

pattern resolved on the 50X Polaroid is 287 lines per mm (Group #8 and Element #2), see Figure 1. The theoretical resolution of a 0.10 NA objective is 300 lines/mm. The finest pattern just resolved with this objective using the Kodak MegaPlus camera is 256 lines/mm (Group #8 and Element #1), see Figure 2.

High magnification photomacrography in the laboratory was previously done with a Zeiss Ultraphot II microscope using Luminar lenses. Fortunately, these lenses were optically corrected for 35 mm format and lower camera magnifications than when used on the Ultraphot with its 1 meter bellows draw and 4 x 5 camera back. My personal camera equipment is based upon the Olympus Camera system. The Olympus Auto Bellows was a good candidate for use with the MegaPlus camera and the Zeiss Luminar lenses in the Case Materials Engineering Laboratory. I made an extension tube in my home machine shop to couple the Zeiss lens holders to one of my Olympus Auto Bellows and modified the camera mount from OM to Nikon F mount. The resulting bellows system is shown in Figure 3. A stereo microscope eyepiece in a holder adjusted to be parfocal with the camera is used to locate the field on the object for digital imaging with the camera mounted in place of the eyepiece holder. The maximum magnification of the 63 mm Luminar on this bellows is 5.2X, which is less than a factor of two of the optimum magnification of 3X for this lens. The theoretical resolution of this lens at 5.2X and f/4.5 is 280 lines/mm. The finest pattern resolved in a digital photomacrograph with this lens is 256 lines/mm (Group #8 and Element #1), see Figure 4. This is also the finest pattern resolved with the 1X objective of the Zeiss SV 11 stereo microscope using 25X Zeiss eyepieces.

The Olympus bellows was used for about a year when cracks were detected in the plastic dovetail inserts, see Figure 5. These plastic inserts were eliminated in my homemade heavy duty bellows shown in Figures 6 and 7. The rack and pinion focusing and auto aperture closing linkage of the original Olympus design

were eliminated in the heavy duty version. The female dovetail slides were machined from continuous cast zinc aluminum alloy ZA12 bar stock furnished by Zincoaloy Inc.⁴ This bearing alloy was very easily machined to high precision using high speed steel tool bits. The resulting bellows is much more rigid and very easy to use with the MegaPlus camera. No lubrication is used on the bellows rail, yet the movement is silky smooth. The lens and camera boards were machined from aluminum plate. These separate boards could be integrated into single piece castings of the ZA12 alloy for production quantities using low cost graphite molds. The f/2.8 38 mm Olympus Zuiko macro lens is capable of higher resolution than the f/4.5 63 mm Luminar lens, but with the disadvantage of shorter working distance. The fine focusing ring on the Olympus lens is an advantage. The Olympus lens resolved 287 lines/mm (Group #8 and Element #2) at f/4 and 323 lines/mm (Group #8 and Element #3) at f/2.8, see Figure 8. The corresponding theoretical resolution limits are 300 lines/mm and 430 lines/mm. This later value exceeds the resolution of the CCD array. Laboratories fortunate enough to own a Wild M400 Macroscope should be able to match the digital imaging performance of the bellows system. Other laboratories with limited capital budgets will hopefully find the information in this article helpful for maximizing the return on their investment in high resolution digital imaging.

References

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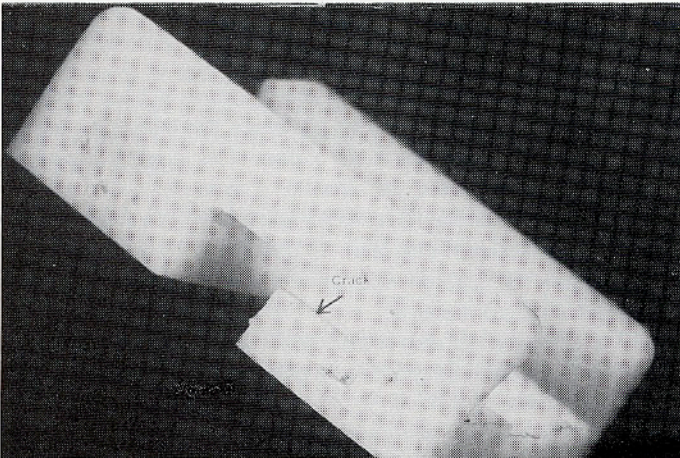


Figure 5

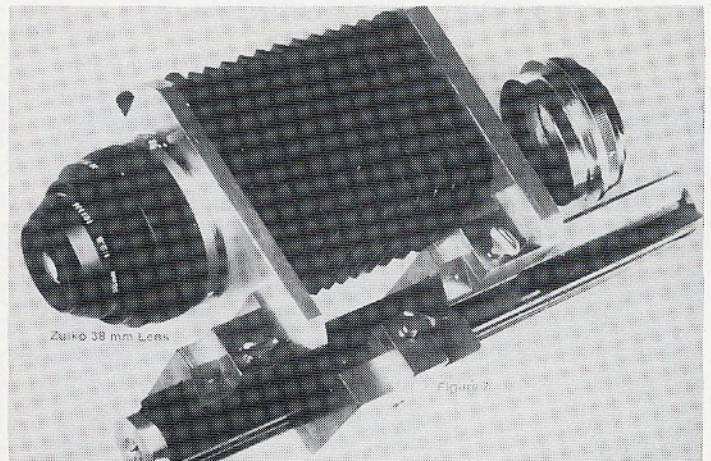


Figure 7

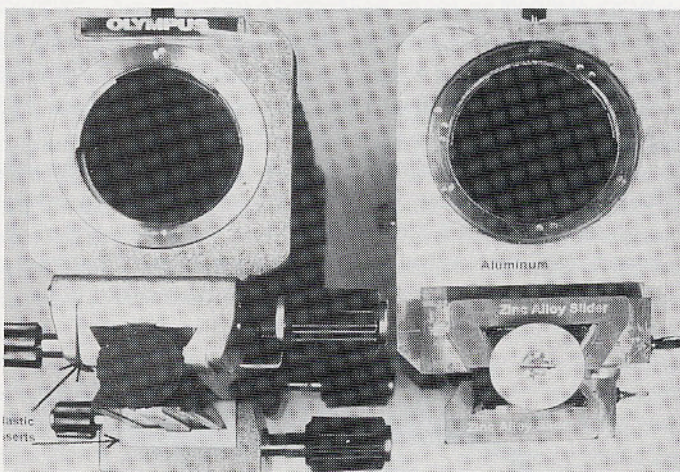


Figure 6

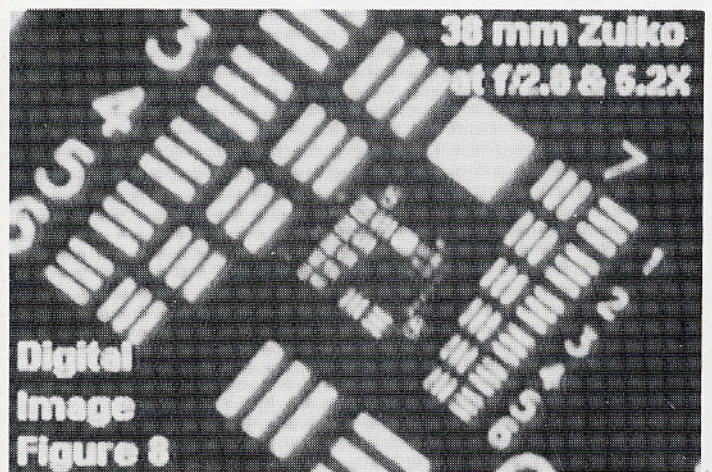


Figure 8