavelength. Because short-wave light (blue) is refracted more strongly, blue rays will converge at a closer focal point. The effect is similar to that of a lens with a short focal length, which depicts objects at a reduced scale. The focal length is linked to the magnification factor, and that is why a variation in the refractive index also causes a variation in magnification. This error is called lateral chromatic aberration and it mostly affects the reproduction of fine structures. A white image point is separated into its component colors and reproduced as a stretched rainbow. A dark point with a light background is reproduced with a color fringe that appears in blue on the upper rim and in red on the lower rim.

Aberrations are often reduced when the lens is stopped down, because marginal rays no longer contribute to the imaging errors. Lateral chromatic aberration is not diminished by stopping down the aperture and it is very difficult to correct. Both chromatic aberrations (lateral and longitudinal) increase from the center of the image towards its edges.

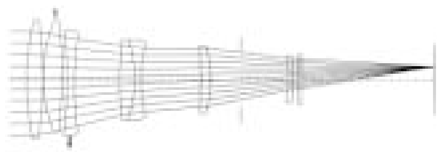
These seven imaging errors are called the Seidel aberrations, because Ludwig von Seidel was the first person to examine them on a scientific basis around 1850. There are still other aberrations, which are classified as aberrations of higher orders. The index of refraction is at the bottom of all aberrations and calculations are based on the sine of the refracted angle. The sine function can also be expressed as a geometric series: $\sin p = p - p^3/3! + p^5/5! - p^7/7! + \ldots$

Each term in this series is related to a group of aberrations of a certain order. The first term represents an error-free image, as it occurs in the center of a picture. This very small area around the optical axis is called the paraxial region. It is logical to associate it with aberrations of the first order. The next term incorporates the number "3" and i therefore refers to aberrations of the third order (the Seidel aberrations). Because this series only contains uneven numbers, the next term refers to aberrations of the fifth order, and so on.

An optical designer can avail himself of a long list of steps that he or she can take to determine the imaging performance. The choice of the proper glass is a very important factor and since the properties of glass affect the correction of errors to a significant extent, it provides additional room for creativity. But certain glasses are 300 times as expensive as standard glasses, possibly difficult to process and they may be quite heavy. Then the selection becomes very critical. Other possibilities, like the use of aspherical surfaces and apochromatic correction are described in the chapter entitled "Core technologies".

The computed imaging performance will not be achieved if all the other factors of influence are not under control. One of the most disturbing influences is caused by decentering. Every lens element has its own optical center, which should be aligned on the main optical axis during the assembly of a multi-element lens. If that is not the case, for instance when the lens element is slightly shifted at a right angle to the optical axis, the imaging performance can be diminished significantly. A lens can also be tilted, which means that its center may well be positioned on the main optical axis, but it may be seated at an angle.

Centering errors influence the optical performance, specifically contrast and the reproduction of the finest structures on the image plane outside the center of the image.



Stray light is another unpleasantly disturbing influence. Stray light consists of those rays that do not contribute to the formation of the image, but which are reflected by the glass surfaces and dispersed by the remaining aberrations or reflected inside the mechanical lens mounts or by the blades of the iris diaphragm. This kind of light produces an overall veil across the image plane, it brightens shadow areas, causes halos around highlights and diminishes contrast. Therefore stray light is a combined result of residual aberrations, mechanical construction and assembly, and the properties of the glass.

Lens coating is a process designed to reduce reflections. A simple anti-reflection substance, for instance lithium fluoride, is vaporized and deposited on the glass surface until it reaches a specified thickness. The thickness of the coating depends on the wavelength that is to be corrected and it amounts to ë/4 (a quarter of the amplitude of a wave cycle). This means that interference reduces reflections of this wavelength considerably and almost completely for the adjacent wavelengths. Coatings are also used to balance the color rendition of lenses so that they all match. In practice, multiple layer coating systems are also used for the reduction of broad band reflections. There are very few rules in this field: antireflection systems are part of specific optical systems and their properties. In the final analysis, it does not matter what kind or methods of anti-reflection measures are taken, what matters is that they should be effective.

Diameter of the circle of least confusion

Even the most highly corrected lens still has residual aberrations. A point light source is depicted as a miniscule bright spot. With modern Leica lenses, the order of magnitude of the diameter of that tiny spot is between 0.01 and 0.02 mm. As stated earlier, this circle of dispersion consists of a bright core surrounded by rings of dispersion of diminishing brightness. It is not easy to determine the overall diameter of this bright spot, because it depends upon the minimum brightness of the last ring that is to be included in that diameter. Even so, a standard circle of least confusion has been defined as having a minimum diameter of 0.03 mm. Every bright spot on the image plane with a diameter that is smaller than 0.03 mm is perceived by the viewer as a point light, when enlarged 3 times. Therefore an optical reproduction can be less sharp than it should be as a result of the correction of residual aberrations in the system. This property can be used for reproducing (with good sharpness) the object plane on which the lens has been focused, as well as the planes that are located directly behind and in front of the object plane. Since most photographic objects are distributed over a distance from the lens, one should be able to depict a certain depth of space with sufficient sharpness. The diameter of the circle of confusion determines the depth of field and the depth of focus. The depth of field scale on a lens provides information about the extent of distances within which objects located in that range will be rendered with adequate sharpness. The relationship between f-stops, depth of field and distances can easily be read on that scale. Nevertheless, one must remember the diameter of 0.03 mm, which is the basis for these computations, as they are used for the depth of field scales on Leica lenses. In projection and in enlarging, the depth of field is necessarily smaller, because all image points are being enlarged. The usable depth of field is often one or two f-stops smaller than indicated. Therefore, when using a working aperture of f/4, one should use the depth of field indicated for an aperture of f/2.8.

Impressum

Editor: Erwin Puts, Utrecht NL
Technical support: Peter Karbe, Leica Camera AG
Translation: Rolf Fricke, Rochester USA
Photographs: Erwin Puts, Utrecht NL
Design and Layout: Coremdia, Hamburg

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