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ERNST LEITZ GMBH WETZLAR
GERMANY

Subsidiary: Ernst Leitz (Canada) Ltd., Midland, Ontario

List 560-20/Engl. Printed in Germany VII/68/FX/SD

Leitz

Multibeam Interference Attachment

for Incident Light

Instructions

Leitz WETZLAR

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Multibeam Interference Attachment for Incident Light

		Page
	Introduction	2
1	Outfit	4
2	Sodium vapour lamp	5
3	Multibeam head with plane reference mirror	6
4	Basic interferometer unit	7
5	Setting the multibeam interferences	8
6	Sign determinations (elevations or depressions)	9
7	The measurement	10
8	Correction factors	11
9	General suggestions	12

Introduction

The narrow and sharp multibeam interferences allow **more accurate direct measurements of fringe displacements** and therefore of differences in level than the wider and more blurred two-beam interference fringes.

The special advantage of multibeam interference consists in the measurement of very small fringe displacements, i. e. very small differences in level. The measurement of fringe displacements exceeding one fringe width (level difference in air $> \frac{\lambda}{2}$) is, however, also possible, provided the path of the displaced fringe can be clearly recognized.

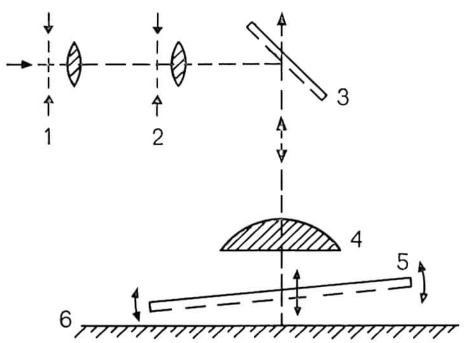
The basic arrangement of the system of multibeam interference phenomenon is the "real wedge" (see Fig. 1).

According to Fig. 2 rays entering the real wedge and reflected by the surface of the sample can interfere with the rays reflected by the reference surface. To be able to interfere the rays must meet the condition of coherence, which is given by light sources of short coherence length such as the low-voltage lamp only with very short distances between sample- and reference surface. If the reflectance of sample and reference surface is poor, it results in practically **two-beam interferences** with an approximately sinusoidal intensity curve between the interference minima and -maxima. As the reflectance of sample- and reference surfaces increases the interference fringes become progressively narrower and sharper owing to the inceasing proportion of rays reflected several to many times in the interference.

Fig. 1

Beam path in the incident-light microscope with "real wedge" as interference arrangement.

1 Aperture diaphragm
2 Field diaphragm
3 Semi-transparent deflecting plate in the opak illuminator
4 Objective
5 Tilting and vertically adjustable reference mirror (reference plate)
6 Surface of sample



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These interferences are therefore called **multiple or multibeam interferences** (Tolansky*). Besides high reflectance the following conditions must be met for the production of perfect and sharp multibeam interferences:

1) Long coherence lengths of the interfering light rays (phase differences of up to a multiple of the wave length after multiple reflection), i. e. strongly monochromatic light or mixed light of a few strongly monochromatic, widely separated spectral lines

2) Light, ideally parallel as well as perpendicular to the sample surface

3) Maximum distance between reference and sample surfaces only a few light wave lengths, i. e. with a reference surface slightly inclined to the sample surface the surface structure to be examined should be as close as possible to the point of mechanical contact between the two surfaces

*) TOLANSKY, S.: Multi-beam interferometry of surfaces and films, Oxford 1948
TOLANSKY, S.: Surface microphotography, London 1960

Naturally, the maintenance of these optimum conditions becomes less and less critical as reflectance decreases. The following equipment is necessary and the following operations must be carried out to maintain these conditions:

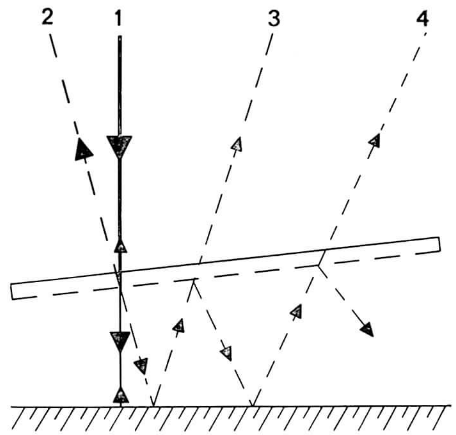
1) Spectral lamps (gas discharge lamps of not too high pressure), of intense emission lines of wider separation in the visible region (e. g. sodium or mercury lamp)

2) Reducing the condenser aperture by closing the aperture diaphragm

3) Controlled lowering of the reference surface until mechanical contact with the sample surface, controlled tilting of the reference surfaces, which for matching with the shape of the sample surface and possible displacement of the contact zone into the image field of the object has different shapes (plane, spherical, cylindrical) in addition to various reflectances.
The sample surface to be examined should have the highest possible reflectance; if this is not an inherent property, it can be obtained by evaporation with appropriate metals. This is advisable also when different components of different rapid phase change of the reflected light waves are present in the structure to be measured.

Fig. 2

Multibeam interferences by multiple reflection in the real wedge (after TOLANSKY)



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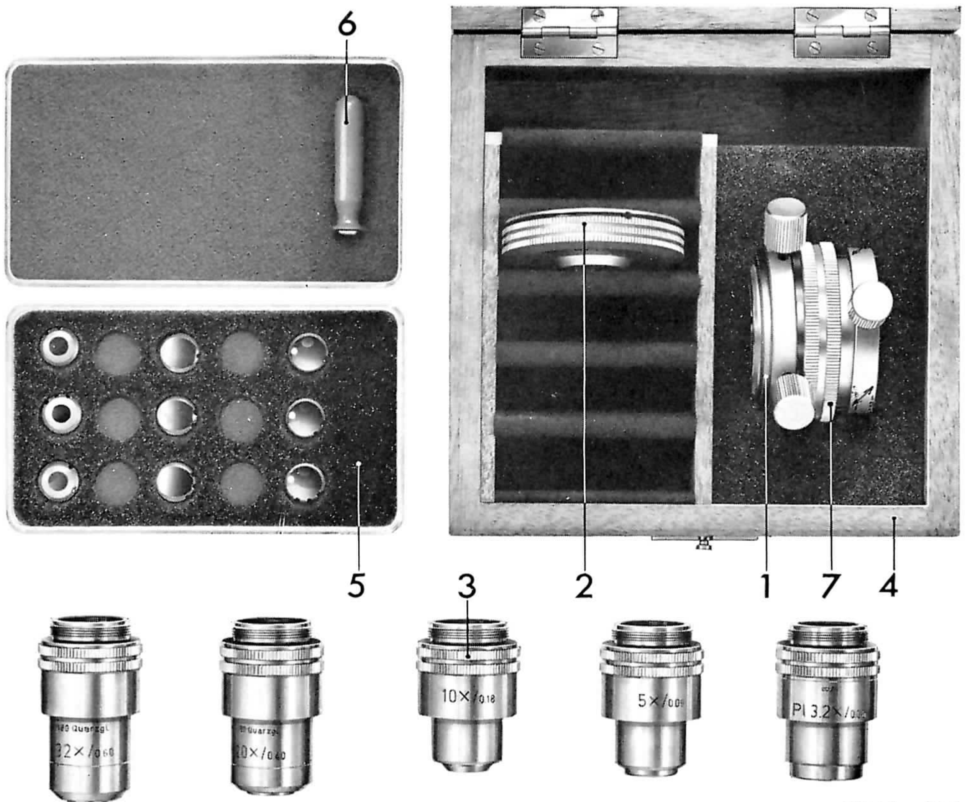
1 Outfit

The LEITZ Multibeam Interference Attachment (Fig. 3) consists of

1) Basic unit with knurled ring for vertical adjustment
2) Multibeam head
3) 3 objectives of the user's choice
   Pl 3.2 x/0.06
   5 x/0.09
   10 x/0.18
   H 20 x/0.40
   H 32 x/0.60
4) Storage case
5) Case for the reference mirrors
6) Suction device for transferring the reference mirrors into the multibeam head

Fig. 3



2 Sodium vapour lamp

1) The sodium vapour lamp instead of the standard low voltage lamp is mounted on the stand:

a) **METALLUX®/ORTHOLUX®**

Aperture for low-voltage lamp in the stand
Adapter, 30mm diameter
Sodium lamp

b) **PANPHOT®**

Thread for low-voltage lamp in stand
Adapter (514 246)
Sodium lamp

2) Switch on mains unit (position 1). If the lamp does not ignite on its own, press ignition button. The lamp requires about 2 minutes for reaching its full light intensity.

3) The high monochromasia of the sodium light may cause a weak interference fringe system, running horizontally through the field of view, especially during the heating-up period, owing to residual reflections on the beam splitter of the illuminator. This stationary system of fringes is of no significance in the multibeam interference measurement.

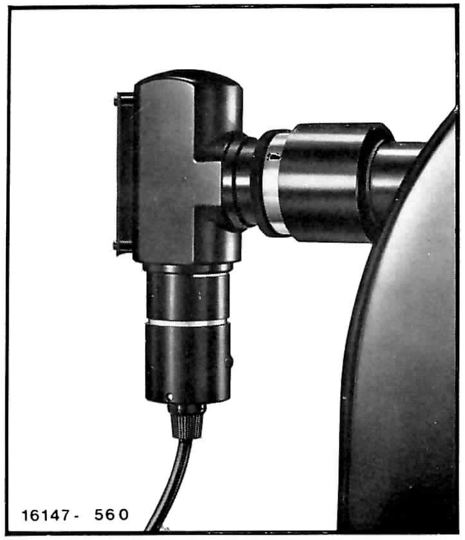


Fig. 4

Close-up of the ORTHOLUX with sodium vapour lamp

Fig. 5

Close-up of ring adapter and sodium vapour lamp on the PANPHOT

3 Multibeam head with reference mirror

1) Open the holding device (3 leaf springs) for the reference mirror by means of lever (7-3) on the outside of the attachment

2) During this manipulation hold the attachment so that the appropriate reference mirror can be inserted in the free central opening of the head with the aid of the small suction device (3-6). Proceed carefully to avoid damage to the surface coating of the mirror.

3) After insertion of the reference mirror close the holding device by means of lever (7-3).

4) Attach multibeam head with reference mirror to the basic unit (3-1) as shown in Fig. 7. Make sure that the multibeam attachment is securely engaged on the basic unit.

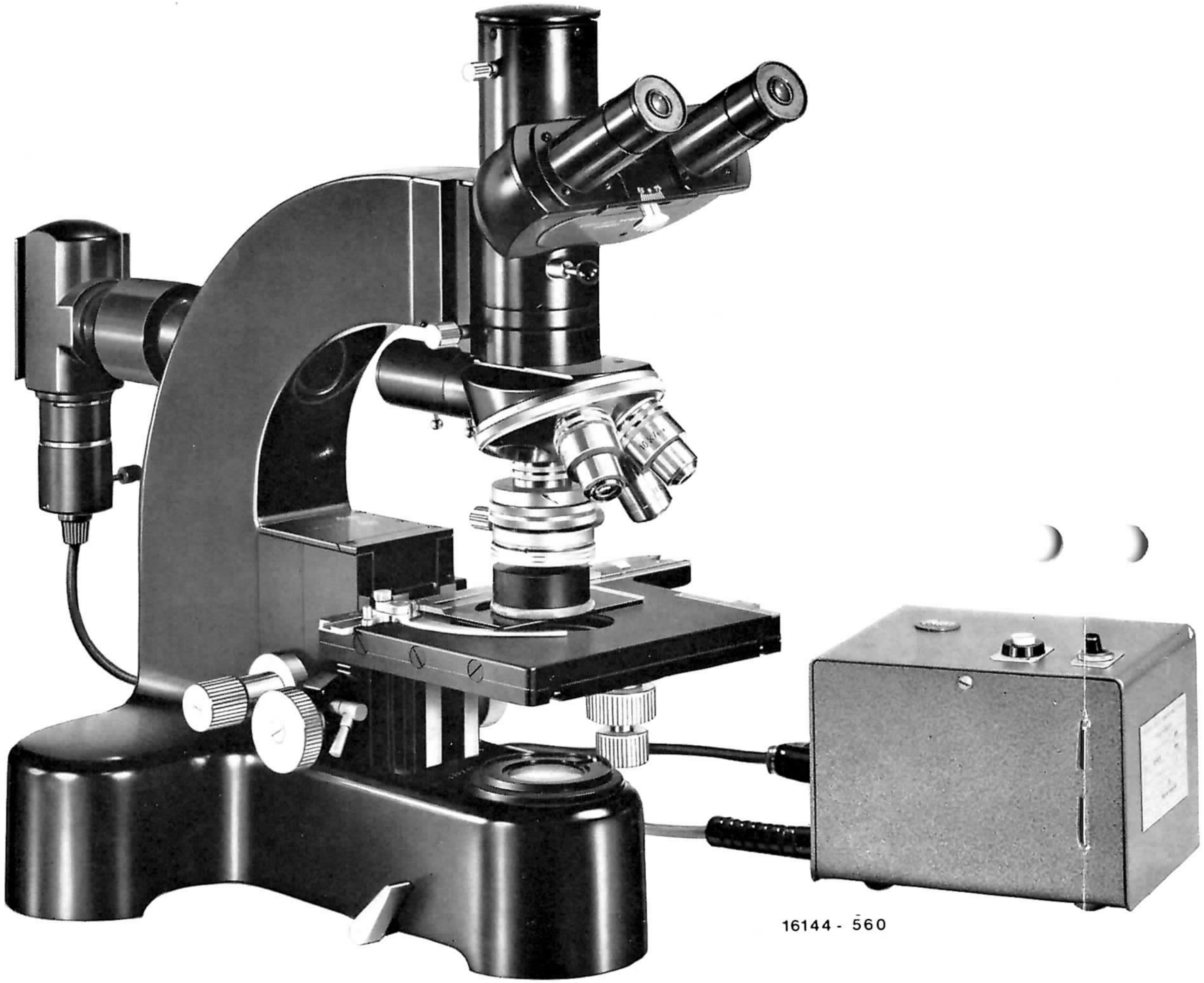


Fig. 6

ORTHOLUX with multibeam interference attachment in position. The Pl 3.2 x/0.06 objective has been omitted to permit an unobstructed view.

4 Basic interferometer unit

1) Hold the unit **as shown in Fig. 7.** Rotate the ring (3-7). This raises and lowers the multibeam head (3-2) with the reference mirrors (cf. 3-5).

2) Align the lower part of the unit by means of the two knurled screws (7-1) so that it will be approximately parallel to the knurled ring (3-7).

3) Lower the microscope stage.

4) Push the aligned basic unit **to the stop over the objective** used and clamp it firmly with the fixing screw (7-2), so that the two centring screws (7-1) point to the front and the fixing screw (7-2) points to the rear.

5) Rotate the knurled ring (3-7) in ascending direction of the arrow and set it at the top position.

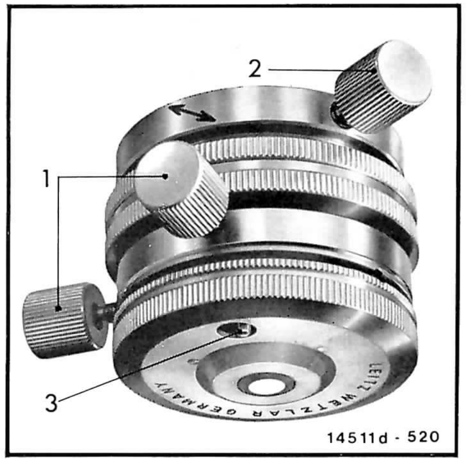


Fig. 7

Multibeam interference attachment with reference mirror

1 Knurled screws for adjusting the basic unit

2 Fixing screw

3 Lever for actuating the three leaf springs

5 Setting the multibeam interferences

1) Align the sample (e. g. a metal section) carefully on a metal object slide (hand press) and place it on the microscope stage.

2) Carefully raise the object stage and focus the sample. Recognition of the object surface will become difficult when the reference mirrors of high reflectance are used. To find the object plane, close the field diaphragm of the opak illuminator and focus it sharply.
The field diaphragm is now opened (the iris must just disappear beyond the edge of the field of view) and the sample moved slightly to and fro; its surface or structure can now be focused by means of the fine adjustment.

3) Close the aperture diaphragm of the opak illuminator and move the reference mirror slowly to within about 0.3mm of the sample surface by means of the knurled ring (3-7) of the basic unit. (Horizontal observation of the light slit between the surface of the mirror and that of the sample).

4) While continuously observing the sample lower the reference mirror further by means of the knurled ring. Interrupt the operation as soon as interference fringes become visible. Align the interference fringes by means of the two knurled screws (7-1) vertically to the structures (scratches, etc.) to be measured. Set the width of the fringes by the same method.

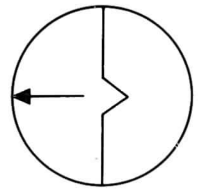
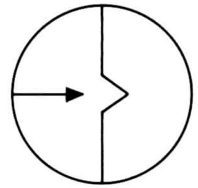
ATTENTION: DURING THIS PROCEDURE THE REFERENCE MIRROR MUST NOT YET COME INTO CONTACT WITH THE SAMPLE SURFACE.

5) Carefully observing the field of view in the microscope, gently lower the reference mirror until contact with the sample surface. This is recognized by the fact that the interference fringes aligned according to 4) no longer run uniformly through the field of view; their orientation and mutual distance suddenly change. Turn reference mirror slightly back from this position until the fringes just begin to run uniformly through the field of view again. It must be pointed out once more that really sharp multibeam interferences can be expected only if the reflectance of the reference mirror and sample is high. If the reflectance of the surface to be tested is low, it is advisable to use also a reference mirror of the lowest reflectance, e. g. 4%.

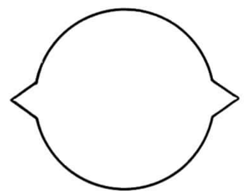
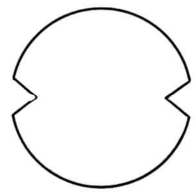
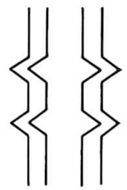
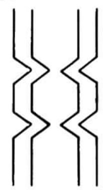
6 Sign determination

(elevations or depressions)

Whether a vertical difference represents an elevation or a depression can be determined as follows:

Situation		Sign	
Reference mirror	Object	Elevation	Depression
Plane	Plane	slight finger pressure on the object stage; interferences move against fringe deviation 	slight finger pressure on the object stage; interferences move with fringe deviation  26170-560

With the following sample/reference mirror combinations the sign can also be determined subsequently on the interferogram:

Situation		Sign	
Reference mirror	Object	Elevation	Depression
Plane spherical spherical	spherical plane concave	fringe deviation away from the vertex of the surface 	fringe deviation towards the vertex of the surface  26171-560
plane cylindrical cylindrical ridge-shaped	cylindrical plane cylindrical-concave plane	fringe deviation away from the vertex of the surface 	fringe deviation towards the vertex of the surface  26172-560

Note: Wrong signs can result from structures which are outside the microscopic depth of field (out of focus) or laterally unresolved.

7 The measurement

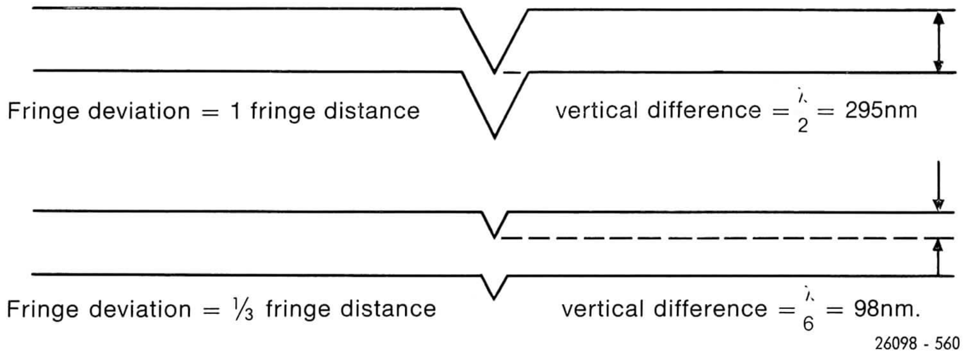


Fig. 8

Interference fringe deviation and measurement of vertical differences (diagrammatic).

The distance between two neighbouring interference fringes corresponds in incident ligth to a vertical difference of half a wave length ($\lambda/2$). A fringe deviation of, e. g. 1 fringe distance (see Fig. 8) at a wave length of 589nm (sodium vapour lamp) therefore indicates a vertical difference of 295nm = 0.295μm.

The measurement of the fringe deviation and thus of the vertical difference of the fringe-displacing structure (see Fig. 8) can be carried out by

a) direct estimation or with the aid of the screw micrometer eyepiece, and

b) by means of a photomicrograph. In order to obtain the highest possible accuracy evaluation is recommended with the aid of a photomicrograph (cf. section 9). In extremely favourable conditions (very high reflectance, strong monochromasia, etc. see above) fringe deviations as small as 1/200 of the fringe distance, i. e. $\frac{1}{400}\lambda$ can still be measured.

In air $d = \frac{m \cdot \lambda}{2}$

where d = vertical difference (μm)
m = relative fringe deviation in fringe widths
λ = wave length (in μm)

Microdensitometers can also be used for the precise evaluation of photographic plates.

8 Correction factors

a) For the use of spherical or cylindrical reference mirrors and/or samples with determination of the fractions m of the fringe deviations on spherical and cylindrical surfaces: Instead of the values L calculated according to Fig. 9

$$m = \frac{4L(A_2 - L')}{A_2^2 - A_1^2}$$

(L, A_1, A_2 are arbitrary units) must be inserted in

$$d = \frac{m \cdot \lambda}{2n_1}$$

where n_1 = refractive index of the embedding medium, air, immersion fluid).

The advantage of spherical or cylindrical reference mirrors with plane sample surfaces consists mainly in the fact that the support points or -zone and therefore also the interferences of the first orders, which are immediately adjacent to the contact zone and particularly favourable for the measurement, are situated in the centre of the image.
It is therefore essential to bring the structure to be measured into the centre of the object field of which an image is formed; in addition the increase of the fringe distance towards the centre of the image permits a more accurate measurement of the fringe deviation;

b) with the (effective) aperture sin α,

$$d = p\,\frac{m \cdot \lambda}{2n_1} \quad \text{where } p = \frac{2}{1 + \cos\alpha} > 1;$$

c) with oblique illumination; if the test surface diverges from the perpendicular to the microscope axis by the tilting angle φ

$$d = g\,\frac{m \cdot \lambda}{2n_1} \quad \text{where } g = \frac{1}{\cos\varphi}$$

d) when the wave length is changed from λ_1 to λ_2

$$m_2 = \frac{m_1 \cdot \lambda_1}{\lambda_2},$$

i. e. at a vertical difference d the fringe deviation decreases as the wave length increases;

e) with indirect vertical-difference determinations on replica films (refractive index n_F) on plane mirrors

$$d = \frac{m \cdot \lambda}{2(n_F - n_1)}$$

(n_1 = refractive index of the embedding medium, e. g. n_{air} = 1.00, n_{H_2O} = 1.33)

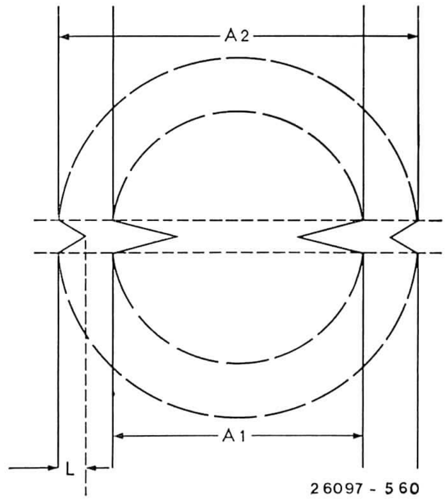


Fig. 9

9 General suggestions

The **reference mirrors** are best **cleaned** with an 1:1 alcohol-ether mixture, and a clean, soft rag.

The multibeam interference attachment can be used on existing objectives of the types mentioned under 1 only within limitations since a perfect fit of the interference attachment on the objective is essential.

The new objectives supplied with the interference attachment have an adapter sleeve. It **may** be possible to fit existing objectives with adapter sleeves, if the objects are returned to our factory or their date of delivery is stated on the order.

It has already been pointed out that evaluation of the **interference patterns on a photomicrograph** is recommended particularly if high accuracy is essential, i. e. if the information content of the fringe pattern is to be fully utilized. This applies especially when sharp multibeam interferences are not obtained (more or less close approximation to the sinusoidal intensity distribution of the two-beam interferences); because the positioning of the vertical crossline of the screw micrometer eyepiece on the median line of the fringes will then be subject to considerably larger errors.

By the use of very contrasty photographic paper (very steep graduation) for the copying or enlarging of the negatives it will be possible to obtain very steep density gradients and therefore relatively sharply outlined interference fringes on the prints, which permit a much more accurate and reproducible measurement of the fringe deviation. If necessary, successive copying will improve results.

The **equidensite method***, too, must be mentioned. It can be realized with simple photographic means: very narrow equidensites (1st order) replace the wide density flanks on both sides of the interference fringes; they almost invariably reveal further details of the fringe pattern, which previously were hidden in the wide density flanks of the interference fringe, in addition to allowing a more accurate measurement of the fringe deviation. The SABATTIER method consisting of the diffuse uniform second exposure of a partly developed copy of the negative on a plate or film is recommended for the production of equidensites.

As it is important that the lines are as sharp and fine as possible, very fine-grain photographic material (e. g. KB 14) must be used. In order to obtain an original sufficiently rich in contrast it may be necessary to make a hard second negative of which a positive is produced as follows:

Set the LEITZ Focomat at enlargement 4 x, stop down enlarging lens to f/16. Place a dish with fresh, unstained paper developer (e. g. Neutol S working solution) on the masking frame.

Insert the negative and unexposed lantern plate in a slide copier, expose, and develop in the paper developer (see above) for 1 min.

Expose the positive in the developer for a second time in the Focomat for 1–2 sec., and continue development for approximately another 2 min. Stop bath and fixing as usual.

* E. LAU u. W. KRUG: Äquidensitometrie. Akademie-Verlag, Berlin 1957.

In the interest of reasonably short exposure times the use of **high-speed** emulsions (particularly sensitive to 589nm wave length) is recommended for the production of photomicrographic negatives with the above-described equipment for multibeam interference with sodium vapour lamp. We obtained satisfactory results e. g. with Ilford HP 3 and Kodak Tri X films.

For the same reason the use of **35mm attachment cameras*** is to be preferred to larger-format ones.

* LEITZ micro-attachment with vibration damper for the LEICA® and ORTHOMAT® fully automatic attachment camera.

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