Test Procedure for Obtaining Resolution Results

Note: This testing procedure was based on the one of Modern Photography magazine and was just modified by Bozhidar Dimitrov and Frederick Wasti.

1. **Only test lenses in excellent optical and working mechanical condition.** Do not submit tests for lenses that appear to have been disassembled, or that have optical blemishes. *Follow the testing procedure as accurately as possible*.
2. **Find a suitable testing location:**
   - A sturdy non-vibrating floor is a must. Wooden or carpeted floors, floors in buildings that vibrate because of outside traffic or use of heavy machinery are not acceptable.
   - The test location must be large enough to support the separation of camera and targets by the following multiples of the lens focal length:
     - 55 for lenses with focal length 135 mm or less,
     - 27 for longer lenses.
3. **Obtain 5 copies of the United States Air Force (USAF) lens test target.** The chart contains *groups* of six *line pairs*. Each line pair contains three horizontal and three vertical lines. Groups are laid out vertically, and are numbered by a large number printed above them. You can purchase USAF charts from Edmund Scientific (1-800-728-6999, ask for "USAF Optical Test Pattern Resolving Power Chart", catalog number `U83,001`). Alternatively, print this file on a 600 dpi laser printer. The PDF file contains groups -4 and larger (-4 and -3 are not numbered), and on my printout the quality of both the horizontal and vertical lines of pair 4 of group 1 is impeccable. At 1:55 magnification this corresponds to 156 lpm, probably quite sufficient for all lenses that we will ever own. At 1:55 line pair 1 of group 1 corresponds to about 100 lpm, and that should be the minimum printing tolerance. Print the file with Adobe Acrobat, and make sure that in the print dialog "Shrink to Fit" is not checked. The side of the large square in the top-center part of the page should be 35.5 millimeters long.
4. **Load the camera with Kodak Royal Gold 100 print film.** We limit the tests to a particular film so that the results from different people are more comparable.
5. **Mount the resolution targets.** Imagine the rectangle part of the wall that is in the field of view of the film. Attach one test target at each corner of this rectangle and one target in the center. The center target should be oriented in a right-side-up fashion. For lenses with focal length 135 mm or less, the four corner targets should be mounted such that their centers are 56 cm (22") above and below and 81 cm (32") to the right and left of the center of the center target. Position the corner targets so that the bottom edge of each target faces towards the center target. Use this diagram as a guide. For lenses between 135 mm and 400 mm use 28 cm (11") and 41 cm (16"). For lenses longer than 400 mm use 15 cm (6") and 20 cm (8").
6. **Mount the camera body on a sturdy tripod**.
7. For lenses of focal length 135 mm or less, position the tripod such that the front of the lens is at a distance 55 times the focal length of the lens from the center target. For longer lenses the distance should be 27 times the focal length. Manipulate the tripod such that the camera's film plane is parallel to the wall and the distance from the lens to each of the four corner targets is equal. It is probably best to mount the targets on a vertical wall and position the tripod on the floor. Position the targets (and hence the camera) as low as possible such that the tripod is extended to the smallest possible extent. *Every effort must be made to assure that the camera body and lens will not suffer from even the slightest vibration during the test exposures.* If you have to, weigh your tripod down by attaching a weight to the center post.
8. **Assure that the target area is uniformly illuminated.**
9. **Determine correct exposure.** Care should be taken to meter off a middle-toned subject that fills the metering area. A gray card and spot metering work best. *Overexposed or underexposed targets will not give proper resolution results.*
10. ***Focus carefully on the center target.*** Be very careful with this, and use a magnifying finder or refconverter if you have one. Possibly consider making a series of full tests with refocusing between the series.

11. **Use the longest mechanical or electronic cable release that you have.** Or if your camera has an electronic self-timer, you can use it instead.
12. Prepare to **keep careful records during the testing.** You must know the exact testing conditions for each and every image obtained. To help out, a series of "yellow stickies" or 3"x5" cards may be used, affixed to the target area. At a minimum, write the lens serial number and aperture on each of these and replace them for each exposure. Also consider writing the lens type, focal length, maximum aperture, etc.
13. After framing and focusing very carefully, **make a series of exposures at the lens wide-open aperture and at each full stop thereafter.** For example, an f/1.7 lens should be tested wide open at f/1.7, and then closed down to f/2, f/2.8, f/4, etc., all the way to f/22). Adjust the shutter speed to compensate for every change in aperture.
14. For zooms:
    - Repeat the tests at the shortest, middle, and longest focal lengths. To allow for comparisons with prime lenses, round the middle focal length to a "standard" one. The Excel resolution chart contains three rows for each zoom, and the middle focal lengths are indicated there. Note that the M40-80/2.8-4 and 400-600/8-12 lenses have very limited zoom ranges, so they will only be tested at the extremes.
    - For testing variable aperture zooms at their middle focal length, assume that the effective widest aperture is half-way between the apertures at the ends. For example, for an f/4-f/5.6 zoom, assume f/4.5 to be the middle (this is not an arithmetic average, but a geometric one). To conform to the test procedure, perform a test at this "half-stop" aperture, and then at the full stops thereafter. Take into account the fact that at because of the variability of the aperture, the aperture ring is a half stop behind the real aperture. So, set the aperture ring between f/2.8 and f/4 to achieve f/4; between f/4 and f/5.6 to achieve f/4; between f/5.6 and f/8 to achieve f/8, etc. If you have a camera body that can be set to aperture priority with the lens aperture ring set on "A", then you do not need to worry about this complication. Just use that mode.
15. **Have the film developed** by a lab using standard C-41 processing.
16. Looking through a microscope or a loupe of at least 20x magnification, **find the smallest (largest numbered) line pairs in the center target that are clearly resolved. Repeat the same for the corner targets** and choose the smallest line pair that is clearly resolved in all four targets. Note that the resolving power of the observing lens must not be allowed to limit your ability to easily read small line pairs on film. *Critical focusing here is just as important as with the focusing of the test lens.*
17. **Convert the corner and center line pair numbers from each test frame into lpm numbers**:

Lpm values for magnification ratio of 1:27

Group	Pair 1	Pair 2	Pair 3	Pair 4	Pair 5	Pair 6
-2	7	8	9	10	11	12
-1	14	15	17	19	22	24
0	28	31	35	39	44	49
+1	55	62	69	78	87	98

Lpm values for magnification ratio of 1:55

Group	Pair 1	Pair 2	Pair 3	Pair 4	Pair 5	Pair 6
-2	14	15	17	19	22	24
-1	28	31	35	39	44	49
0	55	62	69	78	87	98

+1	110	123	139	156	174	196

18. If you have followed all of the above steps as carefully as you can, mail the results to me and feel very proud of yourself!

Note: The numbers in step 15 are obtained by first calculating the lpm number at the target plane, and then dividing by the magnification ratio (i.e., multiplying by 27 for 1:27 magnification). The target plane lpm values are given by the following table:

Lpm values (at the target plane)

Group	Pair 1	Pair 2	Pair 3	Pair 4	Pair 5	Pair 6
-2	0.250	0.281	0.315	0.354	0.397	0.445
-1	0.500	0.561	0.629	0.707	0.794	0.891
0	1.00	1.12	1.26	1.41	1.59	1.78
+1	2.00	2.24	2.52	2.83	3.17	3.56