A thousandfold linear enlarging

If you look through a powerful microscope at developed film of ultrahigh resolution, then you will see so-called 'grain'. But this isn't really the silver grain, but only gaps between the developed crystals. These gaps form a 3 dimensional layer, and are also able to image with a certain depth the more-or-less acute light ray of the photolens, with its level of detail. If you look perpendicularly onto a developed layer which has been imaged at an angle, then you will see a certain overlap of the developed crystals, and the resolution will look worse than if you looked from the exact same angle of the original light ray. Until now, this theoretical view has never played any practical part with usual films in gaining the maximum resolution.

The following was made for getting a 1000x enlargement of a Gigabitfilm-negativ, photographed with a diffraktion limited lens 1:2.5 (State of the art, as of 1989):

First a special lens was made (a variation of the 'Homal'-method (1) for microprojection, using Dr. PAUL RUDOLPH's original hyperachromatic negative lens (2), the presuccessor of the famous Planar of today) to fit to a standard enlarger. The purpose being to enlarge an area of 16x21 cm by 100 fold, using a normal separation of 70 to 80 cm between the head of the enlarger and the baseboard with normal separation from the film to the rear node of the lens. A modification of the light source with a weaker diffuser of the enlarger was advantageous, for the achievement of normal exposure times. Without the diffuser, there were disturbing diffraction overlays due to imperfections, or fluctuations in the refractive index of the emulsion, as with a point source of light.

Test enlargements showed freedom from distortion, image field smoothing and even resolution without disturbing chromatic effects. A lens designer who had just computed a new range of optical systems for aerial photography said after seeing these images: *"If you had asked us to produce these quality parameters, it would have cost you plenty of money."* These enlargements produced with this 100 fold lens looked substantially better than with a conventional Apo enlarging lens. With conventional Apo lenses, a direct 100x could only be produced with difficulty in the laboratory, – this isn't really acceptable for the normal user; because who has access to a projection area of 5 metres to make such enlargements?

I was still not happy with the resolution of edge detail, even with the 100 fold enlargements using this special lens. I knew that by using "optical tricks" under the microscope, that I could get more detail from the negative. Thus I decided, after a vague clue from a publication of the 1930s (3), to do as complete as possible **an optical reconstruction** of the conditions surrounding the taking of the image, in order to obtain the maximum image quality in ray path retracing during enlargement.

The same lens (4) as used in taking the image was attached to the enlarger, the same aperture (1:2.5) was used, as well as the same position as on the camera. Of course the negative was mounted centrally, therefore everything was in exactly the same position as for taking the image. Since the taking lens used was one that can be corrected for every image ratio by using floating elements, only instead of a distance setting of 50m, only 2m was used for the enlargement. I considered this acceptable. A small format camera, minus lens, was installed at the image plane on a micro slide. The camera was also loaded with Gigabitfilm. The focussing region was stepped driven through in about 40 increments of a few hundredths of a millimetre each. The best looking positive, with a low gamma, was again copied at 20x linear onto a Gigabitfilm in 4 x 5 inch, again using a number of fine focussing steps. The finished negative served as the optimised negative for – all factors taken into consideration – the 1000 fold linear enlargement on normal photographic paper (with it's low resolution around 30 lp/mm). Here was the big surprise: This image showed more detail than I seemed to see under the microscope!

About this image quality (State of the art of Gigabitfilm progress in 1989 – today it's even bettter.) it should be remarked that losses during multiple copying added up, and **to further optimise the process – any condenser which is in use today presents some fundamental optical problems.** For new design of condensors or scanners for high resolution it could be important.

Literature

1. **KURT MICHEL**, ***Die Mikrophotographie***, Berlin 1962, Band X – Die wissenschaftliche und angewandte Photographie, page 227-229,

2. **MORITZ VON ROHR**, ***Theorie und Geschichte des Photographischen Objektivs***, Berlin 1899, p. 387 – 390; exemplares of D .R.P. 71473 in the focal length -58mm and -75mm in the threelens-version were used, later twolens-version cannot be used, even from other manufacturer.

3. **Dr. K. FISCHER, *Photographische Industrie – 1933***, p. 880, „Irrtümer um den Vergrößerungsapparat“ This article will give notes for further improvement to the optical specialist. *"Errors in enlarging apparatus".* Quote:...*you should be aware of how the greyscale of the negative is altered during enlargement, for example, after notes from Zeitschrift für wissenschaftliche Photographie 1933, 31, p 306, and Zeitschrift für wissenschaftliche Photographie 1933, 32, p 410 (Photometry of areas of similar density but differing grain size.) Because it can be seen that the differences in tone from the negative are not transferred proportionally into the positive, but are substantially modified, depending on the aperture and on the surface area of that density. Starting from a certain size, say 1cm square, they are translated accurately into the positive, however if there is a 1mm square dark area within a bright field, that will be much lighter. As can be seen from an example on page 309, fig. 5 for instance from an absorbtion of 96.3% using parallel light, to 60% with an aperture of 1:0.5. From this result, in passing, the requirement is to enlarge using the same relative aperture that was used for taking the image, as well as to position the enlarging lens over the same point of the negative as was used for taking the image. Only then will the enlarging optics not introduce any errors into the translation of the tonal range. If this deleterious effect isn't noticed in daily use, it's because the errors in the photographic emulsion (non-linear density curve) cause much larger deviations in the tonal range translation....*

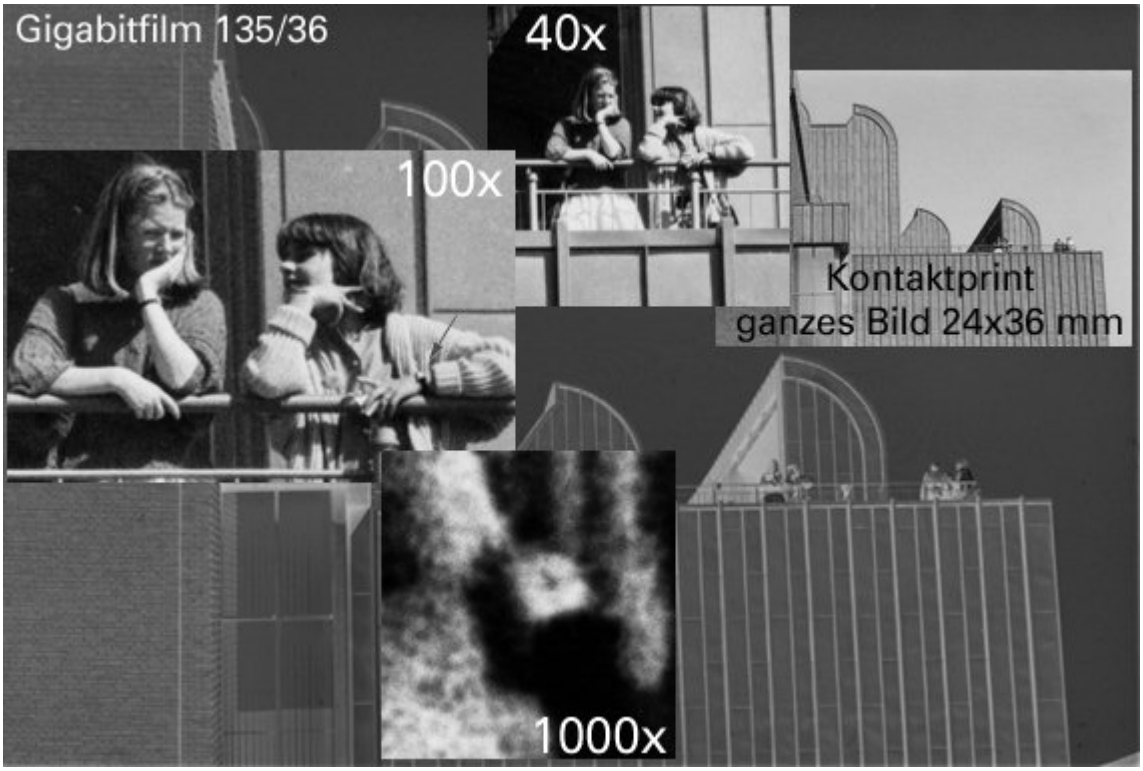
4. Selected by the maker Vivitar from only lenses which meet the design criteria, Vivitar Series 1 macro 90mm f/2.5, sold in Germany by a company "Satic" in Bochum, who produced diffraction limited lenses for dust counting analysers, and also imports used arial recognition lenses and other equipment used for astronomy. The picture with this lens was photographed with a Canon F1 body in Cologne around the Museum LUDWIG, for to get optimal results with a heavy tripod, with mirror locking up and with cable release. The Gigabitfilm used was 900 linepairs/mm/ ISO 25. Much later I mentioned under the microscope this interesting motive on the roof of the museum.

5. **MAURICE FRANCON**, ***Interferences, diffraction et polarisation***, Berlin 1956, p. 356, Tableau 12, in Handbuch der Physik, Band XXIV – Grundlagen der Optik (Fundamentals of optics).

	Éclairage cohérent	Éclairage incohérent	
	Microscope	Microscope	Lunette astronomique
Limite de séparation d'une mire de FOUCAULT	$z = \frac{\lambda}{2n \sin u}$	$z = \frac{1{,}03\,\lambda}{2n \sin u}$	$\theta = \frac{1{,}03\,\lambda}{D}$
Séparation de 2 points brillants sur fond noir	$z = \frac{1{,}63\,\lambda}{2n \sin u}$	$z = \frac{1{,}22\,\lambda}{2n \sin u}$	$\theta = \frac{1{,}22\,\lambda}{D}$
Limite de perception d'un disque noir sur fond blanc [1]	$z = \frac{0{,}06\,\lambda}{2n \sin u}$	$z = \frac{0{,}09\,\lambda}{2n \sin u}$	$\theta = \frac{0{,}09\,\lambda}{D}$
Limite de perception d'une ligne fine noire sur fond blanc	$z = \frac{0{,}01\,\lambda}{2n \sin u}$	$z = \frac{0{,}02\,\lambda}{2n \sin u}$	$\theta = \frac{0{,}02\,\lambda}{D}$

[1] z=rayon du disque.

Picture Example Gigabitfilm



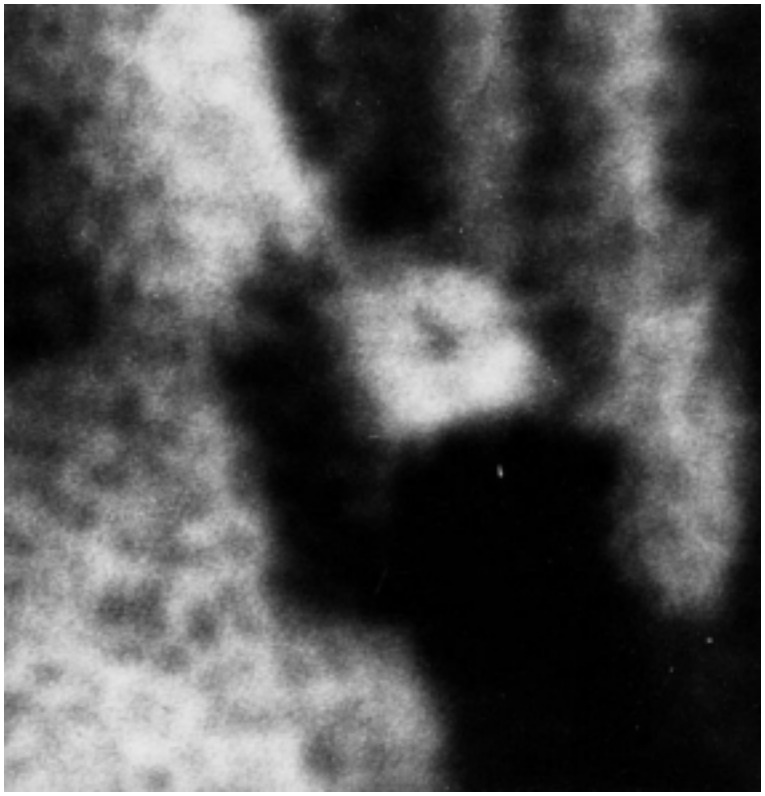
Please note:

A thousandfold linear enlarging from a 35mm format negative results in a print size of 24x36 **meters!**

The original photo[1] of the shown thousandfold detail is exactly 100mm long and 105mm high.

You can download this picture part as an uncompressed picture file (675 KB) from the area Information/Science/Optics.

Possibly with different digital picture optimization processes further details are visible. If you have experiences please contact us.



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1 This picture is identical to the original print!