Evaluating A Macro Photography Camera

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Introduction

My company, AMF, purchased a general-purpose digital camera five years ago, the Sony Mavica, model MVC-FD83. The digital capability and floppy disc drive media proved very practical for general documentation purposes. The floppy discs made it convenient for any employee to work with the images. After about 20,000+ images the floppy drive wore out and a new camera was needed. Meanwhile I had personally purchased a Nikon Coolpix 995 camera with a 3.3 Megapixel resolution (a big improvement over the Sony Mavica 0.9 megapixel resolution) and close focus (2 cm) capability. This became a consideration for an AMF camera and we ordered one on eBay, which was lost by the USPS - it was insured.

Earlier in 2005 I purchased a Sony T1 with a Magnify mode that featured a very close focus (1 cm) and 5-megapixel resolution. This camera has provided many of the images used on posters, reports, fundraiser book, procedures, and power point presentations, especially for the BPB project. The ability to produce a large image of a very small object has proved very useful for our engineering and publicity projects.

The Sony T1 works especially well as a general documentation camera for me because I always have it with me, I have extra memory cards, 1 GB total for about 500 images, and 2 extra batteries for any photo shoot requirements. All of this fits in my shirt pocket and is with me 24/7. The T1 has two serious limitations. The first is sharpness with magnification, and the second is working distance for lighting. An example of an image the T1 is capable of is shown in figure 1 at the right. The BPB uses many small parts and to be able to photograph them without the flatness of a microscope image is very useful for documents, Power Point Presentations, publicity, and posters. Other BPB parts are even smaller and a good macro photography camera with good lighting could produce adequate images.

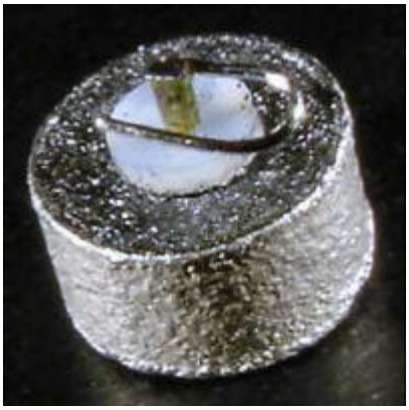

Fig. 1 - 2.4 mm dia.BPB Stim.Cap.

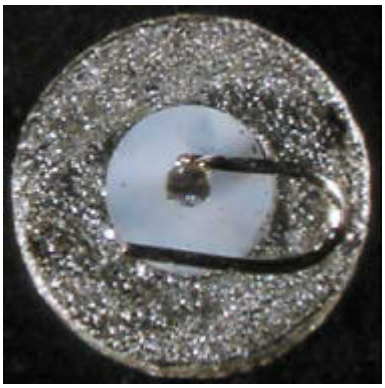

Fig. 2 -Top view of BPB Cap.

The close focus of the Sony T1 provides reasonable magnification for small objects, such as the BPB stimulation capacitor, but the small working distance makes lighting the subject very difficult. How do you front light a subject within a space of 1 cm (394 mils) between the lens and the subject? The sharpness issue involves both the sharpness of the lens system and the depth of field. The advantage of a macro photograph over an image as seen by a microscope is the increased depth of field. The tools, parts and BION® microstimulator products themselves fall into the range of subject size that is best photographed by what is usually called macro photography.

In addition to the close focus lighting limitations that many amateur grade digital cameras have, their light sensitivity and light gathering power is limited compared to conventional 35 mm film cameras with a quality macro lens. The Nikon 995 and Sony T1 are limited to F9 and F8 respectively. Each f-stop increase produces a greater depth of field. Thirty-five millimeter single lens reflex, SLR, camera lenses typically stop down to F22 or F32. A high intensity light and a slow shutter speed is the price to pay, but the depth of field increases under these conditions and approaches the 3.1 mm diameter of the BPB with a magnification of 2x to 5x.

Evaluating available cameras.

The first thought for a high quality digital camera is the professional large format, 10 megapixel resolution or higher, models. At this resolution the quality is equal to 35 mm film and 35 mm SLR versions are available that use a wide range of standard lenses. These models, however, are very expensive with prices in the range of $5,000 to $40,000. A practical alternative is the high-end amateur digital SLR. These camera bodies are in the $ 800 to $1,100 range with a good macro lens slightly less.

Researching the available models - the technology is changing rapidly - and talking to professionals who use these models, immediately suggested the Nikon D70 body and 105 mm or 65 mm F2.8 macro lens. Everyone I talked to thought that Nikon lenses were excellent quality.

The desired requirements for a macro photography (defined as image:object ratios from 1:1 to 10:1) camera/lens are:

Table 1 - AMF Macro Photography Requirements

#	Parameter	Desired Value	Comments
1	Depth of field	3 to 5 mm.	BPB part sizes. High F-Stop required.
2	Magnification	1X to 5X	Fill frame for maximum effect.
3	Working Distance	12 to 20 cm	Required for lighting subject.
4	Sharpness/resolution	Greater than T1 (45 l/mm)	Required for details. Higher is better.

Several tests were made to measure the performance of the T1 with regard to the requirements in table 1. The objective is to improve on the performance of the T1.

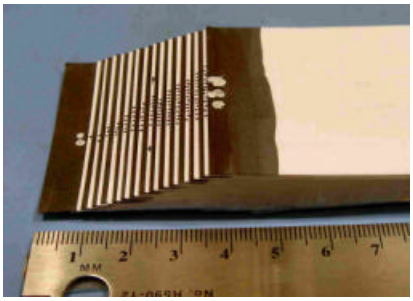

Fig. 3 - Photo test Subjects

The "tools" used to evaluate the T1 are shown in figure 3 on the right. Each black and white step of the pad is 11 mils above the one before it. The easiest way to determine magnification capability is to photograph a scale and enlarge it to the point where image degradation is apparent. This was done in figure 4. Note the uneven lighting and lack of sharpness. While the images of the capacitor in figures 1 and 2 may look OK, technically they are lacking detail - sharpness and resolution at the desired magnification for small parts. The images in figures 1, 2, & 4 are at maximum T1 magnification. Is it obvious as to why figures 1 & 2 are "better looking" than the ruler in figure 4? The "secret" is in the lighting. The side lighting of the capacitor allows the lights to be closer and below the plane of the subject. The large flat ruler restricts the lighting. While the T1 is quite fast and easy to use for smaller subjects the working distance is a major limiting factor for both subject orientation and lighting for the higher magnifications. There are other features that limit the T1 for small part photographs. These are the lack of a 1/4" x 20 tpi tripod mount, and the lack of a means (threads) for lens or filter attachment.

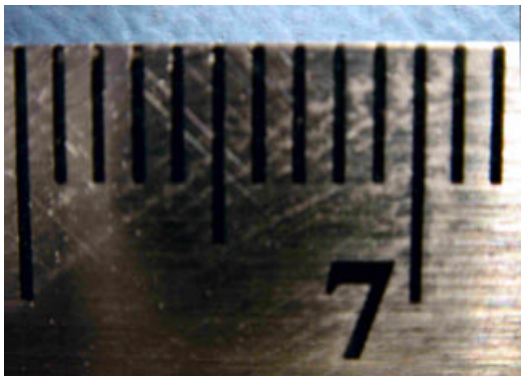

Fig. 4 - Magnification test - 5 X

The photo subject used to measure the optical resolving capability is the Target shown in figure 5 at the right. Both positive and negative versions are available from Edmund Industrial Optics. We have the positive version on order for future use.

The Target consists of ten groups of line pair elements. These line pair elements are arranged in decreasing sizes. Note in figure 5 that the -1 group has all six of its line pair elements in one column. Also note that there is a large white square between the Groups -1 and -2. Observe that because the line pair elements, consisting of three horizontal and three vertical white bars, decrease in size that the smallest group, -1, has extra space in its column. This space is used for the first line pair element of group -2. The number of the six line pair elements is printed on the left or right side of the bars; one through six.

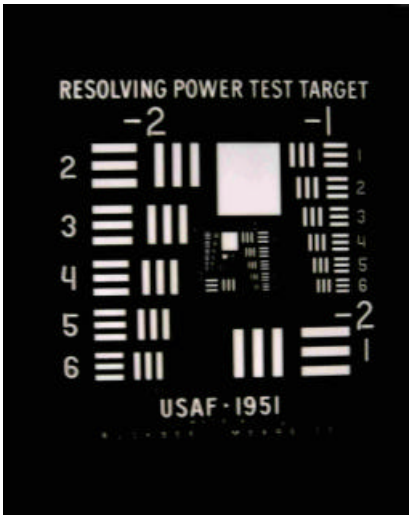

Fig. 5 - USAF 1951 Resolving Power Test Target.

The ten groups are numbered [-2, -1], [1, 0], [3, 2], [5, 4], [7, 6]. For each of the bracketed groups there is a white square. The resolution of of figure 5 is such that you can only easily see two white squares. A third white square is visible when you know where to look. The smaller white square is below the lower left corner of the large white square. This is the corresponding white square for group 1 on the left and group 0 on the right for the next smaller group.

The limited resolution of figure 5 may be used to illustrate how you might read the chart. First let's define how the group and line pair elements may be identified. If you wanted to identify the lower left set of line pairs (elements) you could write this as -2.6. The lower right set is -2.1. The upper right set is -1.1 and the upper left set is -2.2. What is the resolution shown in figure 5? We can see (resolve) some of the line pair elements but not all of them. We know the smallest, group 1, is on the left of the smaller white square. The larger group, 0, starts on the bottom at the left column (0.1) and continues on the right column (to the right of the smaller white square. Some instructions say that you read the smallest group and element pairs that you can clearly see all three vertical and horizontal bars. I look for the group that you can just be sure that you can identify that there are three bars in each direction and then "read" the value as one line pair value less. I would read the resolution of figure 5 as 0.4.

Table 2 — Group and Line Pair Element Number to Line Pairs per Millimeter*

NUMBER OF LINE PAIRS/MM IN USAF 1951 RESOLVING POWER TEST TARGET												
Element	Group Number										For #55-622 Only	
	-2	-1	0	1	2	3	4	5	6	7	8	9
1	0.250	0.500	1.00	2.00	4.00	8.00	16.00	32.0	64.0	128.0	256.0	512.0
2	0.280	0.561	1.12	2.24	4.49	8.98	17.95	36.0	71.8	144.0	287.0	575.0
3	0.315	0.630	1.26	2.52	5.04	10.10	20.16	40.3	80.6	161.0	323.0	645.0
4	0.353	0.707	1.41	2.83	5.66	11.30	22.62	45.3	90.5	181.0	362.0	–
5	0.397	0.793	1.59	3.17	6.35	12.70	25.39	50.8	102.0	203.0	406.0	–
6	0.445	0.891	1.78	3.56	7.13	14.30	28.50	57.0	114.0	228.0	456.0	–

** Groups 8 and 9 are on a higher resolution target, which is 7.4 times more expensive, $850.00*

One of our engineers, Marty Vogel, personally owns a Fugifilm S1 body which is equilivent of the Nikon D 70. He also has the Nikon 105 mm macro lens. Walter McCracken owns the Nikon D70. Rick Wolf owns a negative version of the USAF 1951 Resolving Power Test Target that provides a numerical measure of resolution from 0.25 line pairs per millimeter, l/m, to 228 l/m. He also has a Nikon 55 mm

macro lens. These items were borrowed and test photographs were made. Time and availability of the test cameras and lenses quickly indicated that the easiest test to make was a photograph of the back lit USAF 1951 Target. Initial test images were made using normal lighting against a white sheet of paper. When the target was backlit the resolution increased by one group number. This process would also provide a guide to apparent magnification in addition to providing a numeric reading of resolution. The magnification requirement is more easily addressed using extension tubes readily available for SLR cameras, something that is not possible with the T1. Increasing magnification does not increase resolution.

In addition to the camera and lenses mentioned above I borrowed a Tiffan close up lens set with +1, +2, and +4 lenses for the Nikon 105 mm macro lens from Valencia Camera. Marty and I arranged with Bel Air Camera to photograph (back lit using a slide reviewer) the USAF 1951 Target using the D 70, 55 mm F-2.8 Macro lens, 24 mm extension tubes, +2 close up lens, Sony model 828 camera (next step above the T1), Cannon Digital rebel, and MP-E65mm photo macro lens.

Table 3 shows the resolution results of the test images. Figures 6 & 7 show the two best resolution images. Sharpness was not demanded for these tests because others took some of the photos.

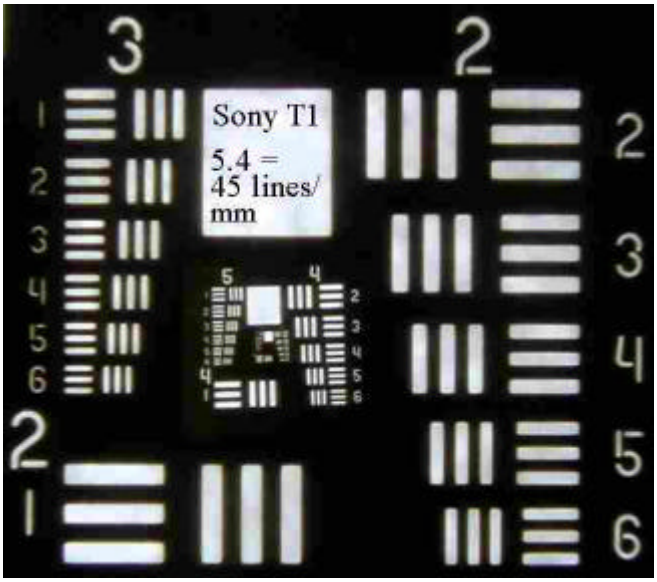

Fig 6 - Sony T1 Resolution Test at 1 cm distance.

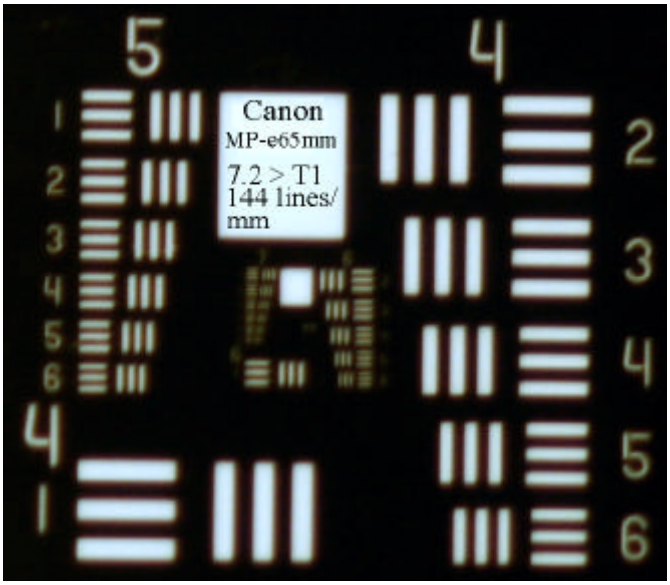

Fig 7 - Canon MP-E65mm Photo Macro lens

Table 3 — Results of Resolution Tests

#	Optics Used	USAF Target	Resolution line pairs/mm
1	Konica Digital Copier Model 9769[(1)]	2.3	5.04
2	Average human eye[(2)]	2.4	5.66
3	Fuji S1 with Nikon 55 mm micro lens	4.6	28.50
4	Nikon D70 with Nikon 55 mm micro lens	5.1	32.00
5	Sony T1, Sony 828[(3)]	5.4	45.3
6	Olympus Stereo Microscope SZ61[(4)] 0.4 to 2.5X	6.1	64.00
7	Canon Rebel with MP-e55 mm 1X-5X lens[(5)]	7.2	144.0
8	High Quality Leica Microscope Z6 APO[(6)]	—[(7)]	702

See Notes on the next page.

Notes:

(1) Set copier to the light side to resolve the lines the best.

(2) Based on four "older" male eyes with glasses. 2.4 is optimistic in most cases. (MV-3.1, RW-2.2, RN-2.1, GR-2.0)

(3) The Sony 828 does not have a close focus mode so magnification is less. The results were slightly less than the Sony T1.

(4) This is a typical zoom micro electronics assembly grade microscope.

(5) This is a specialized lens that only works over the macro range and does not focus to infinity.

(6) Baed on published specifications. Lesser quality optical systems do not give this specification.

(7) This device is beyond even the high resolution version of the 1951 USAF Resolution Target.

Conclusion

The camera/lens models tested were limited to those in the high amateur-low professional category and were readily available. Technical details on consumer products such as those listed in Table 1 are difficult to find. Actual image tests using the same subject provided a few surprises. One important lesson that was learned from this exercise is the importance of lighting and exposure. The range of observable resolution values may spread over a full group of six line pair element values. This was experienced with every optical system tested, including the human eye.

The Canon MP-E65mm is the highest performer tested and is designed exactly for the task of small object photography. While the Digital Rebel body was used to make the test images (hand held on a camera store display case and not at optimum exposure) professional reviews recommend a different body as being better suited for the MP-E65mm.

See figure 8 at the right. The lens extends showing 1X, 2X, 3X, 4X, & 5X markings on the tube for magnification.

Fig. 8 - Canon MP-365mm lens

The canon lens as described at www.epinions.com: "A unique lens exclusively for use in the macro realm, the MP-E65mm can fill a 35 mm frame with an object as miniscule as a grain of rice! Floating internal lens elements keep the resolution sharp throughout the range of focus. The lens also has an element of ultra-low dispersion glass. For macro shooters with a desire to document the diminutive, the MP-E65mm is a quantum in ease-of-use compared to previous solutions involving bellows." The quote is from: http://www.epinions.com/Canon_MPE_65mm_f_1_2_8_1_5x_Macro_Photo_Lens___Lens_2540a002/display_~full_specs

The MP-E65mm is part of the Canon EOS series of cameras and lenses. The test photos were taken with the EOS 300 (Digital Rebel) but all reviewers and professional photographers commented that the EOS 300 was not recommended for magnifications greater than 2X because of "mirror slam." The timing of the SLR mirror, followed by the shutter opening, is too short to be vibration free during high magnification exposures. The EOS 10D was recommended. The 6.2 megapixel EOS 10D, however, has been replaced by the 8.2 megapixel EOS 20D.

Recommendations

AMF should buy the Canon photo macro lens and digital SLR body to provide a macro photography capability for our small parts, tools, and fixtures. Accessories that would also be required are a shutter release, compact flash cards, and a camera rail to mount the camera onto a copy stand, and a set of polarizers. Estimated costs are listed in Table 4 below.

Table 4 — Estimated Costs for Macro Camera

#	Qty	Item	Approx Cost	Comments
1	1	Canon EOS 20D Camera	$1,499[(1)]	Body only, 8.2 mega pixels.
2	1	Canon MP-E65mm Lens	$ 900	1X to 5X photo macro lens
3	1	Canon RS80N3	$56	Electronic shutter. List is $70.
4	2	Compact Flash Card[(2)]	$ 170.00	512 MB high speed cards because of larger images
5	1	Camera Rail[(2)]	$ 250 est.	A suitable model has yet to be found
6	1	58 mm Polarizer[(2)]	$ 70.00	
		Total	$ 2,945[(3)] or $ 3,045	

Notes: (1) List price. A combination body and 18-55 mm zoom lens may be purchased for $1,599. This is probably desirable so the camera has general use in addition to macro photography..

(2) These items are not essential as exiting items may be substituted saving $490.

(3) Several hundred dollars may be saved if we use competitive Internet suppliers. Items 1 & 2 may be purchased for under $2,000 if purchased at the lowest price and (1) is ignored.

Fig. 9 - Canon EOS 20D Digital SLR

Table 4 — Internet Costs for Macro Camera

#	Qty	Item	Cost	Comments
1	1	Canon EOS 20D Camera with 18-55 lens, 8.2 mega pixels	$1,279.99	Infiniti Catalog #: 9442A008 http://www.infinitiphoto.com/viewitem.php?IndexID=5173&zTab=de
2	1	Canon MP-E65mm Lens 1X to 5X photo macro	$ 794.89	17th Street Photo SKU 2540A002i http://www.17photo.com/product.asp?id=2540A002i&estshipping=1
3	1	Canon RS80N3 Electronic shutter	$ 49.89	17th Street Photo SKU 2476A001 http://www.17photo.com/results.asp
		Total	$ 2,124.79	

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