The Zeiss Interference Microscope

by Fritz Schulze, Canada

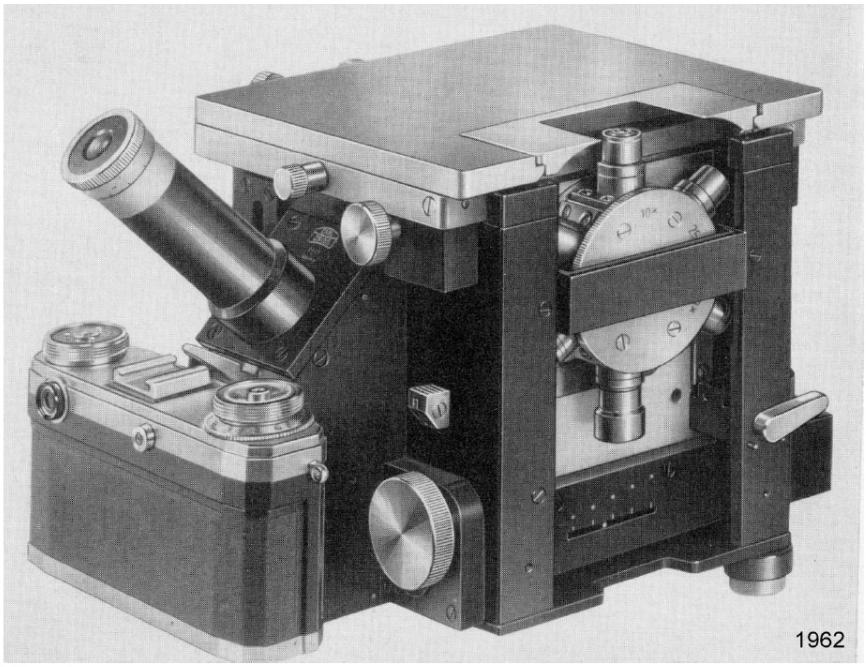


Fig.1

Interferometry, a subject which is difficult to condense into a few pages. I shall try nevertheless.

We all know that if two waves overlap and crest meets crest, the wave is intensified, if crest meets trough, the wave is cancelled.

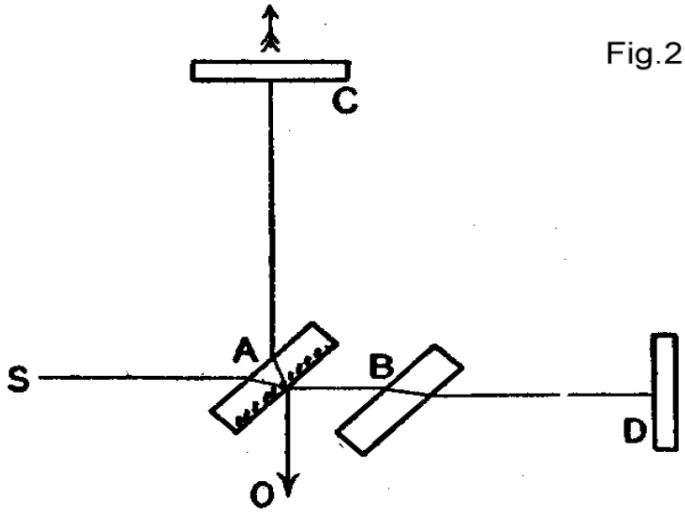


Fig.2

Schematic of the Michelson Interferometer

S = light source
A = semitransparent mirror
D = reference mirror
C = sample surface (test piece)
O = to observer
B = compensating plate (for thickness of mirror)

A light beam entering from S is split into two beams. One passes through the mirror to be reflected by D and then in turn reflected to O. The second is reflected by the mirror to C whence it is reflected back through the mirror also to O. Here both beams interfere. If the superimposed images in O are parallel, the resulting "image" will be either white if their distance is one or a multiple of their wavelength, or black if their distance is half or a multiple of their half wavelength. If now one image is tilted, for example by mirror D being at a slight angle, parallel interference lines will appear. These lines are ½ wavelength apart, irrespective of their apparent distance from each other.

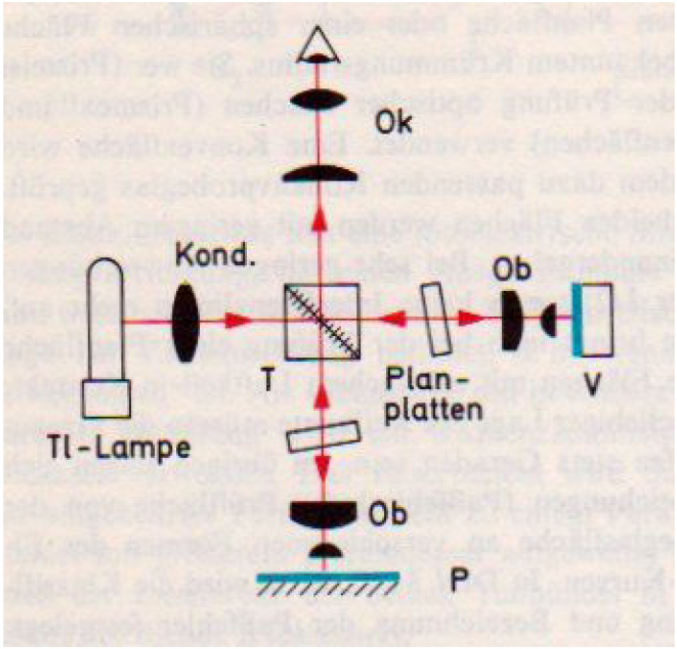


Fig.3

A schematic of the interference microscope:
Tl = light source (Thallium lamp) λ = 0.54µm
Kond = condensor
T = semitransparent mirror (prism)
Ob = two objectives
V = reference mirror
P = object to be tested
Planplatten = plane-parallel plates for internal fine correction

The two objectives must be absolutely identical. The effect is similar to the one described above. In the case of the Interference Microscope it is the object on the gimballed stage that can be tilted to obtain the desired interference image i.e. widen or narrow the space between the fringes.
Interference is optimal if the intensities of the interfering light beams are the same or at least very close. To this end reference mirrors of different reflectivity can be slipped on the corresponding objective.

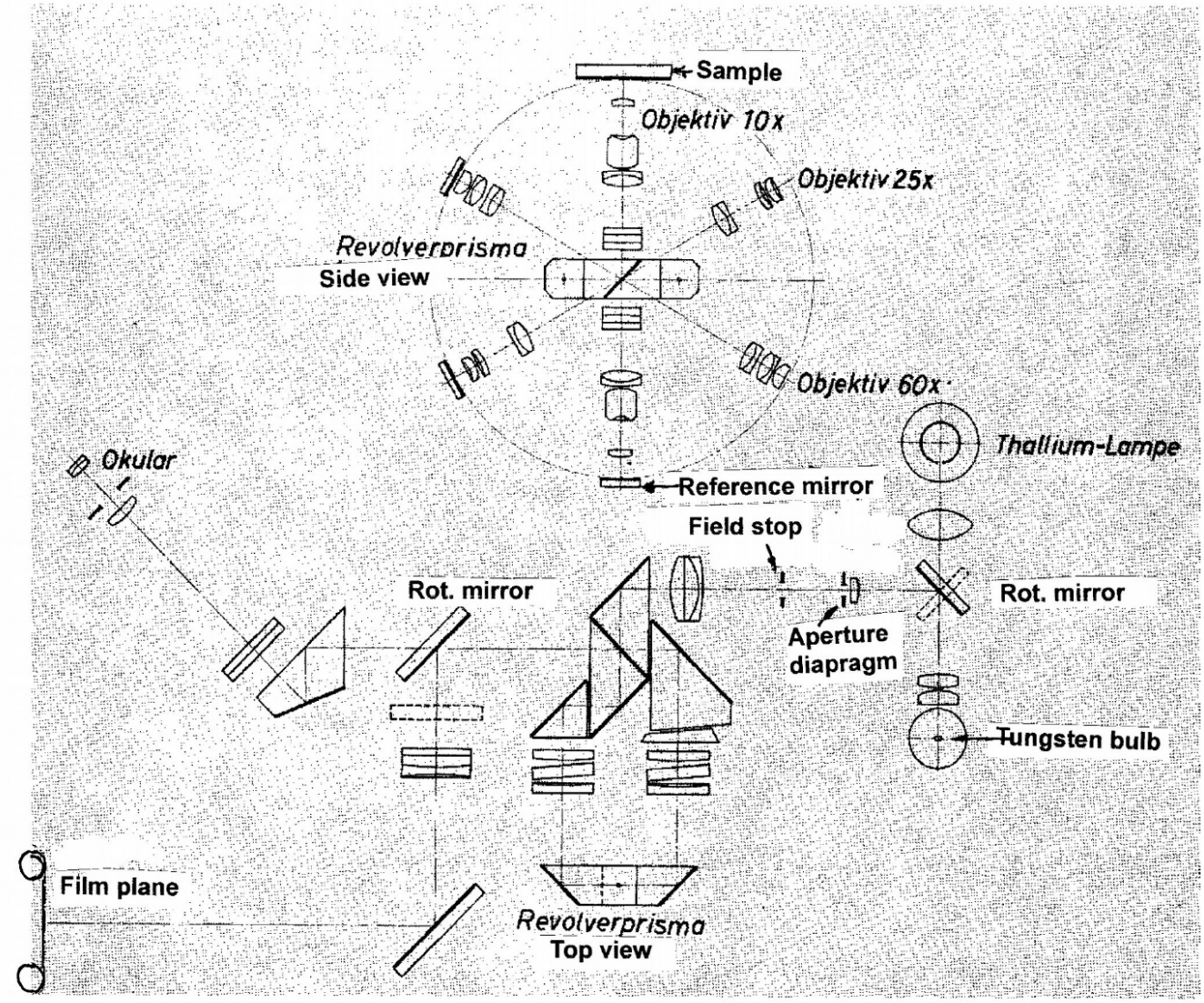
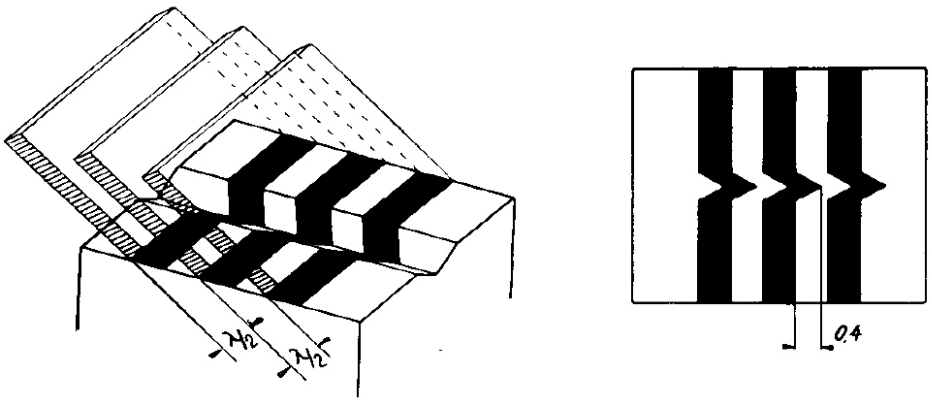


Fig.4
A more detailed schematic of the Interference Microscope: Top = revolver with the objectives. bottom: the illumination and observation system up to the central revolverprism. All this intricate optical arrangement had to be squeezed into a cube approx. 20cm side length (see Fig. 1).

Fig.5



Interference fringes as they occur on a sample surface and as it looks in the eyepiece.. The pattern of the fringes in this case indicate a groove of 0.4λ = 0.21µm (Thallium λ = 0.54µm

The Zeiss Interference Microscope was designed as a compact and ergonomic instrument in a small solid body required for the necessary stability. The light source is a Thallium lamp providing green light of the wavelength λ = 0.54µm. The three paired objectives 10x, 25x, and 60x result in magnifications of 80, 200, and 480x respectively and cover a sample area of 0.28 - 1.85mm. The reference mirror is slipped over the lower objective. The measuring range (depth) is 0.03 - to 2µm. The stage which carries the objects to be examined can be tilted in two axes which enables the user to arrange the interference fringes as required for the orientation of the manufacturing marks. Widening the fringes increases the accuracy of the measurement.

Here some practical examples:

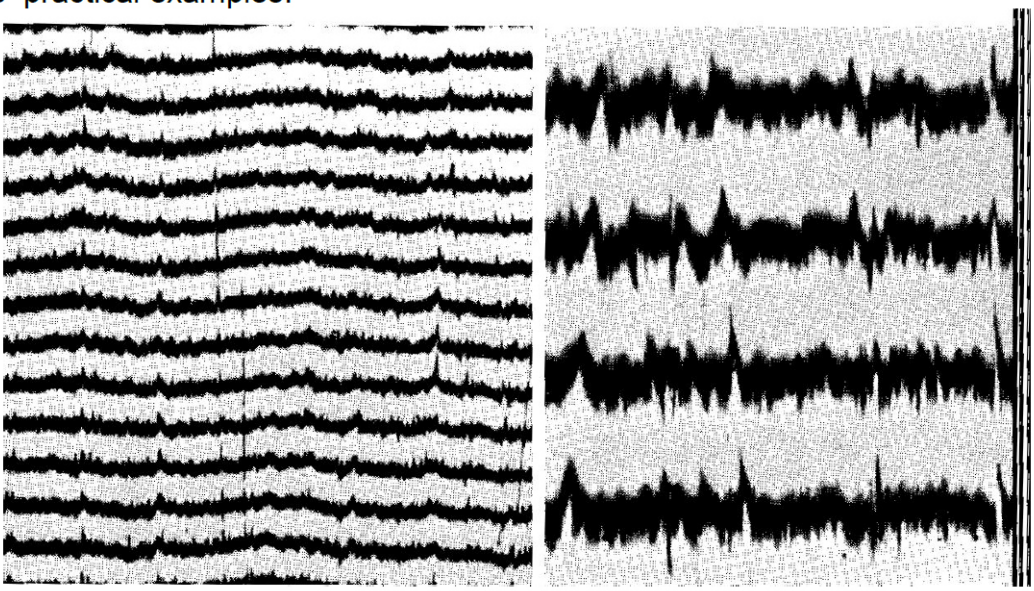


Fig. 6

Left: ground steel surface, objective 10x. Each peak represents the scratch of a grinding grain. Average value of the roughness is 0.2 width of a fringe = 0.2 x 0.27 µm (λ/2 =Thallium) = 0.054µm.
Right: the same speciment, this time with the objective 60x

Notice that the interference pattern also shows the overall flatness of the object.

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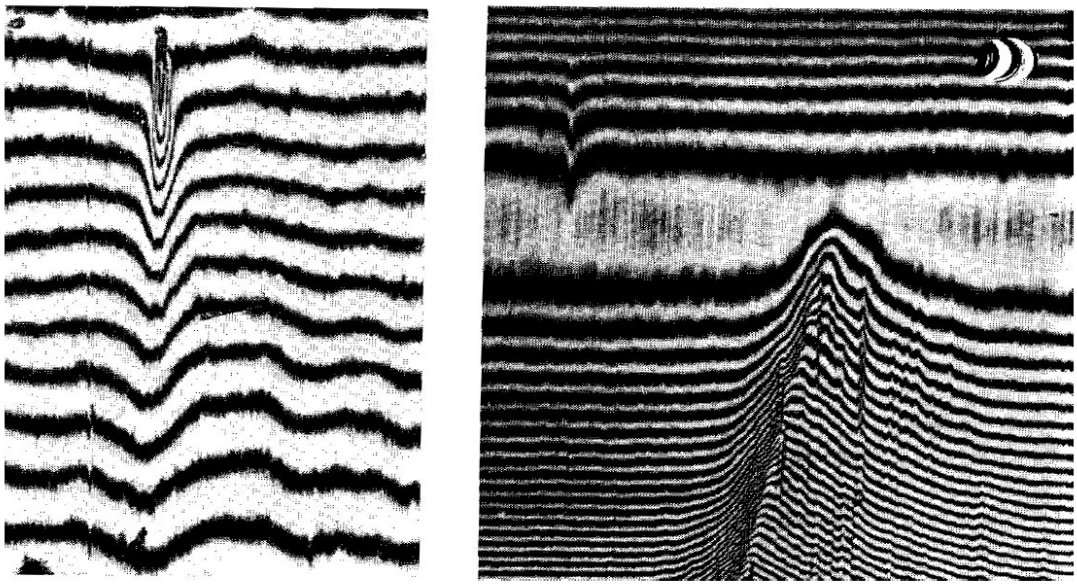

Fig.7

Left: a polished aluminum mirror, objective 25x. Average roughness R = 1/10 width of a fringe = 0.027µm, but one large scratch increases from bottom to top, from 0.3µm to >1µm.

Right: a deep scratch in a polished cylindrical aluminum surface, objective 25x.

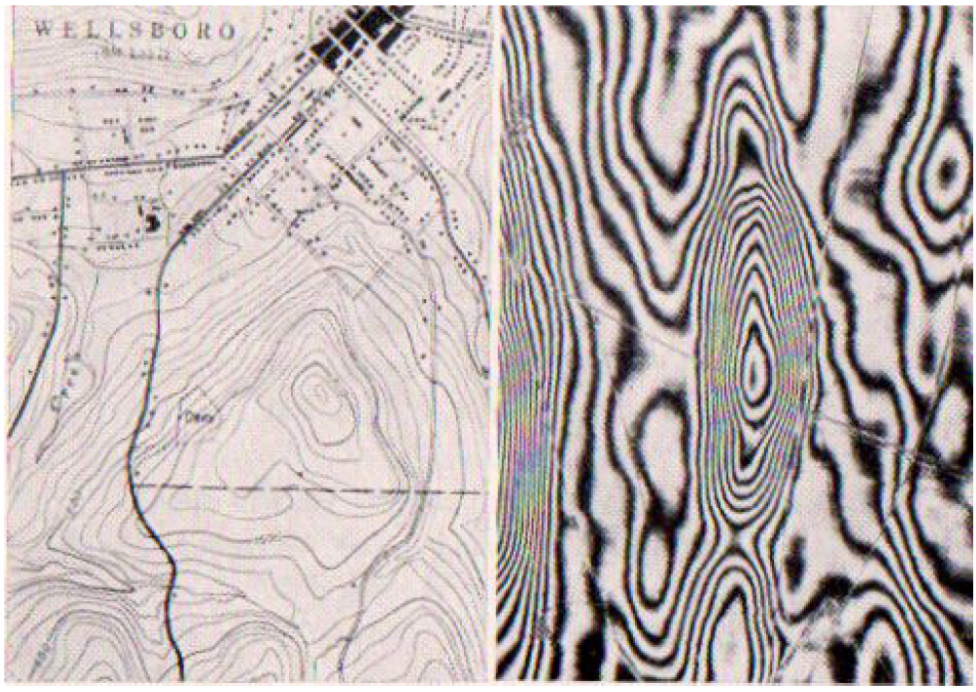

Fig. 8

Comparison of an uneven surface with a topographical map. Here the interference fringes appear like the contour lines of the map and render an accurate impression of the quality of the surface, an advantage of the interference microscope versus unidirectional systems, such as the Zeiss Light Section Microscope (See Micscape .Issue 321, Dec.2022).

Objects with depth difference beyond the normal range can, nevertheless, be examined with **white** light (switch from the Thallium lamp to a tungsten bulb). White light interference results in coloured fringes where the maximum zero order is a white line bordered on both sides with a black line which makes it easy to detect and follow in a maze of fringes otherwise indistinguishable in monochromatic light.

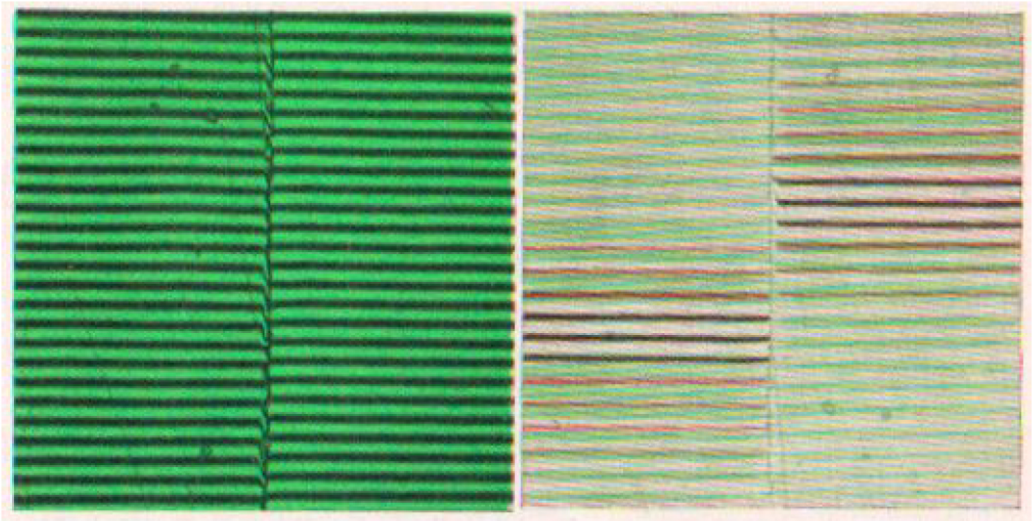

Fig. 8

Measuring the thickness of a transparent lacquer layer on glass. Left in monochromatic light: the fringes of the lower and upper surface cannot be distinguished. In white light (right) the displacement is clearly visible: 7 fringes x 0.27 = 1.9µ thickness.

Confronted with concave surfaces the user can employ the lacquer replica method, where a thin layer of lacquer is applied and then lifted off my means of a hardening plasticine-like substance. The replica can then be examined in lieu of the original.

It is often desirable to obtain a permanent record of the tested surface. To this purpose a 35mm camera body can be attached to an outlet at the front of the microscope. The crossshairs in the eyepiece define also the film plane. If both crosshairs and interference image are in focus, the photograph will be sharp. The photograph can then be enlarged and the fringes more precisely measured.

Reference: This article is based on a publication in Zeiss Werkzeitschrift 30/1958 by Martin Uhlig
Fig.3 credit: Gottfried Schröder “Technische Optik” Vogel Verlag 1980
All other illustrations :by Carl Zeiss Oberkochen.

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Published in the January 2023 issue of *Micscape* magazine.

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