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Resolving Power and Contrast

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Interest in photography - be it professional or as a hobby - is growing constantly. It is therefore not at all surprising that more questions are asked about the performance of lenses before a person decides on the purchase of a camera or a new lens. Such questions cannot be answered in just a few words because, in evaluating a photographic lens, a great number of factors has to be taken into consideration. The following article may furnish valuable hints to anyone interested in the study of image quality in photographic lenses.

lens manufacturers are frequently asked what the resolving power of their lenses is, in the assumption that the resolving power is a criterion for quality. However, the German optical industry does not disclose any figures concerning resolving power for the following three reasons:

1. The disclosure of figures on the performance of lenses is rather problematical. A proper evaluation of the quality of a lens is possible only if several numerical values are known. which - for example give information on

   - the sharpness of the lens over the entire image area from the center to the very corners of the field,
   - the image quality at different lens openings, starting with full aperture,
   - the image field illumination (vignetting toward the corners), the distortion, etc.

   These performance data must be carefully balanced and different emphasis must be placed on the various values depending on the intended use of the lens, a. g. for general photographic purposes, for portraiture, for enlargements, or copy work.

   Consequently, only a person fully experienced in the testing of photographic lenses will be able to evaluate such data without the risk of misinterpretations.

   Furthermore, any data on the performance of a certain lens is useful only if these values can be fully applied in the regular production run of a given type of lens.

2. When determining the resolving power, it is possible to influence the results quite considerably by using photographic emulsions and development techniques which deviate from the common practice. As a result, as long as no standard specifications exist, manufacturers may be tempted to apply measuring techniques which may upgrade the results but do not correspond to actual conditions.

3. Finally - and this is the main reason why the German optical industry refrains from giving lens resolution figures - the resolving power is not as important a criterion for image quality as is generally believed. This statement will be proved in the following paragraphs.

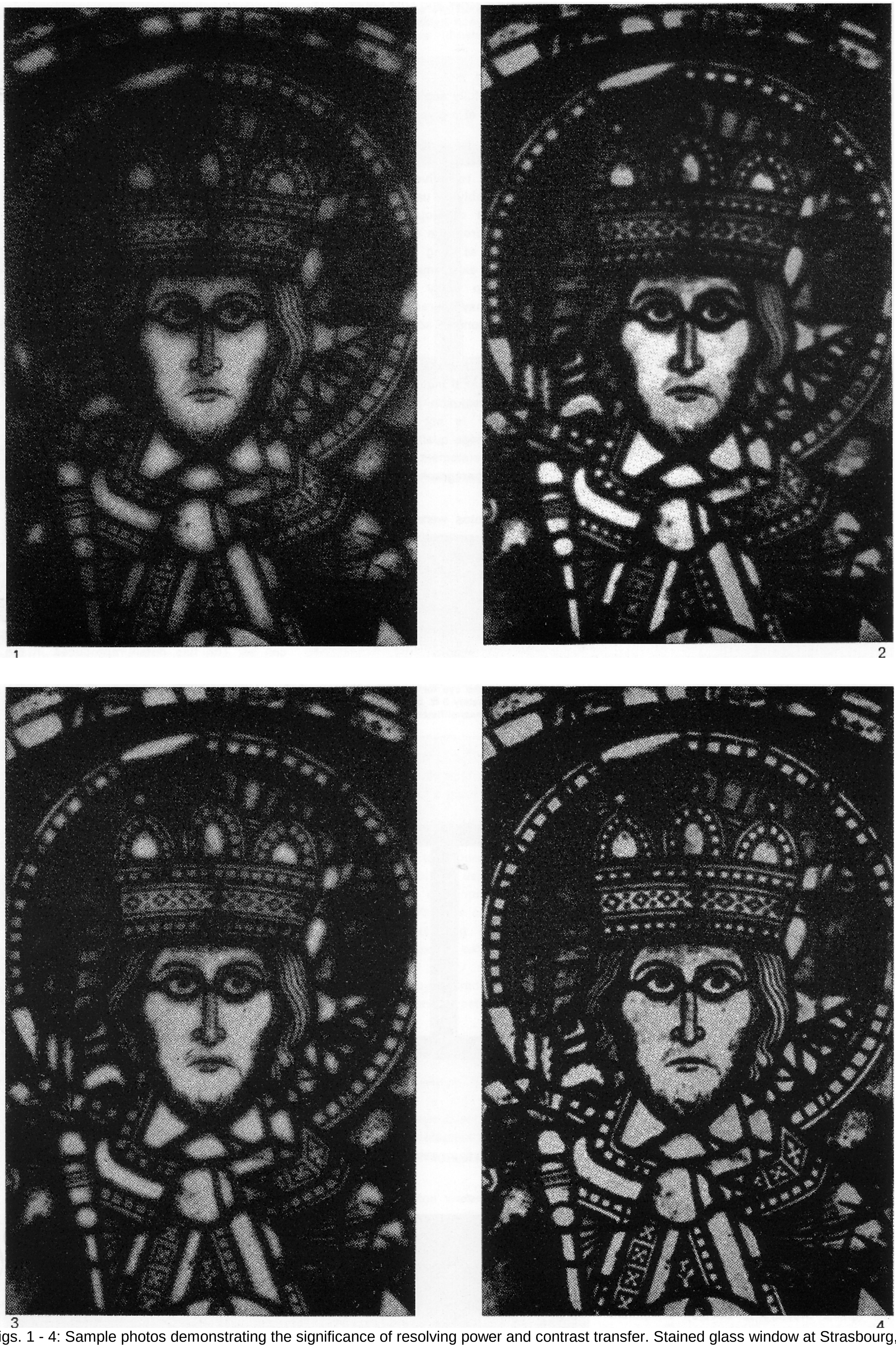
A number of photos were taken with perfectly uniform image quality over the entire field, so that it is not necessary to balance center sharpness against edge sharpness. Neither do these pictures show any visible vignetting nor distortion. We may, therefore, use these photos without any reservation for comparative image quality tests.

Let us first consider photos 1 and 2. They are both of poor quality. If you had to choose, however, which of the two would you prefer? At first glance, you would probably select photo 2. At least, that is what everyone did who saw the pictures up to now. Photo 2 appears to have much higher contrast than photo 1, the latter giving the impression of being fuzzy. However, if you take a close look, you will notice that photo 1 has a considerably higher resolution and better definition than photo 2 which, upon close examination, is rather unsharp. We do not know for which of the two pictures you will finally settle. Your decision will largely depend on your personal preference. In any case, however, you will certainly not find photo 1 so much better as the resolution figure would have it. Actually, the lens resolution figure for photo 1 is twice as high as that for photo 2.

Let us now turn to photos 3 and 4. Their image quality, or at least the image quality of photo 4, is much better than that of the pictures previously studied. And yet, it is photo 3 which has the higher resolution. This is easily recognizable in the ornaments of scepter, crown and robe. But unless we take a very good look, we do not realize it. The higher resolution, therefore, is of no consequence for the impression created by the picture.

Far more striking examples could be presented in photos of really good image quality. Unfortunately, this cannot be done here because the screens employed in the printing process would destroy the fine detail which we need to prove that a poorer photo actually can have the higher resolution. But with the aid of a trick we can create similar conditions to those encountered in very good pictures. For this purpose, we need only choose a larger viewing distance. in other words, we observe photos 3 and 4 from a distance of, say, 3 or 6 feet instead of from the normal reading distance of approximately 10 In. There will then be absolutely no doubt about which of the pictures is the better one, and we realize of how little avail high resolution can be. The fine detail reproduced in the photo with the higher resolution can no longer be clearly seen. In other words, it does not matter whether it is resolved or not.

The above examples have demonstrated that it Is possible to have poor photos showing high resolution, and good pictures with moderate resolution. Two photos of identical resolution may be entirely different in image quality. Just compare photos 1 and 4 from a distance of about 3 feet. Both pictures have the same lens resolution figure - but what a difference in image quality. It is evident that the resolving power - or at least the resolving power alone - is not the ' decisive criterion in evaluating the quality of photographic lenses, and this is what we have tried to show.



Figs. 1 - 4: Sample photos demonstrating the significance of resolving power and contrast transfer. Stained glass window at Strasbourg, cathedral, showing the Emperor Henry 11.

At this point the question may be raised whether the poor image quality in photos 1 and 3 may not primarily be the result of softer printing as compared to the printing of photos 2 and 4. The answer is no because all four examples were taken on identical photographic material and treated alike during processing.

There is, of course, a possibility of improving photos 1 and 3 to a certain extent during processing (by using high-contrast photographic material with the added control of dodging, redevelopment etc.), but the improvement will be rather insignificant even with a subject of very few Intermediate tones, as is the case in our examples. With true half-tone pictures, the above technique would be practically useless, because any attempt at improving the image through the use of high-contrast photographic material would automatically lead to a decrease of tonal gradation.

But, you will ask, what is it that distinguishes photo 4 with its modest resolution from photo 1 which has the same resolution as 4, and photo 3 with high resolution? What then, if not lens resolution, is a valid criterion for image quality?

Our comparative photographs have shown that the image quality is not so much determined by the definition of fine detail as by, the manner in which the more easily perceptible, larger structural elements in the picture are reproduced. The more faithful the contrast ratio, the better the image quality. It is obvious that the degree of accuracy of contrast rendition in an image depends on how coarse or fine the respective structural elements of the image are. The contrast in very coarse structural elements will always be reproduced to a fairly accurate degree. On the other hand, there is no such thing as "true contrast rendition" as soon as we go beyond the limit of resolution. Details, however, the size of which lies between these two extremes, will not be reproduced absolutely true, but still with more or less good contrast.

In order to get a better idea of the image-forming properties of optical systems, it seems appropriate to look at contrast rendition as a function of the size of a given detail. A very simple method is employed for determining contrast. Screens are used with equidistant white and black lines of the same width. The number of lines In 1 mm space serve as a measure of the size of a detail. Figure 5 shows sketches of two such screens. Figure 6 indicates the contrast rendition as a function of the screen size employed for the test. Line 5 represents the ideal contrast rendition in a perfectly "true" optical image (1).

(1)=It is non-existent in practice, because a certain unsharpness is caused by diffraction of the light at the diaphragm opening even in a perfectly error-free lens. Moreover, an additional unsharpness is produced by the scattering of light in the photographic emulsion. It is known that any unsharpness leads to a loss in contrast transfer.

Curves 1 to 4 represent the contrast in our four sample photos. The numbers of the curves correspond to the numbers of the illustrations. It will be noted that in photo 1 the contrast of even coarse details (a few lines per millimetre) is strongly reduced. This is the reason why the picture looks .1 soft" or "fuzzy". By comparison, the contrast of photo 2 fails off more slowly from the ideal value. This photo therefore seems to be richer in contrast. It is true, of course, that photo 1 contains much finer details than photo 2, though at the sacrifice of contrast.

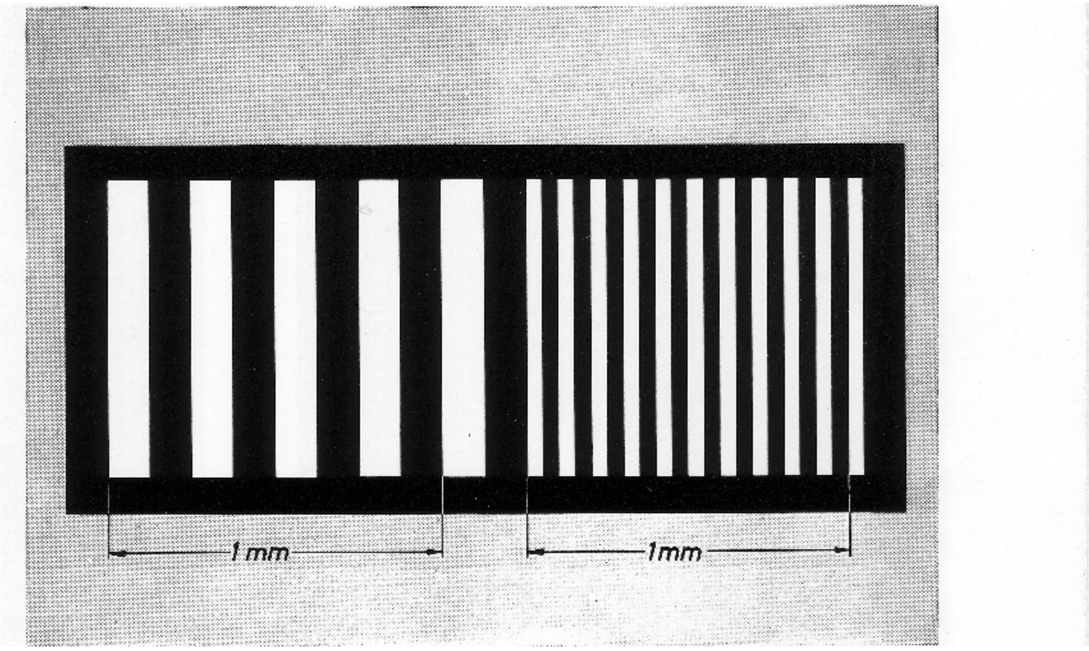
In order to render fine details visible, little contrast is required. Under favourable viewing conditions, about 5% will suffice. This value is marked in the curves by a circle. Each circle indicates the limit of resolution, and the resolution figure is given by the respective number of lines/millimetre. Thus, in photo 1 the resolution is about twice that of photo 2, while it is identical to photo 4, as was mentioned before. - What was said about photos 1 and 2 is applicable also to pictures 3 and 4 with the only difference that the curves of contrast transfer show higher values than the curves 1 and 2, thus representing a higher image quality.

All this can be read at a glance from the contrast transfer curves. But that is not all. If we include in our study the limit of resolving power of the human eye, as represented by the vertical line 6, this line will divide the range into two regions, one in which fine detail is perceived by the eye (left of the line), and the other in which fine detail Is invisible to the eye and thus not of interest (right of the dividing line). Line 6 applies when looking at the photos from normal viewing distance. As the viewing distance Increases, the number of perceptible details decreases, and the dividing line is displaced to the left. For observation from a distance of approximately 3 ft., for example, line 7 applies. Therefore, within this range of detail perception, contrast transfer curve 4 is closer to the straight line 5, representing the ideal lens, than contrast transfer curve 3. Consequently, photo 4 must have a better image quality than photo 3.

Considering all these facts, there is no doubt why the resolving power as such is not a suitable criterion for image quality. It is only a point on the curve of contrast transfer, and we have seen that in good images this point even lies far outside the important image-forming range. What really matters is the contrast rendition within that part of the range in which detail can actually be perceived by the human eye at normal viewing distance.

The theory of contrast rendition (in technical literature, generally referred to as "frequency response function" or 'contrast transfer function" of the lens and the photographic emulsion) has, in the course of the last 15 years, been discussed in many scientific publications, and a number of techniques for the measurement of contrast transfer as a function of detail size has been described. These ideas have prompted the optical industry to develop equipment which still requires a relatively large amount of mechanical and particularly electronic devices. The use of such equipment is, however, very advantageous, because it permits not only far-reaching automation of optical testing procedures, but will also lead to important new knowledge and thus eventually benefit the quality of optical systems.

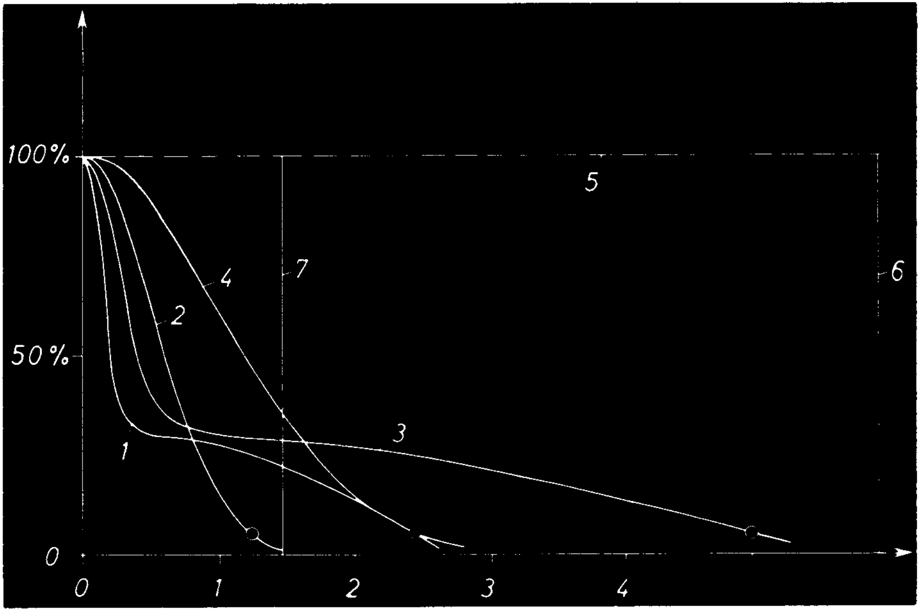
Fig. 5: Examples of line screens as used for the measurement of contrast transfer. The screen size is expressed by the number of lines/millimetre (frequency).



4 lines/millimetre 10 lines/millimetre

Fig. 6: Contrast transfer curves for the ideal image (5) and sample photos 1 to 4 (curves 1 to 4). The limit of resolving power of the eye for a viewing distance of 10 In. is shown by the straight line 6, for a viewing distance of approximately 3 ft. by line 7. Multiplied by 10. the figures given for detail size could be the conjugate numbers of lines/millimeter in the negative.

Contrast transfer



lines/millimeter