The Exakta List Resolution Program

The Exakta List Lens Resolution Program

I. introduction

This test is based on the use of Ihagee fixed mount and Ihagee/exakta interchangeable mount lenses to photograph a resolution target (figure 1.). The target is composed of 199 pairs of dark and light lines of progressively decreasing widths. The photographic images of the target are sent to M. Higgins for analysis with a computer program written to work with the free-ware image analysis application “Scion Image” (WWW.scioncorp.com/) . The analysis involves digitizing the photographic images with a film scanner (4000 dpi). Then, the program determines the first occurrence of line spacings in the digitized target image which show given amounts of contrast reduction. These pages describe: how the test works, information for photographer as to how to run the test, and how the resulting images will be analyzed. To get a free Exakta List Target and other testing materials send an email to Michael Higgins (mhiggins2814@netzero.com) or a request a package by mail to Michael Higgins, 604 S. Washington Sq. #2814, Philadelphia, PA 19106, USA. The target to be used is a modification of one invented by the very gifted Norman Koren http://www.normankoren.com/ whoes site was discovered for me by Miles Upton. The difference between Norman Koren’s target and the one I am providing is that Norman plots the line widths on a log base 10 scale, whereas I use a linear scale. Even though the log scale is more in keeping with sin frequency function of the MTF procedure, I wanted the line widths to be directly related to their widths in mm not their widths transformed into units of log base 10. The target allows one to measure resolution by the Modulation Transfer Function (MTF) principal. You can read about MTF testing at Norman’s site and in the below. Briefly, the principal of MTF test is that it exploits a phenomenon of which most photographers are all too aware. Namely as the detail in a photographic subject becomes smaller, the lens begins to resolve this information with decreasing amounts of contrast. This is seen in images of the target as the lines in the target grow thinner. In this case, the dark lines become progressively lighter and the light lines become darker (i.e., a decrease in contrast) until they merge into a gray zone which shows no detail. The computer program identifies the thickness of pairs of lines that first show a 50 and then a 10% decrease of the maximum amount of contrast measured in the image . The results are stated in line pairs per mm (lp/mm) at the 50 and 10% contrast reductions. A line pair is a dark and lighter line of the same width. They are placed side by side on a target on the basis of decreasing width. In Figure 1. the number 2 precedes the first dark and light lines of the first line pair. This number 2 is a frequency term which indicates that the first two lines to the right of this number equals two line pairs per mm. Each subsequent pair of lines is increased in frequency by the next larger positive integer (2, 3, 4, 5 to 200). The calculation of the width in millimeters for each line in a pair is given by:

W = 1mm/ (the frequency of line pairs to be considered, in this case it is 2)* 2 (the number of lines in a

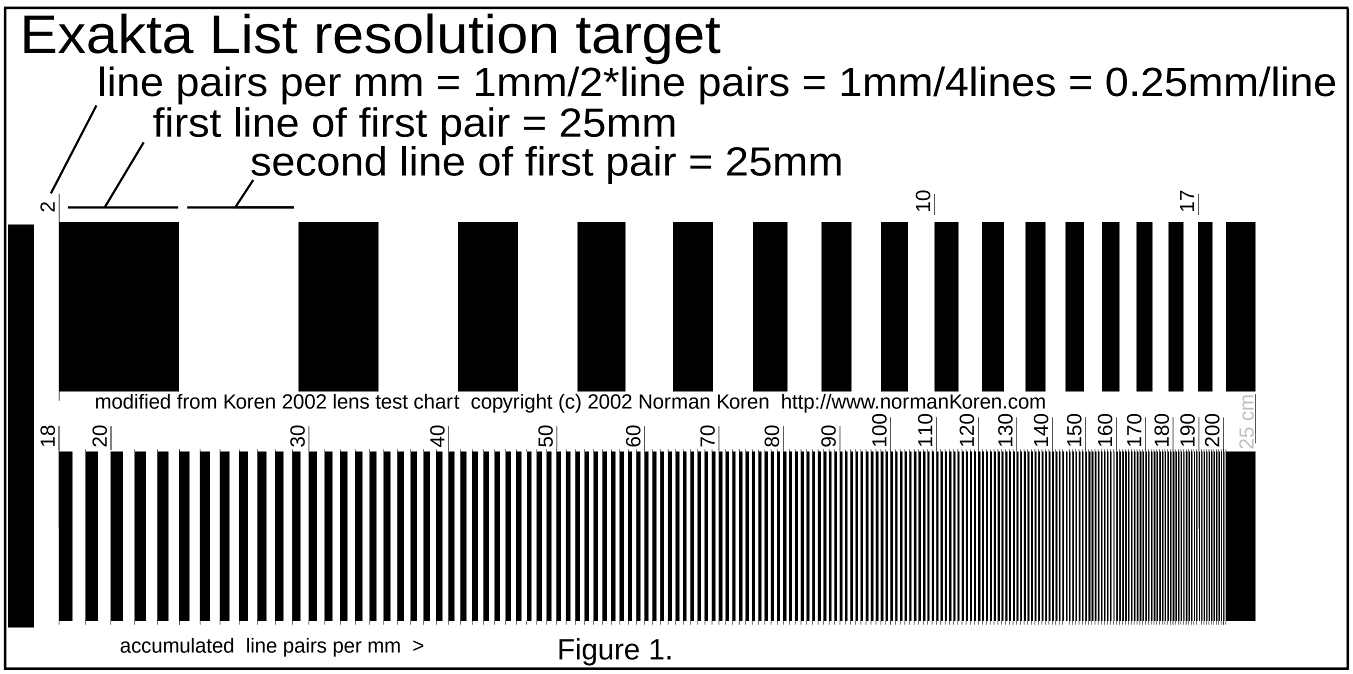


Figure 1.

pair) (1)
Where: W is width of each line in a pair

Substituting into equation (1) the numbers for the first line pair (frequency of two) it will be seen that both of the lines in the first pair should equal 0.25mm:

0.25mm per line = 1mm/(2=two lines in the pair)*2 (or some higher frequency)

When you receive your target and should you measure the width of the first two lines, a width of 25mm not 0.25mm will be observed. This because the target width will be reduced at the film plane when the lens is positioned at the proper distance from the target. The 0.25mm width will be obtained on the film plane of the camera when target to lens distances listed under the 100X columns of Table I are used. At the 50 and 25X distances, the first two lines in the target should measure at the film plane 0.5 and 1mm. At the 100X lens to target distances, the target can measure resolutions up to 200 line pairs per mm (lp/mm). Using a film scanner is used to divide the image into the small boxes or pixels (figure 2.). Each pixel is assigned to a given row and column. Also, each pixel is given a gray level value (Figure 3.). In the early days of computers, eight binary numbers were used to carry out computer instructions and to store data. At that time, a convention was developed to code for graphical information wherein when all eight binary numbers equaled one (11111111 in binary, or 255 in decimal numeration) a pixel was the coded for white and when all eight binary numbers were set at zero (00000000 in binary, or 0 in decimal) a pixel carried the code for black. The 254 numbers between 255 and 0 identified levels of gray (see figure 3.). Though 8 bit computer code is a thing of the past this 8 bit convention of assigning gray levels for pixels of images is still in use and it is code we employ here.
Returning to Figure 2, the first line pair of the target was resolved by the lens with complete accuracy (that is the dark line was coded to be 0 and the white line was determined to be 255). To calculate the

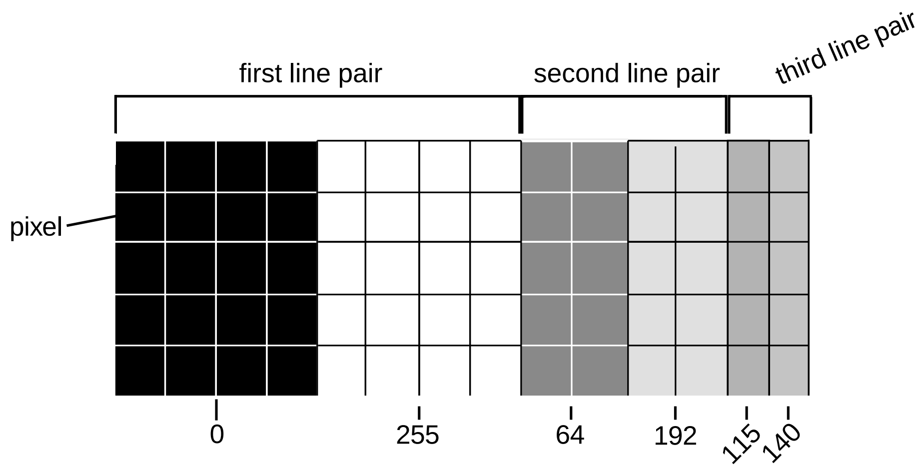


Figure 2. Gray level values for three digitized line pairs

the shorter 50 and 25X distances the maximum resolution of the test is limited to 100 and 50 lp/mm.The figures 100, 50, and 25X are magnification values which describe how many times the line widths on the properly positioned film plane must be multiplied before they reach the actual widths on the target.

The Use of Modular Transfer Function (MTF) in Measuring Lens Resolution

Consider figure 2. This is a diagrammatic image which shows a hypothetical, digitized image taken from a piece of film. In this case, the target contains only 3 line pairs. By digitizing the photograph, it is meant that contrast difference for this line pair the darker value is subtracted from the lighter one (255=255-0). This subtracted value is 255 and represents the maximum contrast value of which this lens is capable and is called the 100% MTF value. This 100% value is also used to calculate the two additional MTF values (50 and 10% MTF levels) which will be used characterize the resolving power of the lens. Given 255 being the 100% MTF, the 50 and 10% MTF figures for this example would be 125 =255*0.5 and 25.5=255*0.1. Now the remainder of the test involves measuring the width of lines in pairs and gray level difference

Gray levels coded in eight binary numbers and their decimal equivalents

Key gray levels used in MTF testing	Gray level colors	Decimal equivalents	Binary numbers
		0	00000000
		10	00001010
		20	00010100
		30	00011110
		40	00101000
		50	00110010
		60	00111100
64 (50%)		70	01000110
		80	01010000
		90	01011010
		100	01100100
		110	01101110
115 (10%)		120	01111000
128 (center)		130	10000010
140 (10%)		140	10001100
		150	10010110
		160	10100000
		170	10101010
		180	10110100
		190	10111110
192 (50%)		200	11001000
		210	11010010
		220	11011100
		230	11100110
		240	11110000
		250	11111010
		255	11111111

Figure 3.

between each line in a pair. When the difference in gray values in these pairs first equals 128 and 25.5 or below, the width of the line pairs which gave these differences is recorded. Note that in figure 2 line pairs with these contrast differences are found in the second and third line pair respectively The 50 MTF% value gives a idea as to how the higher contrast portions of the image will be resolved and the 10% describes how fine detail in low contrast portion of the image will appear. While the 10% low contrast figure is what captures most of the interest, the information in an image that this number evaluates usually makes up a relatively small portion of a total image. Directly below I describe the steps in testing a lens.

II. UpdatedTest Procedures

1. **Lens to Target Distance as a Function of Lens Focal Distance and Magnification**: Tables Ia, Ib, and Ic give the lens to target distances appropriate to the focal length of the lens and the desired magnification to be used. I strongly recommend using the 50x distances. If resolution results with the 50x distances indicate greater than 100 lp/mm are obtained (the maximum which a 50X distance can report), I will ask that this lens be retested using the 100x distances. In these cases, I will analyze these images by making an enlarged intermediate image prior to scanning which gives the analysis software the same number of pixels per target length as the 50X magnifications.

2. **Camera - Target Setup:** (figure 4.) Mount the target on a flat wall in a level position. Use a carpenter's level if necessary in reducing tilt of the target. Also, use the level on the camera-tripod mount as well. If the target and film plain are not parallel, portions of the lines on the target may be distorted. In addition it is important that the center of the lens be at the same height as the center of the target.

3. **Edge and Corner Resolution:** This test was envisioned to measure the central resolutions of lenses. However, there has been some interest in testing the corner and edge resolutions as well as the center. If you would like to do this, be sure to mount the secondary targets at the edge or corner of the field of view (figure 5., not at the edge or corner of your central work area). You can generate two or more targets from the one you received from me by cutting the top and bottom row of the target longitudinally into two strips. If you need more targets just ask.

4. **Notes:** It is essential that you post a note with the target concerning the relevant characteristics of the lens which is being tested (figure 5.). The note should contain the following: lens manufacturer (like Zeiss, one word names please), name for the lens model (like Tessar), focal length, maximum aperture, serial number and the aperture used for the photograph. Such notes can be made with a text editor- word processor on your computer. Type the needed data (or possibly use a list of lenses you already have on hand). To convert this text into notes select the relevant text (hold down the left mouse key while moving the cursor over the text you want to display). When the text has been selected change the font size to at least 80 points (a little larger than an inch), use the bold setting and then print them. The printout can then be cut into individual notes for posting. If this isn't a possibility, two persons have used chalkboards and another used a felt-tipped pin on normal white paper. With this done, no other documentation should be needed. The acid test is: **can you read your note through the view finder of your camera?** If no, use a larger font size.

focal length of lens (mm)	Table Ia: lens to target distance in: meters, magnification 100x	50x	25x	feet, magnification 100x	50x	25x
7	0.71	0.36	0.18	2.32	1.17	0.60
12	1.21	0.61	0.31	3.98	2.01	1.02
16	1.62	0.82	0.42	5.30	2.68	1.36
18	1.82	0.92	0.47	5.96	3.01	1.54
20	2.02	1.02	0.52	6.63	3.35	1.71
21	2.12	1.07	0.55	6.96	3.51	1.79
22	2.22	1.12	0.57	7.29	3.68	1.88
24	2.42	1.22	0.62	7.95	4.02	2.05
25	2.53	1.28	0.65	8.28	4.18	2.13
29	2.93	1.48	0.75	9.61	4.85	2.47
30	3.03	1.53	0.78	9.94	5.02	2.56
35	3.54	1.79	0.91	11.60	5.86	2.99
36	3.64	1.84	0.94	11.93	6.02	3.07
38	3.84	1.94	0.99	12.59	6.36	3.24
40	4.04	2.04	1.04	13.25	6.69	3.41
45	4.55	2.30	1.17	14.91	7.53	3.84
50	5.05	2.55	1.30	16.57	8.37	4.27
52	5.25	2.65	1.35	17.23	8.70	4.44
54	5.45	2.75	1.40	17.89	9.04	4.61
55	5.56	2.81	1.43	18.23	9.20	4.69
58	5.86	2.96	1.51	19.22	9.70	4.95
59	5.96	3.01	1.53	19.55	9.87	5.03
60	6.06	3.06	1.56	19.88	10.04	5.12

focal length of lens (mm)	Table Ib lens to target distance in: meters, magnification 100x	50x	25x	feet, magnification 100x	50x	25x
70	7.07	3.57	1.82	23.20	11.71	5.97
75	7.58	3.83	1.95	24.85	12.55	6.40
80	8.08	4.08	2.08	26.51	13.39	6.82
82	8.28	4.18	2.13	27.17	13.72	6.99
85	8.59	4.34	2.21	28.17	14.22	7.25
90	9.09	4.59	2.34	29.82	15.06	7.68
95	9.60	4.85	2.47	31.48	15.90	8.10
98	9.90	5.00	2.55	32.47	16.40	8.36
100	10.10	5.10	2.60	33.14	16.73	8.53
101	10.20	5.15	2.63	33.47	16.90	8.62
105	10.61	5.36	2.73	34.79	17.57	8.96
120	12.12	6.12	3.12	39.76	20.08	10.24
125	12.63	6.38	3.25	41.42	20.92	10.66
135	13.64	6.89	3.51	44.73	22.59	11.52
145	14.65	7.40	3.77	48.05	24.26	12.37
150	15.15	7.65	3.90	49.70	25.10	12.80
152	15.35	7.75	3.95	50.37	25.43	12.97
165	16.67	8.42	4.29	54.68	27.61	14.07
178	17.98	9.08	4.63	58.98	29.78	15.18
180	18.18	9.18	4.68	59.65	30.12	15.35
200	20.20	10.20	5.20	66.27	33.46	17.06
210	21.21	10.71	5.46	69.59	35.14	17.91
240	24.24	12.24	6.24	79.53	40.16	20.47
250	25.25	12.75	6.50	82.84	41.83	21.33

focal length of lens (mm)	Table Ic: lens to target distance in: meters, magnification 100x[a]	50x	25x	feet, magnification 100x	50x	25x
300	30.30	15.30	7.80	99.41	50.20	25.59
360	36.36	18.36	9.36	119.29	60.24	30.71
385	38.89	19.64	10.01	127.58	64.42	32.84
400	40.40	20.40	10.40	132.55	66.93	34.12
500	50.50	25.50	13.00	165.68	83.66	42.65
600	60.60	30.60	15.60	198.82	100.39	51.18
610	61.61	31.11	15.86	202.13	102.07	52.03
640	64.64	32.64	16.64	212.07	107.09	54.59
800	80.80	40.80	20.80	265.09	133.86	68.24
1000	101.00	51.00	26.00	331.36	167.32	85.30
1200	121.20	61.20	31.20	397.64	200.79	102.3
1250	126.25	63.75	32.50	414.21	209.15	106.6
2000	202.00	102.00	52.00	662.73	334.65	170.6

a equals magnification as in regard to the term M in equation

4. **One Negative:** I would like to have one negative for each lens or item to be tested (an item means like another test condition on the same lens such as wide open and shut apertures, as well as the f8 exposure, etc). Please no duplicates. Pick your best shots and mark the ones not to be studied with a big black X placed on the film with something like a felt marker or pieces of tape.
5. **Lighting** is unimportant as long as it is even. You can use flash sources, but use them in the bounce mode to avoid glare. The only caveat with the latter is you will need a flash meter or some test shots.
6. **Film and developer:** The recommended film is T-Max 100 developed in T-Max developer. Deviations are OK.
7. **f stops to be used:** f8 is the standard aperture for this test. You can add fully open and /or closed shots if you wish. In the case of zoom lenses, there should be an f8 exposure from the middle focal length range and you may want to add exposures from each end of the focal lengths that these lenses cover. With mirror lenses, you are stuck with wide open.
9. **Reporting lens opacity, abrasion, fungal infec-**

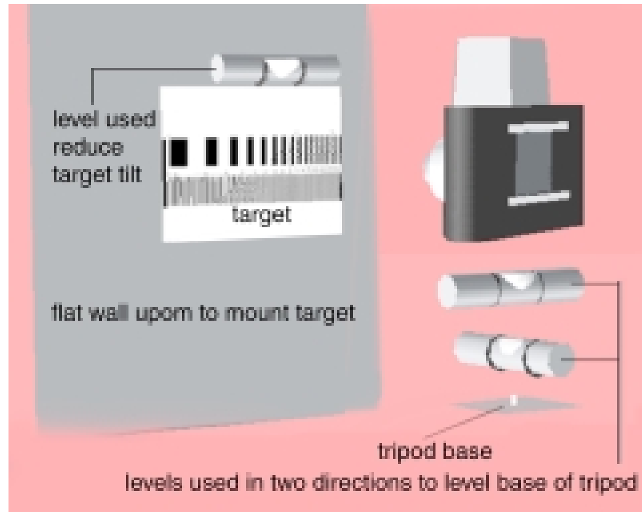


Figure 4.

tions and separations: One of the interests I have in this project is to find what is the impact of glass aberrations on lens resolution. Many photographers assume that a flawless lens is necessary for maximum performance. One recent experience called this conclusion into some question. I was looking at an Exa 0 version 4 with a Meritar. The image was quite good. As I had

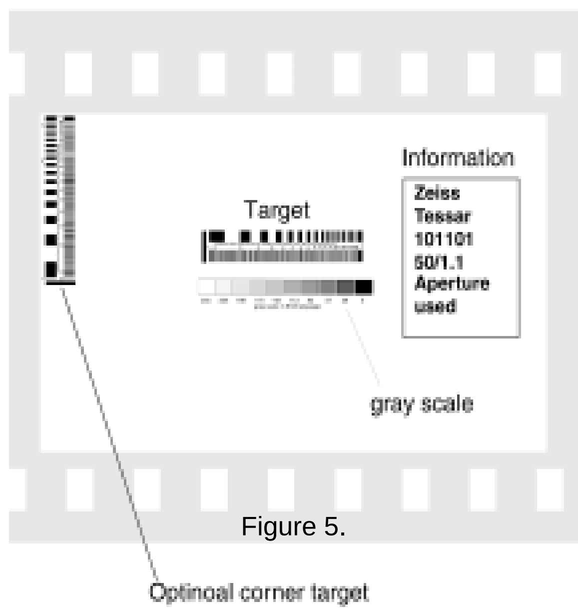


Figure 5.

never examined this lens before, I removed it from the camera and used oblique lighting (see figure 8.) to examine the condition of the glass. What I saw appeared to be two elements broken into four pieces. Maybe perfection in glass elements isn't as important as I had thought. If you are going to have a lens serviced, test it before and after servicing. The data should be extremely interesting. Also, test your dirty/ cloudy lenses even if you never plan on having them

Opcacity Estimation Chart

Abrasion guide

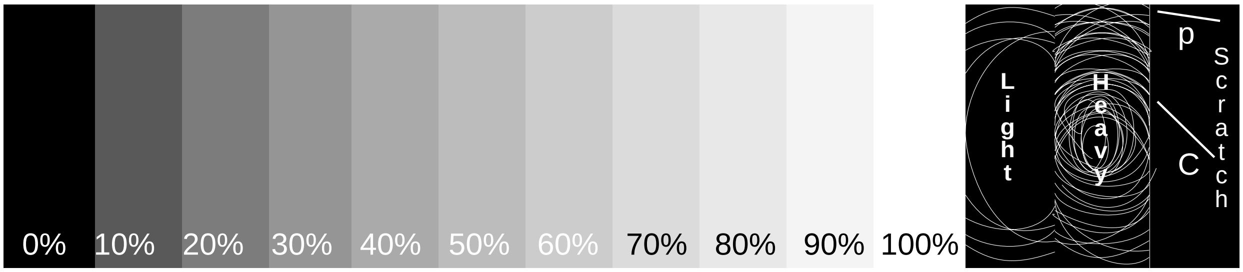


Figure 6.

serviced. As we build a database we will be able to compare the resolution figures obtained from mint lenses with their dirty siblings. Both dirt and lens cloudiness produce lens opacity. I am asking you to estimate the opacity of your lenses. To estimate lens opacity, I have prepared a chart (figure 6.). It was made by superimposing two image layers in Adobe's Photoshop (figure 7.) .The bottom layer was black and the upper layer white. The opacity of the upper layer was varied from 0 to 100%. The results of this work is shown if figure 6. To use the chart use the oblique lighting and viewing conditions shown in figure 8. Then pick the opacity swatch in figure 6. which best matches what you see through the center of your lens. Abrasions are shown on the last three panels of figure 6. For purposes of simplicity, I have divided abrasions into cleaning marks and scratches. According to this definition cleaning marks are superficial and usually circular. Scratches are usually straighter and deeper. In the last panels, I divided cleaning marks into light and heavy, and I suggest we report scratches as to which element affected, length, number and whether they are central (C) or peripheral (P). If any of my criteria, don't match yours, report the stuff any way you want. Lens separations and fungal growth or any other relevant data can be entered under comments. If you would rather not bother with this part skip it.

10. **Tripods:** It is best to use the heaviest tripod available. Also don't forget to use a cable release or your delay settings on the slow shutter speed knob to reduce vibration.

11. **View Finder-Film Plane Correspondence:** Checking the correspondence between the images observed in the viewfinder and at the film plane: Klaus Rademaker sent me a note saying that some of the cameras he had tested showed differences between the plane of focus seen in their viewfinders and at their film planes. Miles Upton has given us methodology to check and correct this in his book. One places a camera on a tripod and focuses a fast lens through the viewfinder on

Two layer method of making opacity standards

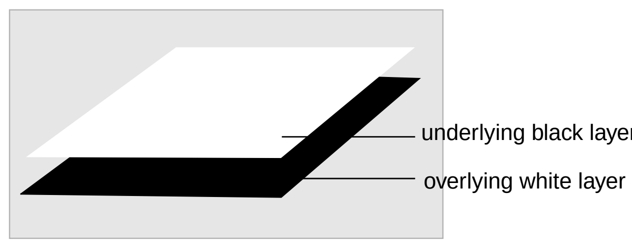


Figure 7.

an object which can be assumed to be at infinity (Figure 8A.). Open the camera and place or tape a viewfinder to the film rails (figure 9b). A magnifying viewfinder would be ideal for this purpose. One then asks whether both images are the same plane of focus? There may be differences at full aperture, but if the image is OK at f8 you have a working solution (because f8 is the critical aperture for our testing). If not, reach for the next camera or viewfinder.

12. **Run a Test Strip of Exposures** Using <=> 50 year old cameras can pose some difficulties. From my observations so far, shutter speeds around 50-100th of a second are usually OK, but exposures greater or smaller than this have been very inaccurate in some cases as to be unusable. The accuracy of the test depends on, in part, having properly exposed negatives. I can't analyze over or under exposures without making some corrections which I would rather not make. I suggest making a test strip of different shutter speeds for every aperture opening you wish to study. In the case of inaccurate shutters, you may need a shutter overhaul.

III. Interpretation of Exakta List MTF resolution data.

Opacity and abrasion test

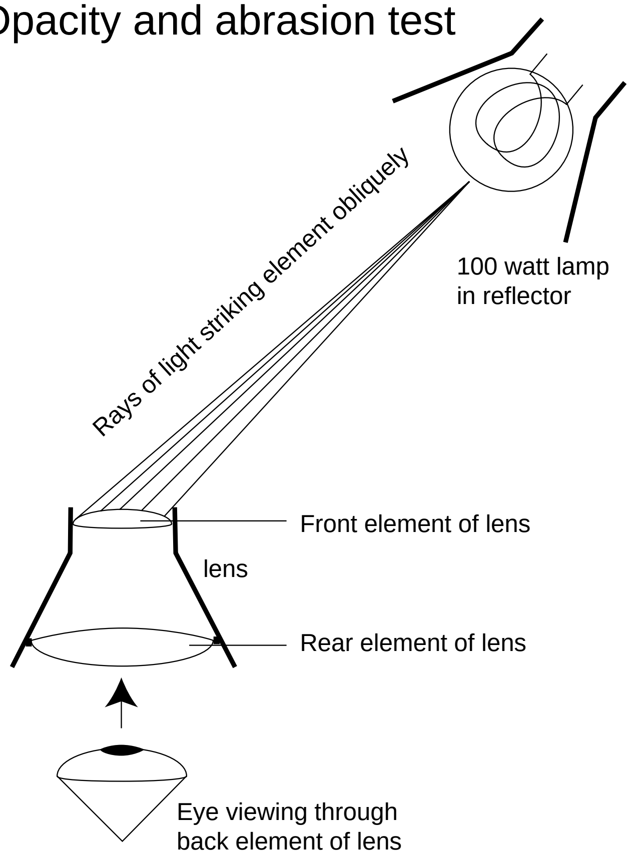


Figure 8.

To do this, a bit must be known as to how the T- Max images of the Exakta List Target are analyzed. In figure 10. is shown a digitized (scanned) image of the cropped target made with a Meyer Primoplan 50mm f1.9 lens at the 50x distance at f8 (note that this image is reproduced here at 72 dpi as opposed to the 4000 dpi captured in the original that was actually analyzed). The first step is to determine the minium and maximum gray levels which a lens can capture on film. This done with the computer program using a mouse-linked tool to draw two rectangles over the first line pairs of the target. In figure 1, two such rectangles are shown in white and marked with the letters A and B. The values for the average gray levels for these rectangles A and B are in the case of the Primoplan image is 39.95 and 156.14 units. Subtracting these values from one another yields 116.19 (=156.14-39.95). Thus 116.19 is then defined as the 100% MTF of this particular lens. The larger this value the more "contrasty" a lens is. The 50 and 10 % levels for the Primoplan are 58.1(=116.16*0.5) and 11.619 (=116.19*0.1).
Figure 10. shows a white line stretched over the bottom row of lines of the target (C). The program measures the gray level of each pixel over which the white line passes. A plot of these gray levels is see in figure 11. Note with increasing distances along the target, the

Correspondence between focus seen in view finder and at film plane

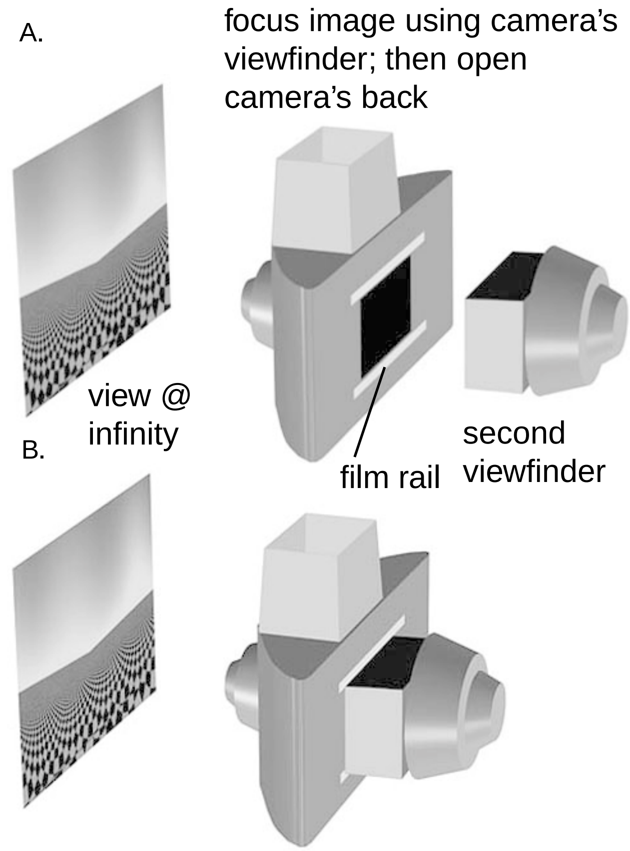
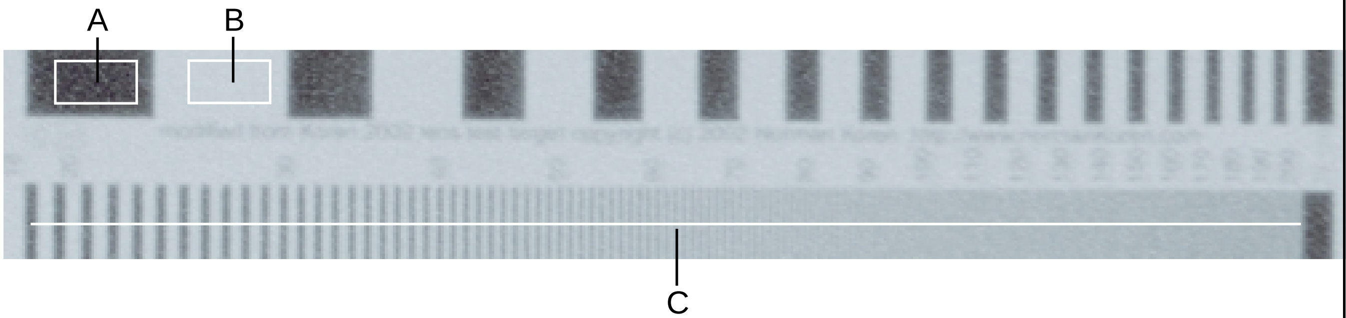


Figure 9.

gray levels show fluctuations of less and less amplitude. Finally, they reach zone of little change (shown by horizontal line in figure 11.) where its travel is only disturbed by noise. The program written for this investigation: searches the data collected along the white line for pairs of adjacent pairs of dark and light lines, calculates the difference in gray level between these pairs and determines the first time that these differences are equal or less than the calculated 50 and 10% MTF values.
The plot of these gray level differences as they relate to target distance is shown in figure 12. This chart also shows a curve fitted to these data which is used to actually select the 50 and 10% MTF values. The two horizontally lines mark the 50 and 10% MTFs for this lens and the first two vertical lines point to the line pair positions at which the curve's values equal or are less than the 50 and 10% MTF figures. Note, the distance (or X axes) of figures 11. and 12. begin with zero and ends with one. In this approach, the first pixel measured along a line as in figure 1.(C), is given the value

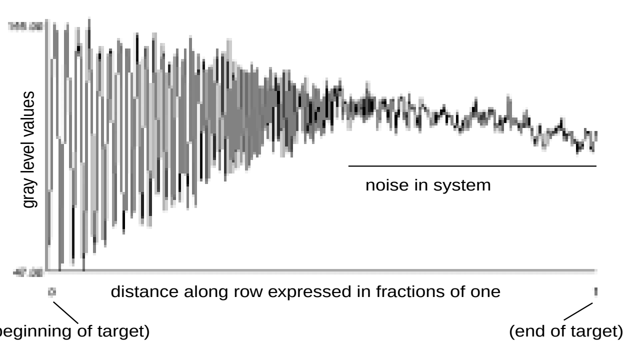
Figure 10. Analysis of a scanned photographic image of an Exakta List Resolution target



of 0 and the last accumulated pixel distance is made to equal one. This is done to make these axes independent of magnification. In figure 12, the 50 and 10% MTFs are reached are reached at the distances (stated in fractions of one) at 0.2454 and 0.5699. An equation converts these fractions into lp/mm. This value is then corrected for magnification, and the final number of lp/mm for the 50 and 10% MTF values can be presented. For the Primoplan used here the lp/mm values found at 50 and 10% MTF were a highly respectable 16.52 and 36.45 lp/mm (figure 14.). To convert these figures into the more usual term of lines per mm, merely multiply by two. This means using concentional testing proceedures that 10% MTF vale is equivalent to 73 lines per mm.

In all cases studied, faint lines were seen stretching vertically across, or partially across, the target to the right of the 10% MTF line. The area under discussion is shown with a white rectangle in figure 13a and in exploded view in figure 13b. In figure 13., pairs of black bars are shown to mark the computer-determined 10 and 50% MTF points. In contrast, determining where the last line fragments end is quite subjective. Why have I included last linear fragment data? I wanted to know how such distances compared with the MTF estimations. Secondly, for people who only have been exposed to non-MTF target results (like the Air Force Target), I thought that they might be able to better evaluate the MTF data if some element of the older testing methods were provided. Thus the last thicker vertical line in figure 12. shows an example of the position to the right of the 10% MTF where “last linear fragments sightings” were seen. Unless asked, I am planning not to continue with last linear fragment estimations. Finally figure 14. indicates how data will be reported for these lens studies. Entries bearing the symbol (a) are optional. You make choose not to post your name, the full serial numbers of your lenses or their opacity. As regards serial number you may allow only first four digits or the full number to appear.

Figure 11. Shows graylevels measured along line marked “C” in figure 10.



Acknowledgments

This test was designed on the guidelines given by Norman Koren’s on his site and his most generous advise (http://ww.normankoren.com/); however, there have been departures (including the analysis programming and target design) obviously for which Norman is in no way responsible.

I thank Norman for teaching me so much about this method. He is a great resource to the photographic community. Hugo Ruys support during the development of a great deal of the software, and especially to Miles Upton for his encouragement and allowing me to make this material available on his site. Also to KLaus Raemaker for drawing our attention to technical matters wnich could degrade the accuracy of the test if not followed

Finally I would like paraphrase Bill Gates is in his introductiiion of IE4. We may not have the best test (his word was browser) but we certainly have the cheapest.

m. higgins, 08/01/03

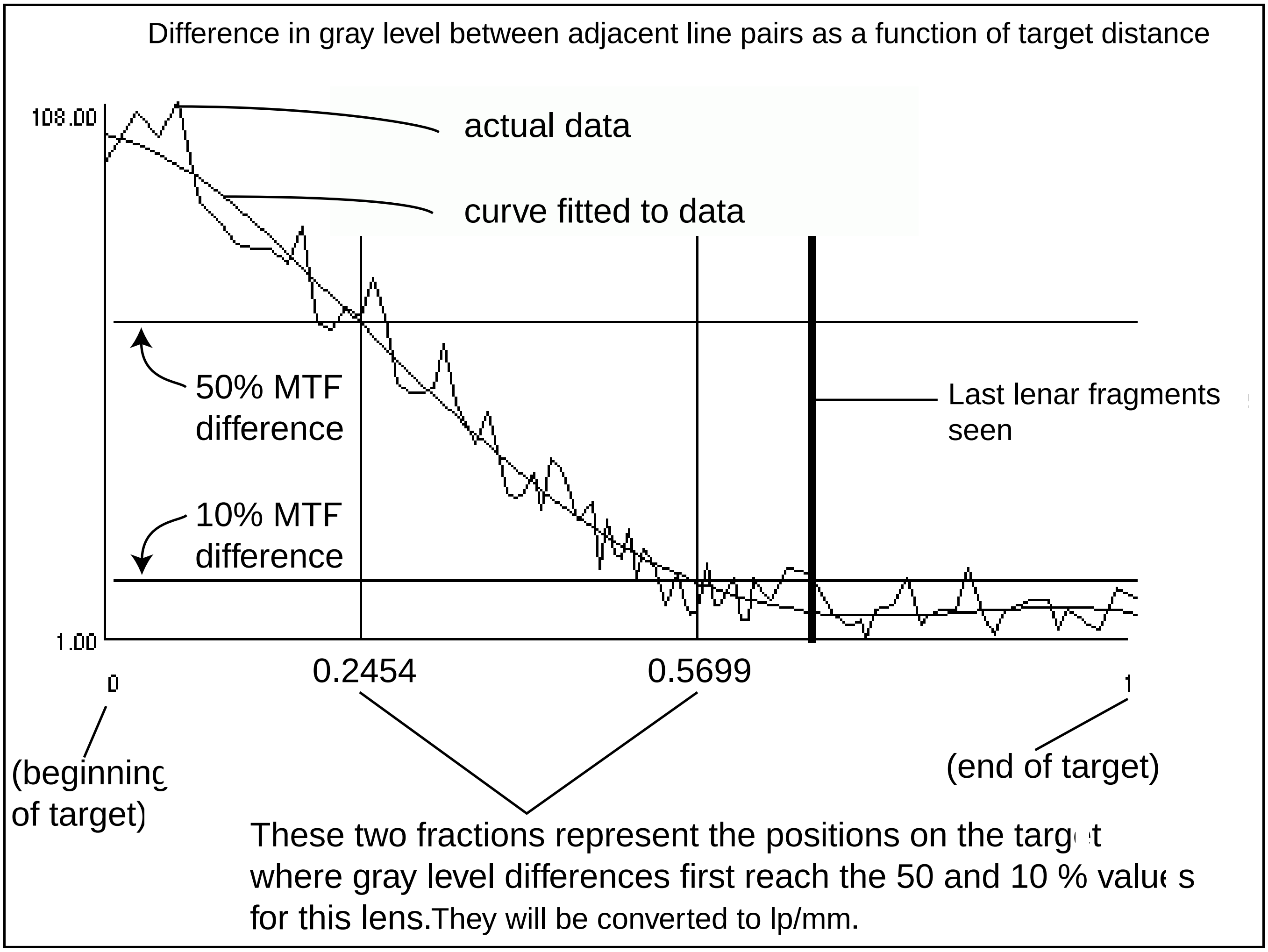


Figure 12.

Figure 13. A. shows the bottom row of the target reproduced in figure 1. The approximate 50 and 10 % MTF positions are marked. B. Gives an enlarged portion of A (the white rectangle in A.) which includes the 10% MTF position and another portion immediately to right of this area where weaker linear signals can be obsered.

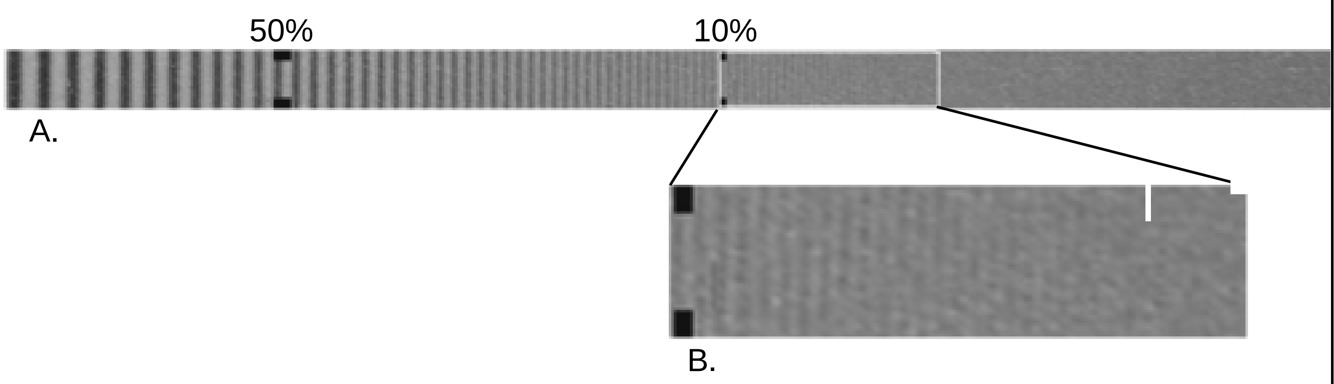


Figure 14. an example of the layout of data to be given for each lens analyzed