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Correlation between the Perturbing Term and the Higher Order Wave Aberrations

In the present paper a correlation of the perturbing term and the higher order wave aberrations of sagittal focus is examined. This correlation is analyzed in a number of systems of essentially different types. Also, the influence of changing the design parameters upon this correlation is investigated.

In the present paper a correlation of the perturbing term and the higher order wave aberrations of sagittal focus is examined. This correlation is analyzed in a number of systems of essentially different types. Also the influence of changing the design parameters upon this correlation is investigated. An obvious economy requirement concerning the method of lens design is that they should be based on simple relations enabling to calculate optical systems, which would satisfy, at least approximately, the specified working conditions. Unfortunately, the majority of relations is very complex so that only their first order approximations (aberrations of first order according to Buchdahl notation, or of third order in earlier notation) are of practical importance. A further progress in the development of optical systems is inevitably connected with the development of the design methods.

The third order aberration analysis is still a decisive factor in the case of simple systems for establishing the system type and selecting the proper glasses. Unfortunately, for more complex optical systems the third order aberrations are too rough. There exist a number of approximate analysis methods for higher order aberrations [1]. One of the most general methods, being simultaneously the most systematic and employing the simplest notation, is that given by BUCHDAHL [2]. It renders possible to calculate the higher order aberrations for any optical system. However, the relations involved are still complex the more the higher orders are taken into account. The complexity of relations between the aberrations of various orders is so great that it is impossible to estimate the higher order aberrations by examimning the lowei orders.

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A slightly different approach has been proposed by one of the authors in papers [3,4]. In these papers relatively simple properties of wave aberrations for sagittal focus have been exploited, which have a particularly simple representation when expressed in terms of H.H. Hopkins variables.

Let us consider an astigmatic beam behind the k-th surface of the optical system. Let S_k denote a sagittal focus of the beam and E_k be a coordinate of the exit pupil centre in the space behind the k-th surface. The remaining notation is shown in Fig. 1,

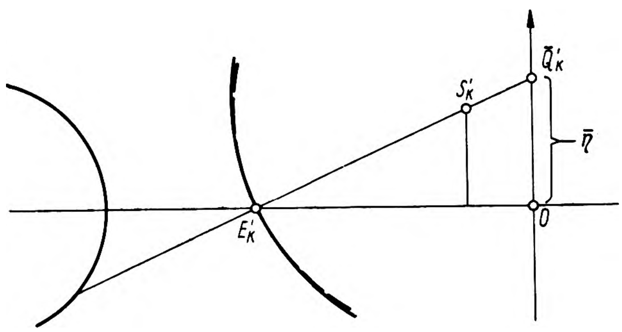


Fig. 1. Astigmatic beam behind the k-th surface

in which the k-th surface is marked as well as two spheres of centres located respectively at the points S_k and Q_k, which correspond to wave surface for an infinitesimally thin beam. The distance between the two wave surfaces measured along the given ray of the astigmatic beam is measure of the sagittal focus wave aberration. This distance for the beam under study may be expressed as a difference of rises of are of both wave surfaces multiplied by the respective index of refraction

$$(W_s)_k = \frac{1}{2}(h_s^2)_k \frac{n_k^{'}}{(\bar{R}_s^{'})_k} - \frac{1}{2}(h_s^2)_k \frac{n_k^{'}}{(\bar{R}^{'})_k}, \qquad (1)$$

where

$n_k^{\prime}$ — refractive index in the space behind the k-th surface,

h_s — normalized paraxial height of the sagittal ray of the astigmatic beam,

$R_s^{\prime}$ — distance from the exit pupil centre to the image sagittal focus,

$\bar{R}_k^{\prime}$ — distance from the exit pupil centre to the intersection point of the central ray and the Guassian plane.

The manner of normalizing of h_s needs some explanation (see Fig. 2). Paraxial angles and heights

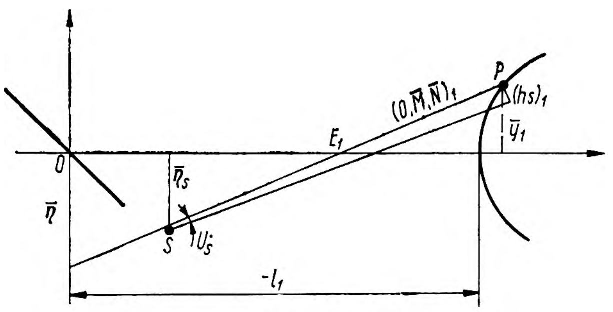


Fig. 2. Paraxial sagittal height of incidence h_s

are not uniquely defined but depend on the normalizing conditions. Only the ratios of heights or angles as well as the ratios of heights to the respective angles have physical meaning. In routine paraxial calculations it is the aperture angle in the object (or image) space, which is usually normalized, if the object beam is parallel to the optical system axis. Normalization of this angle allows to define uniquely both the angles and the incidence heights. Instead of the aperture angle the incidence height may also be subjected to normalization. For an astigmatic beam the normalizing of height h_s is the most reasonable [3]. Then, it is assumed that in the diaphragm plane the sagittal paraxial height h_s is equal to the height of incidence of the paraxial aperture ray, i.e.

$$(h_s)_D = h_D. \tag{2}$$

It is worth noticing that the eq. (1) is quite accurate for the astigmatic beam and includes aberrations of all orders for sagittal focus.

Let us denote by S_k the distance of the sagittal focus S_k in the k-th object space from a point of hiting the Gaussian plane by the principal ray Q_k

$$\delta S_k = (R_s)_k - \bar{R}_k. \tag{3}$$

After rearrangement (shown in [3]) the following expression may be obtained for the wave aberration of the sagittal focus for an arbitrary surface of rotational symmetry

$$(W_s)_k = -\frac{1}{2} n_k \frac{\bar{H}_s}{\bar{H}_k} u_k (u_s)_k \delta S_k, \tag{4}$$

where

$$\bar{H}_s = n u_s \eta_s, \qquad \bar{H}_k = n_k u_k \eta_k \tag{5}$$

u_k — paraxial aperture angle,

u_s — paraxial sagittal aperture angle,

η_s — distance of the sagittal focus from the optical axis,

η_k — distance of the intersection point of the principal ray with the Gaussian plane from the optical axis.

The magnitudes η_s, u_s, η_k are shown in Fig. 2. $\bar{H}_s$ is the Hopkins invariant, which is a generalization of the Legrange-Helmholtz invariant.

Let us multiply both sides of eq. (4) by $\bar{N}_k \bar{H}_k / \bar{H}_s$ (where $\bar{N}_k$ denotes a directional cosine of the principal ray with respect to the optical axis)

$$\frac{\bar{N}_k \bar{H}_k}{\bar{H}} (W_s)_k = -\frac{1}{2} n_k u_k (u_s)_k \bar{N}_k \delta S_k. \tag{6}$$

Let the difference of the respective values in front of and behind a refracting surface be denoted by an operator Δ (for instance $n' - n = \Delta n$). Then the change in expression (6) due to refraction may be written as follows

$$\Delta \left[\frac{\bar{N}\bar{H}}{\bar{H}_s} W_s \right]_k = -\frac{1}{2} \Delta (n u\, u_s \bar{N} \delta S)_k. \tag{7}$$

The number of these equations is equal to the number p of the optical surfaces. When suming up these equations all the terms in the left-hand side cancel each other except the first and the last ones. Consequently

$$\frac{\bar{N}_p \bar{H}_p}{\bar{H}_s} (W_s)_p - \frac{\bar{N}_1 \bar{H}_1}{\bar{H}_s} (W_s)_1 = -\frac{1}{2} \sum_{k=1}^{p} \Delta (n u u_s \bar{N} \delta S)_k \tag{8}$$

This mutual compensation of the respective terms is caused by the fact that the quantity $\bar{H}_s$ is a system invariant

$$(\bar{H}_s)_1 = (\bar{H}_s^{\prime})_1 = (\bar{H}_s)_2 = (\bar{H}_s^{\prime})_2 = \ldots = (\bar{H}_s)_p,$$

while the remaining magnitudes satisfy the relation

$$\bar{N}_k^{\prime} = \bar{N}_{k+1}, \quad \bar{H}_k^{\prime} = \bar{H}_{k+1}, \quad (W_s^{\prime})_k = (W_s)_{k+1}.$$

After transformations which take account of the invariant properties of the astigmatic beam the following formula for an arbitrary surface of rotational symmetry may be obtained [3]

$$\frac{\bar{N}_p^{|}\bar{H}_p^{|}}{\bar{H}_s}(W_s)_p - \frac{\bar{N}_1\bar{H}_1}{\bar{H}_s}(W_s)_1 = \frac{1}{2}\sum_{k=1}^{P}\{h_k\Delta(nu_s)_k \times$$

$$\times [1-\bar{z}_kC_k-(r_s)_kC_k\cos\bar{G}_k]+A_k[\bar{z}_k\Delta(u_s)_k+(h_s)_k\Delta\bar{N}_k]\}. \tag{9}$$

where

C_k — curvature of the vertex of the k-th surface,

$(r_s)_k$ — curvature radius of the k-th surface in the sagittal cross section for a given incidence height h of the principal ray $\bar{y}_k$,

$A_k = n_k i_k$,

i_k — paraxial incidence angle of the aperture angle,

h_k — paraxial incidence height,

$\bar{G}_k$ — angle between the normal to the surface at its intersection point with the principal ray and the optical axis.

For a plane or spherical surface [3] we have

$$1-\bar{z}_kC_k-(r_s)_kC_k\cos\bar{G}_k = 0. \tag{10}$$

The further considerations will be restricted to the plane and spherical surfaces only. Thus, we will exploit the following relation

$$\frac{\bar{N}_p^{|}\bar{H}_p^{|}}{\bar{H}_s}(W_s)_p - \frac{\bar{N}_1\bar{H}_1}{\bar{H}_s}(W_s)_1 = $$

$$= \frac{1}{2}\sum_{k=1}^{P}A_k[\bar{z}_k\Delta(u_s)_k+(h_s)_k\Delta\bar{N}_k]. \tag{11}$$

This formula is exact and includes the aberrations of arbitrary order. For the third order aberrations (first order in Buchdahl notation) this formula transfers into a generaly known relation

$$(W_s)_p^{|}-(W_s)_1 = \frac{1}{4}\sum_{k=1}^{P}\left[n^2i^2h^2\Delta\left(\frac{u}{n}\right)-H^2C\Delta\left(\frac{1}{n}\right)\right]_k. \tag{12}$$

Here, the first sum represents the third order astigmatism, while the second one gives the Petzval curvature. The goal of paper [4] was to transform the formula (11) in order to express it in terms of the quantities, which in the region of the third order aberrations pass over into astigmatism and Petzval curvature respectively. After many transformations the following relation has been obtained

$$\frac{\bar{N}_p^{|}\bar{H}_p^{|}}{\bar{H}_s}(W_s)_p - \frac{\bar{N}_1\bar{H}_1}{\bar{H}_s}(W_s)_1 = \frac{1}{4}\sum_{k=1}^{P}(K+S+F)_k, \tag{13}$$

where

$$K = \left(\frac{2z}{\bar{Y}h}\right)H\bar{H}_s\Delta[-(1/n)],$$

$$S = \left(\frac{2\bar{z}}{\bar{y}h}\right)BB_shh_s\cos\bar{G}\Delta(1/n)+$$

$$+2(Ah_s/\bar{y})(\bar{y}\cos\bar{G}+\bar{z}\sin\bar{G})(\cos\bar{I}) \tag{14}$$

$$F = -(2\bar{z}/\bar{h})A_sBh\Delta(1/n)+$$

$$+2(Ah_s/\bar{y})B_s\Delta(1/n)(\bar{y}\sin\bar{G}-\bar{z}\cos\bar{G}),$$

$$B_s = n\sin\bar{I}.$$

The quantities $\bar{H}_s$, h_s, u_s appearing in this formula are expressible by paraxial magnitudes and the respective quantities for the principal ray, as may be seen in Fig. 2

$$\eta_s = \bar{y}-s\sin\bar{u}, \tag{15}$$

where

$\bar{u}$ — angle between the principal ray and the optical axis.

Basing on relation (15) it may be written

$$\bar{H}_s = nu_s\bar{y}-nh_s\sin\bar{u}, \tag{16}$$

where

$$su_s = h_s.$$

Since H_s is an invariant quality it may be calculated in an arbitrary space. We will estimate it in the space where the aperture diaphragm is placed. Then

$$\bar{H}_s = -nh_D\sin\bar{u}_D. \tag{17}$$

During transformation of the formula (16) the normalizing condition (eq. (2)) was employed and it was also assumed that the principal ray hits the centre of the aperture diaphragm. The last assumption may be unsatisfied if some vignetting takes place. Then the first term $nu_s\bar{y}$ must be taken into account. However, as the value of $\bar{y}$ is not very great it may be assumed for the majority of optical systems that approximately $u_s\bar{y} = u\bar{y}$ (by neglecting the expression $y\delta s^{|}/s^{|}$). From (17) we may calculate the Hopkins invariant $\bar{H}_s$ with the help of which the initial values of $(u_s)_1$ and $(h_s)_1$ are estimated. From Fig. 3, where it is assumed that a homocentric beam emerges from the object point we obtain

$$(h_s)_1 = (u_s)_1\frac{l_1-\bar{z}_1}{\bar{N}_1}, \tag{18}$$

where

$\bar{N}_1 = \cos\bar{u}_1$.

The first paraxial aperture angle $(u_s)_1$ may be calculated from the formula (16)

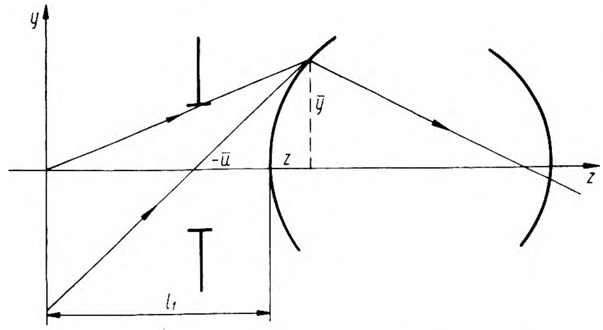


Fig. 3. Astigmatic beam in the object space

$$\bar{H}_s = n_1 (u_s)_1 \bar{y}_1 - n_1 (h_s)_1 \sin \bar{u}_1 =$$

$$= n_1 (u_s)_1 \bar{y}_1 - n_1 (u_s)_1 \frac{l_1 - \bar{z}_1}{\bar{N}_1} \sin \bar{u}_1 .$$

Hence

$$(u_s)_1 = \bar{H}_s / n_1 \left[\bar{y}_1 + \frac{l_1 - \bar{z}_1}{\bar{N}_1} \bar{M}_1 \right], \quad (19)$$

where

$$\bar{M}_1 = -\sin \bar{u}_1 .$$

The remaining values of paraxial sagittal aperture angles and paraxial incidence heights are determined by the following relations

$$(u_s)_{k+1} = (n_k / n_{k+1}) (u_s)_k + (h_s)_k (n \cos \bar{I})_k / n_{k+1} r_k ,$$

$$(20)$$

$$(h_s)_{k+1} = (h_s)_k - \bar{d}_k (u_s)_{k+1} ,$$

where

$\bar{d}_k$ — principal ray length between the k-th and the $k+1$-th surface.

The first equation follows from the basic formula for the sagittal focus, while the other one is an ordinary transfer equation.

Formulae (20) and (17) enable an estimation of values $\bar{H}_s$, u_s, h_s and η_s for each surface of the optical system provided that the tracing of the principal and paraxial rays was made earlier. Quantities K and S appearing in the formula (14) become identical with the Petzval curvature and astigmatism, respectively, in the third order aberration region. Therefore, they were called generalized Petzval curvature K and generalized astigmatism S in the paper [4]. The remaining term marked by F is considerably smaller then the two others and disappears in the Seidel region. It will be called a perturbing term [4]. After expressing the quantities $\bar{M}_k$, $\bar{N}_k$, $\sin \bar{I}_k$, $\cos \bar{I}_k$, $\sin \bar{G}_k$, $\bar{y}_k$, $\bar{z}_k$, $(h_s)_k$, $(u_s)_k$, $\bar{H}_s$ in terms of paraxial parameters and Seidel sums up to the 5-th order of magnitude the following formula was obtained after suitable rearrangements [5]

$$\frac{\bar{N}_p^{|} \bar{H}_p^{|} (W_s^{|})_p}{\bar{H}_s} - \frac{\bar{N}_1 \bar{H}_1 (W_s)_1}{\bar{H}_s} = \frac{1}{4} \sum_{k=1}^{n} (K+S+F)_k , \quad (21)$$

where

$$S = n^2 \Delta \left(\frac{1}{n} \right) \bar{i} \tau^2 \left\langle h \hat{i} + \frac{\tau^2}{2} \left\{ -\bar{u}^2 \bar{i} h - \frac{1}{2} \bar{h} g^2 \bar{i} (\bar{g} + 2\bar{u}) - \right. \right.$$

$$- h \hat{i} V_d - \frac{1}{2} \hat{h} \left| \left(\frac{n}{n'} \right)^2 + 1 \right| \bar{i}^3 + \frac{\bar{h} h \bar{g} g \bar{i} \hat{i} n}{H} + \frac{1}{H} \left[\hat{i} h S_V - \right.$$

$$\left. \left. \left. - \left(\bar{h} i (i+i') - h \bar{i} g \right) \hat{S}_I \right] \right\} \right\rangle - \frac{\hat{i} r n}{H} F + 0(\tau^6) \quad (21a)$$

$$K = -H^2 \Delta \left(\frac{1}{n} \right) \tau^2 C \left\{ 1 + \frac{1}{2} \left[\frac{1}{2} \bar{g} (\bar{i} - \bar{u}) - V_d + \right. \right.$$

$$\left. \left. + \frac{1}{H} (S_V + \hat{S}_I) \right] \tau^2 \right\} + 0(\tau^6) , \quad (21b)$$

$$F = \frac{1}{2} n \bar{g} \Delta \left(\frac{1}{n} \right) \tau^4 \{ \bar{g} \bar{i} (n \bar{i} h g + H u) + \bar{i} (S_{III} + S_{IV}) -$$

$$- \bar{i} \hat{S}_I \} + 0(\tau^6) . \quad (21c)$$

$$\hat{S}_I = \frac{h}{\bar{h}} \bar{S}_I ,$$

$$\hat{h} = h (i + i') ,$$

$$\hat{i} = \bar{i} (u - i') ,$$

$$V_d = \bar{u}_{d+1}^2 - \frac{1}{H} \sum_{k=1}^{d} (S_V)_k ,$$

$$\bar{g} = \bar{u} + \bar{i} .$$

As mentioned above the formulae (21) estimate the respective magnitudes with the accuracy up to the fifth order and thus take account of aberrations of third and fifth order. Higher order aberration are evaluated by examining the difference between the magnitudes calculated from (21) and the aberrations of arbitrary order represented by the formula (11) or by the following equation

$$(\bar{W}_s)_p - (W_s)_1 = \frac{1}{2} \sum_{k=1}^{p} n_k^{|} (h_s) \frac{2}{k} \left(\frac{1}{\bar{R}_s} - \frac{1}{\bar{R}} \right)_k , \quad (22)$$

which follows from (1).

The expression (21c) for F indicates that this quantity should be correlated with the higher order aberrations of sagittal focus. Its simplicity is very promising for the lens designers and therefore F should be carefully examined. However, the exact analytical relation can not be employed as a starting point of a detailed analysis because the expression

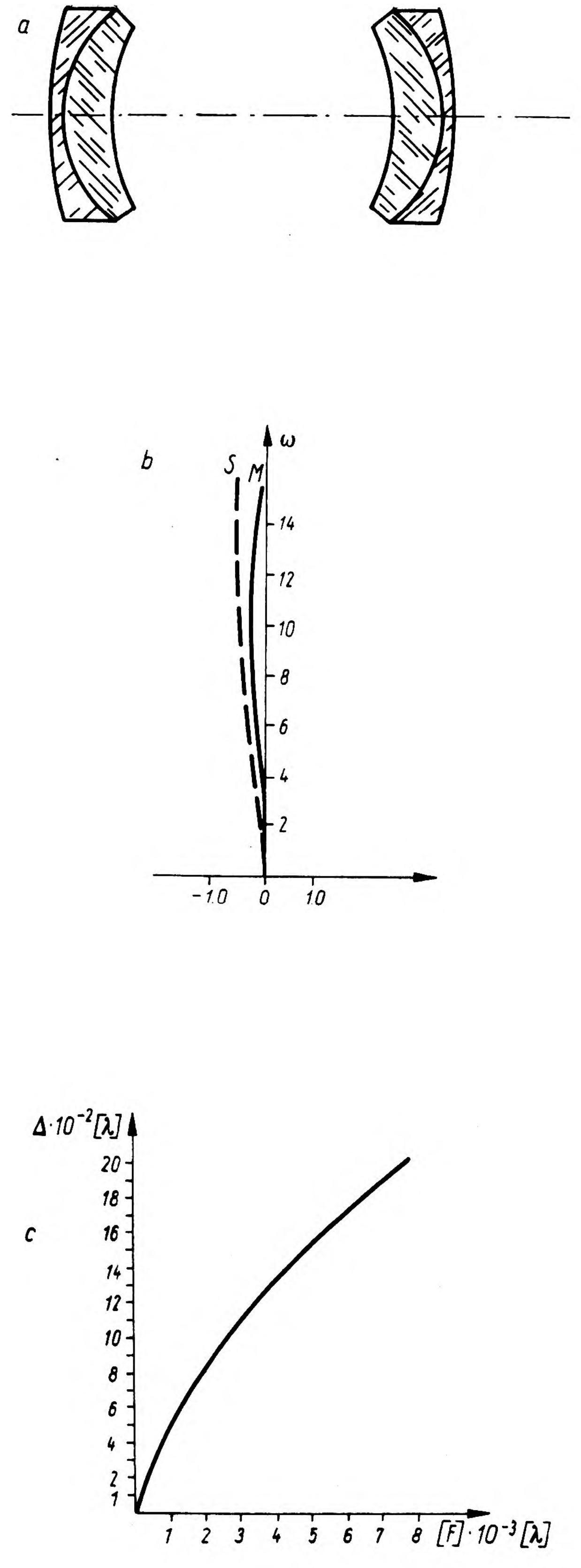


Fig. 4a) Photographic objective, a symmetric aplanate of small relative aperture and moderate field, b) astigmatism and field curvature, c) dependence of the higher order wave aberrations of sagittal focus $\bar{\Delta}$ on the perturbing term F

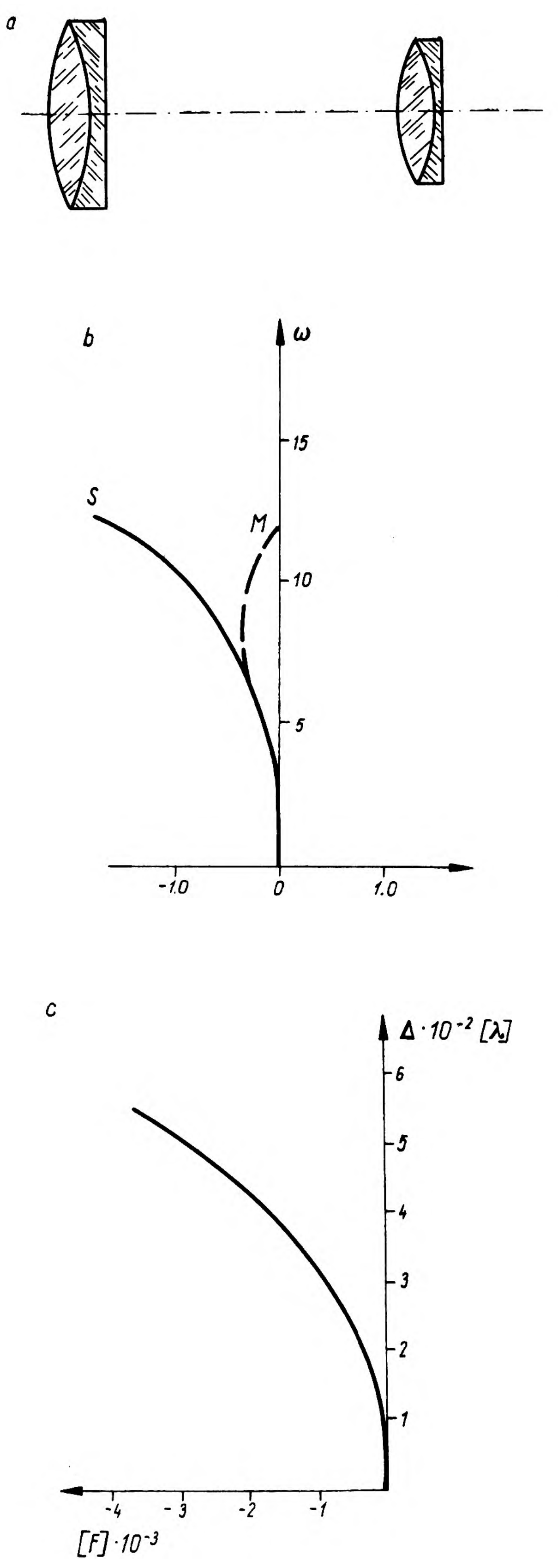


Fig. 5a) Photographic objective of great relative aperture and small field of view, b) astigmatism and field curvature, c) dependence of the higher order wave aberrations of sagittal focus $\bar{\Delta}$ on the perturbing term F

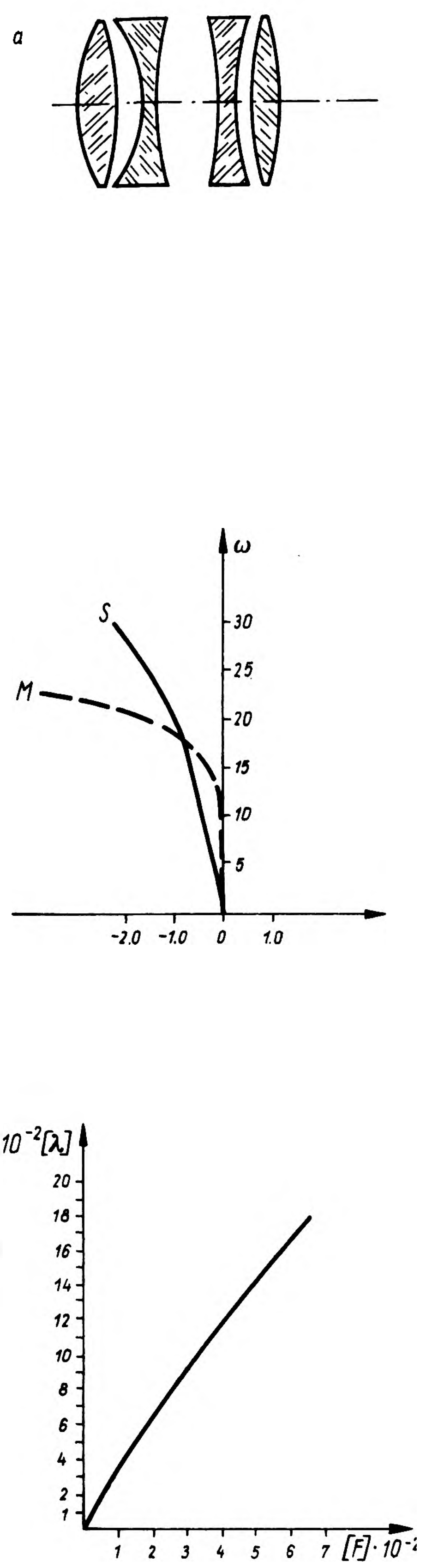


Fig. 6 a) CELOR photographic objective, b) astigmatism and field curvature, c) dependence of the higher order wave aberrations of the sagittal focus $\bar{\Delta}$ on the perturbing term F

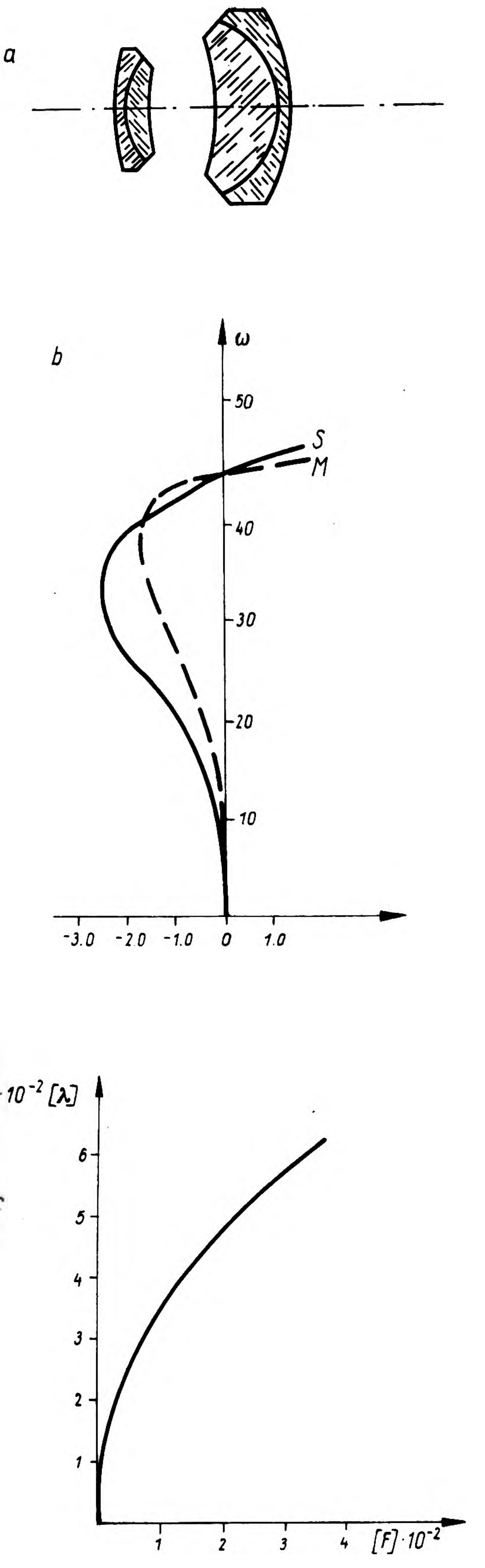


Fig. 7 a) Photographic objective; a wide angle anastigmate b) astigmatism and field curvature, c) dependence of the higher order wave aberrations of sagittal focus $\bar{\Delta}$ on the perturbing term F

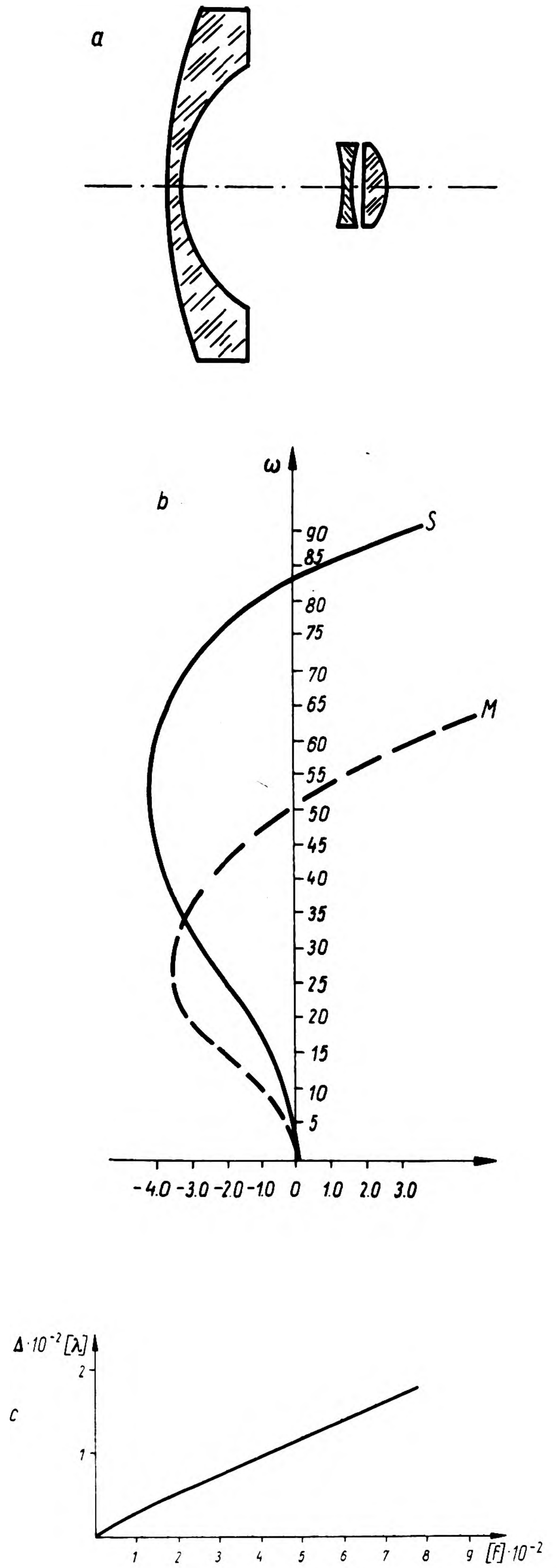


Fig. 8 a) A photographic objective of uncorrected distorsion, b) astigmatism and field curvature, c) dependence of the higher order wave aberrations of sagittal focus $\bar{\Delta}$ on the perturbing term F

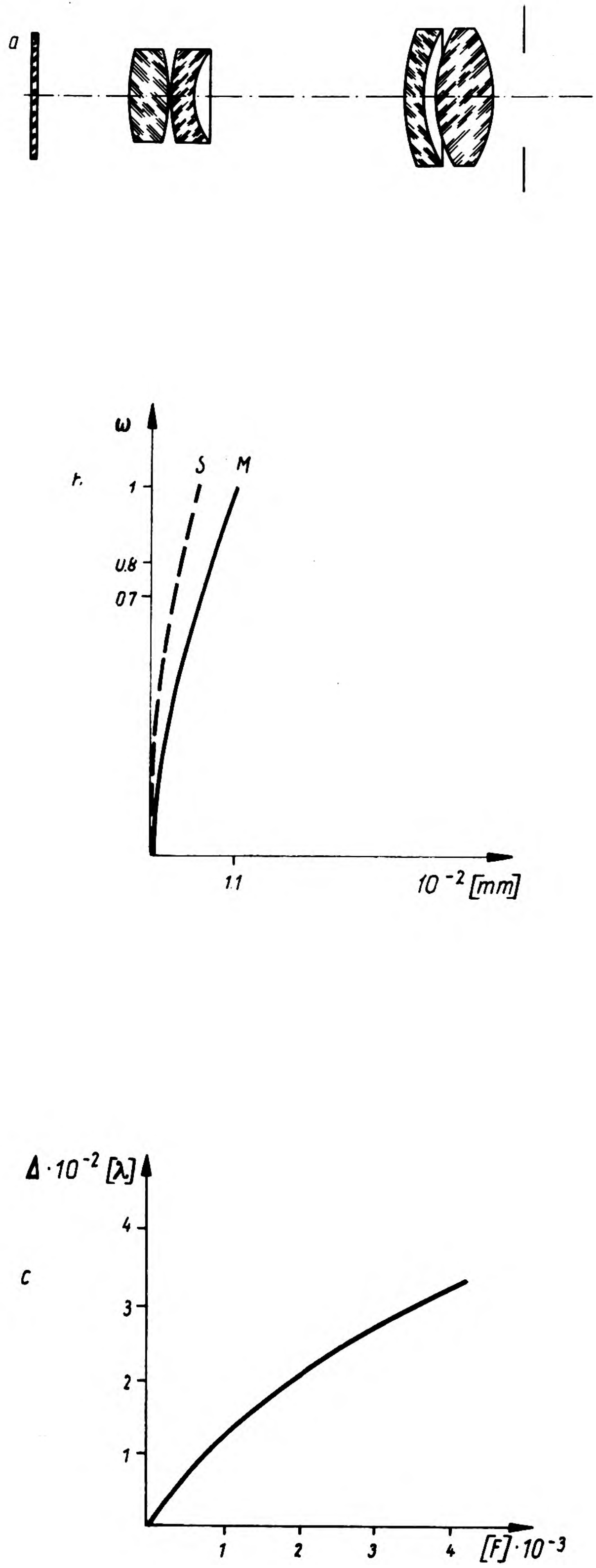
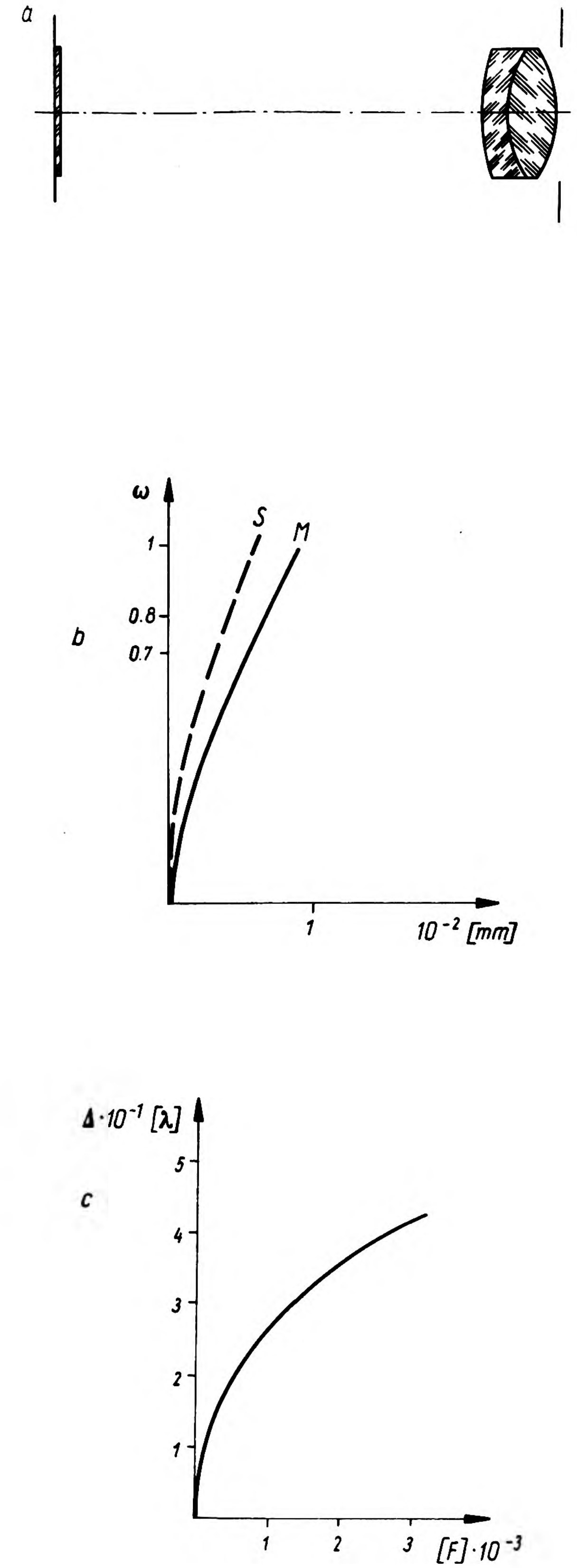


Fig. 9 a) Planachromatic microscope objective of magnification $5\times$ b) astigmatism and field curvature, c) dependence of the higher order wave aberrations $\bar{\Delta}$ on the perturbing term F



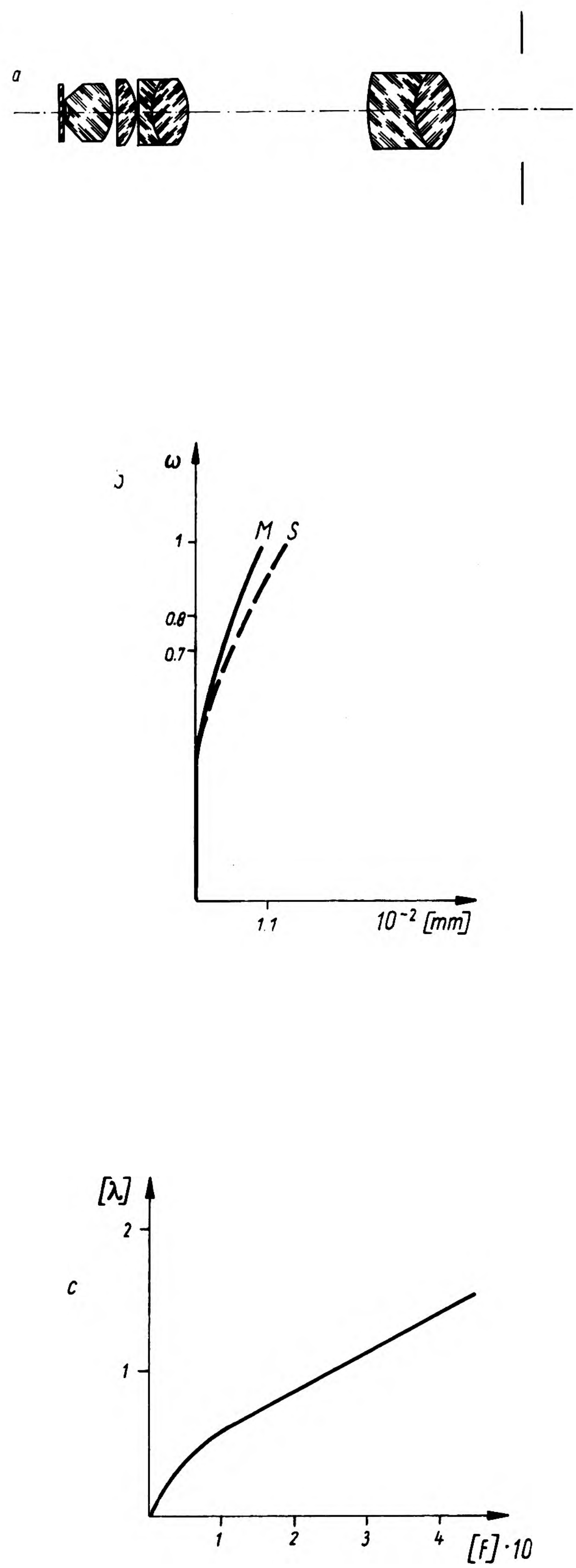


Fig. 10 a) Achromatic microscope objective of magnification 5×, b) dependence of the astigmation and field curvature on field angle, c) dependence of the higher order wave aberrations of the sagittal focus $\bar{\Delta}$ on the perturbing term F

Fig. 11 a) Planachromatic microscope objective of magnification 20×, b) dependence of the astigmation and field curvature on the field angle, c) dependence of the higher order wave aberrations of sagittal focus $\bar{\Delta}$ on the perturbing term F

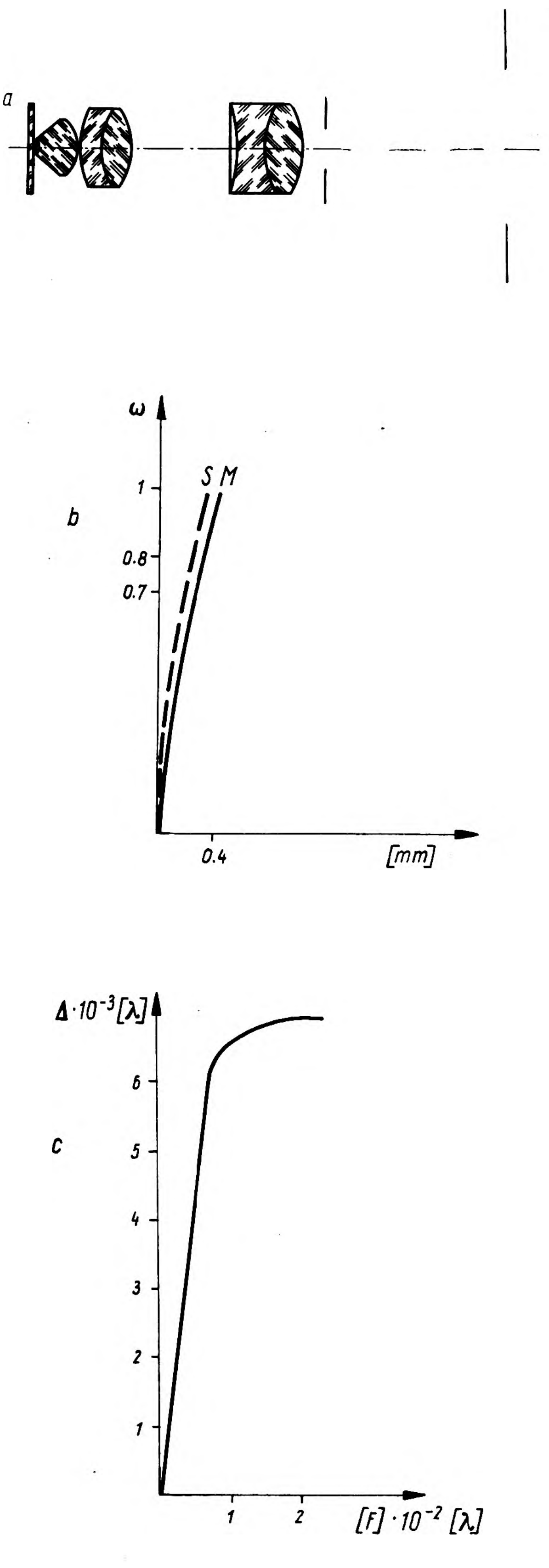


Fig. 12 a) Achromatic microscope objective of magnification 20×, b) dependence of astigmatism and field curvature on the field angle, c) dependence of the higher order wave aberrations of sagittal focus $\bar{\Delta}$ on the perturbing term F

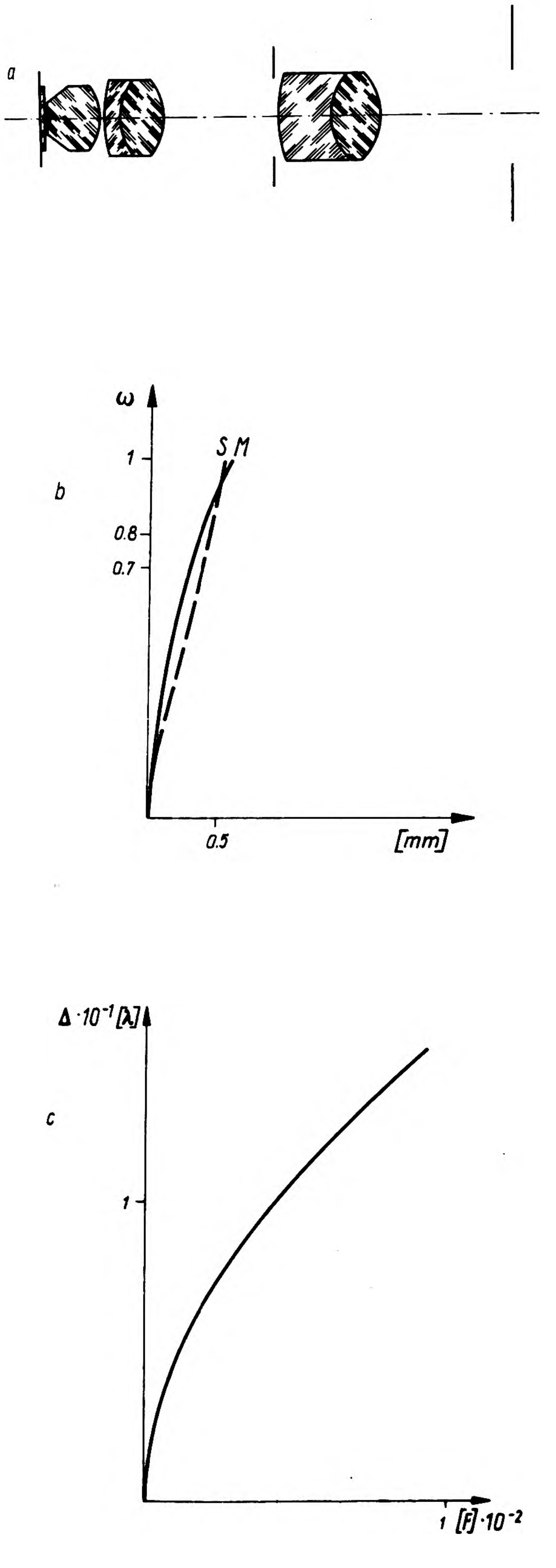
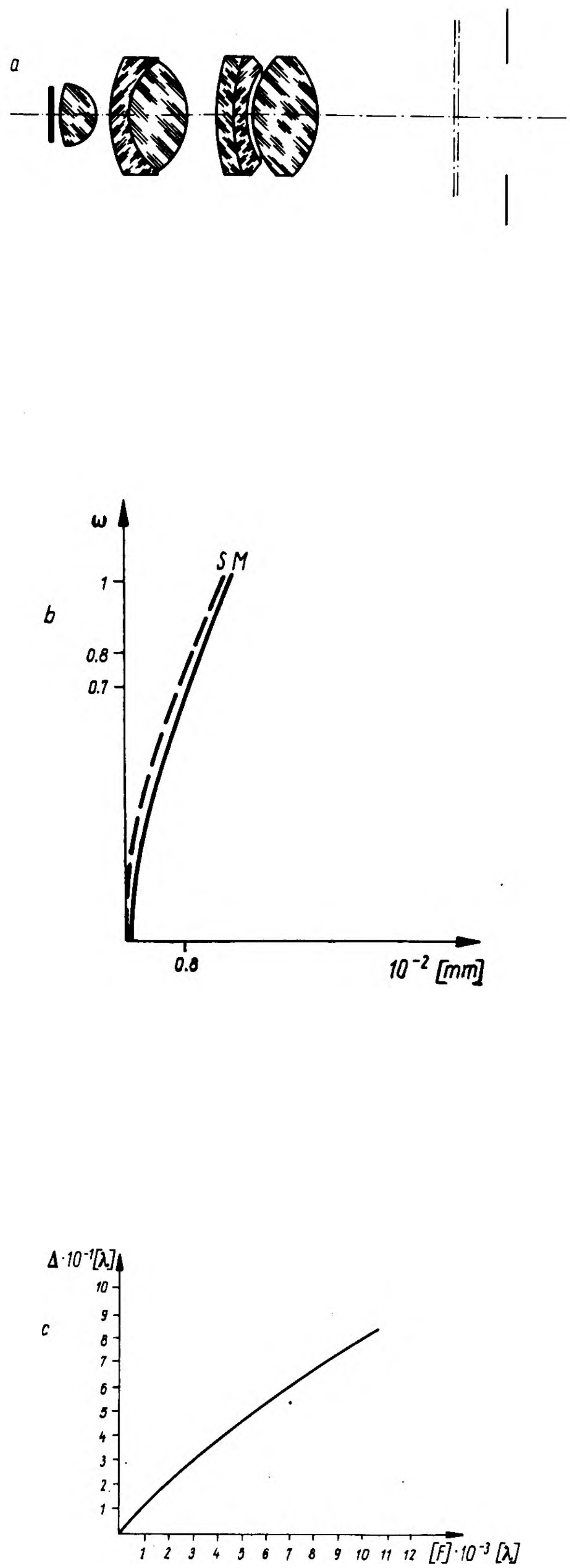


Fig. 13 a) Planachromatic microscope objective of magnification 40×, b) dependence of astigmatism and field curvature on the field angle, c) dependence of the higher order wave aberrations of sagittal focus $\bar{\Delta}$ on the perturbing term F



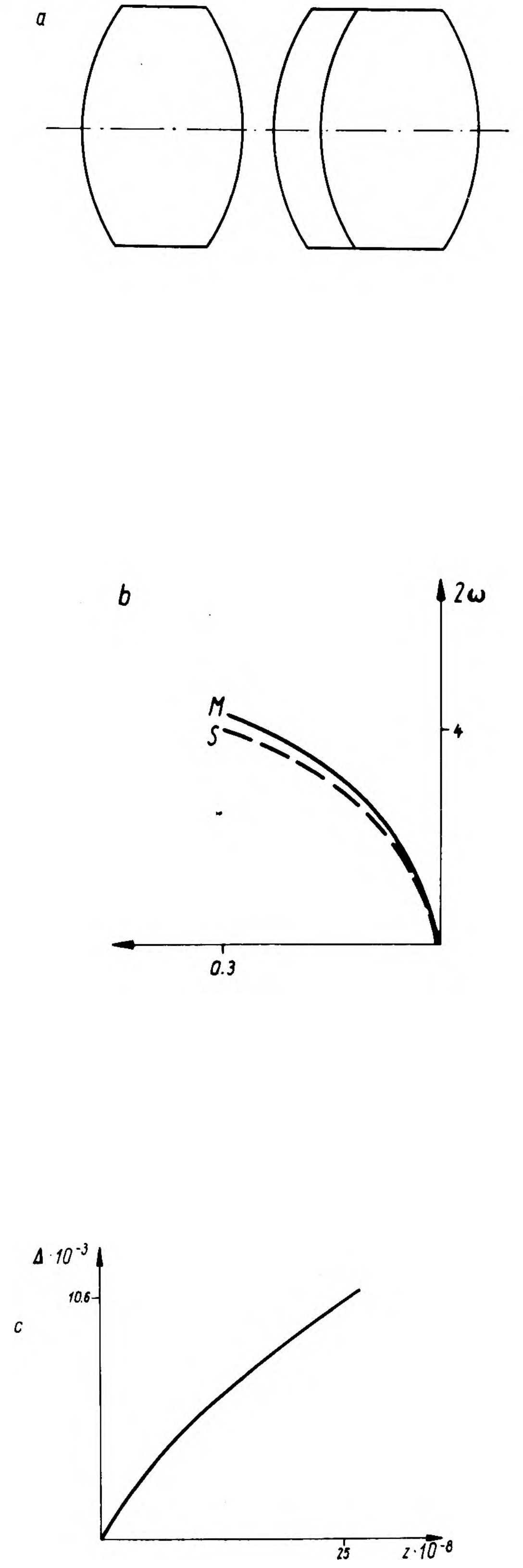


Fig. 14 a) Achromatic microscope objective of magnification 40×, b) dependence of astigmatism and field curvature on the field angle, c) dependence of higher order wave aberrations of sagittal focus $\bar{\Delta}$ on the perturbing term F

Fig. 15 a) Telescope objective, $2\omega = 6°$, relative aperture 1:4, b) dependence of astigmatism and field curvature on the field angle, c) dependence of the higher order wave aberrations of sagittal focus $\bar{\Delta}$ on the perturbing term F

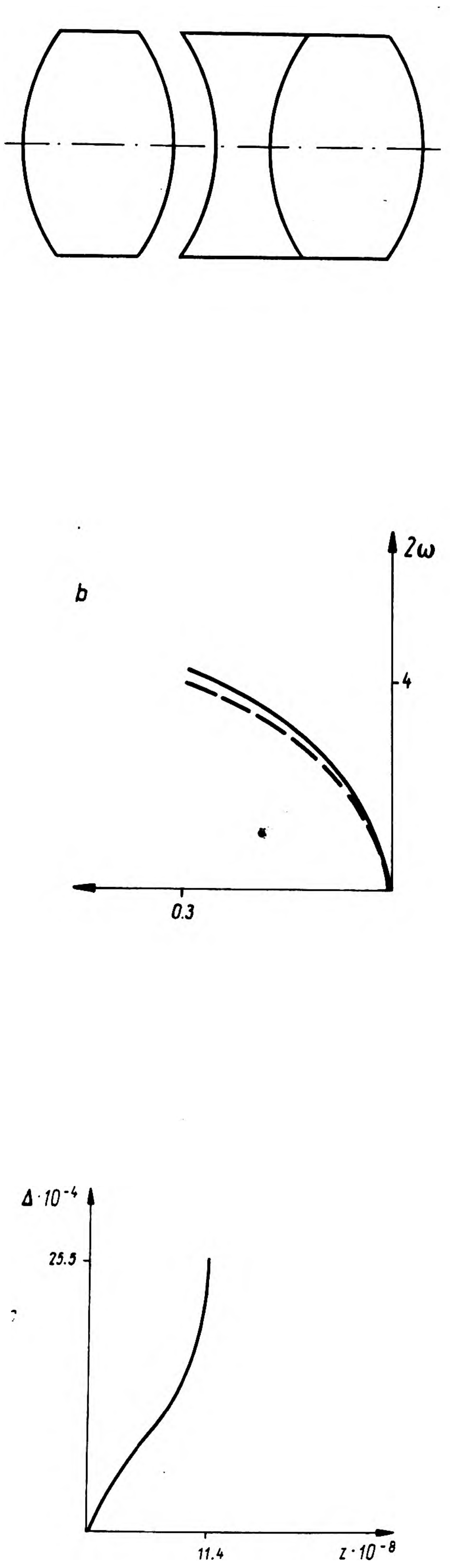


Fig. 16 a) Telescope objective, $2\omega = 6°$, relative aperture 1:4.5, b) dependence of astigmatism and field curvature on field angle, c) dependence of the higher order wave aberration of sagittal focus Δ on the perturbing term F

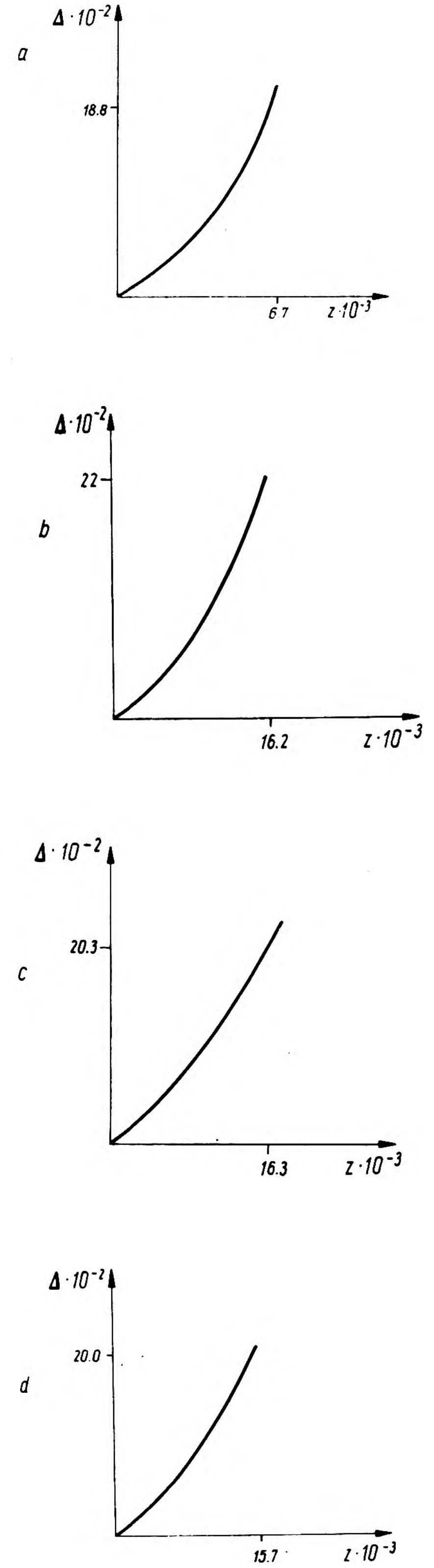


Fig. 17. Dependence of the higher order wave aberration of the sagittal focus Δ on the perturbing term F when changing the parameters of a photographic aplanate objective
a) change of the forth curvature by 122%,
b) change of the sixth curvature by 8.4%,
c) change of the third spacing by 0.9 mm,
d) change of the forth spacing by 0.4 mm

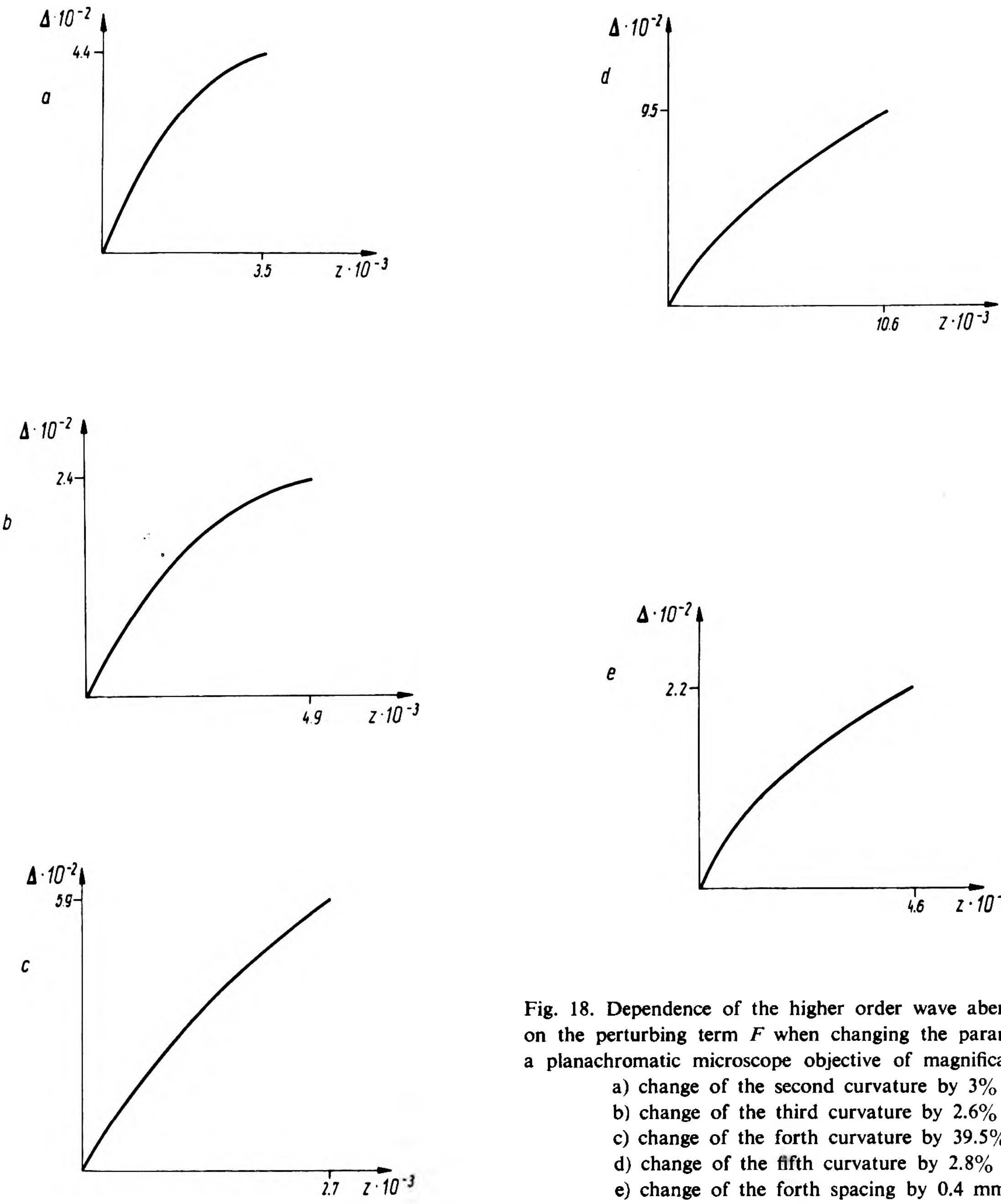
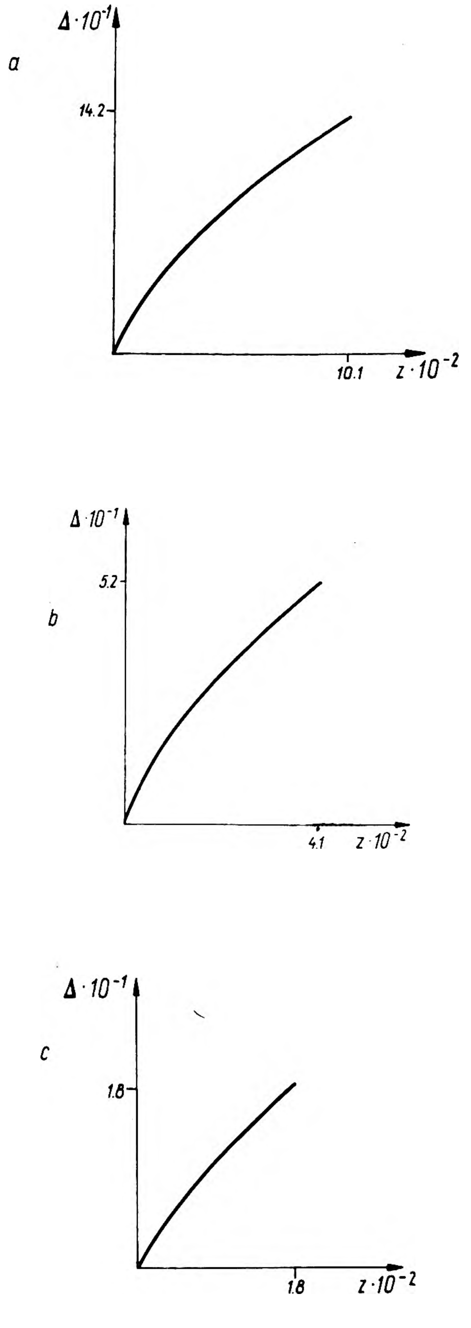


Fig. 18. Dependence of the higher order wave aberration Δ on the perturbing term F when changing the parameters of a planachromatic microscope objective of magnification $5\times$
a) change of the second curvature by 3%
b) change of the third curvature by 2.6%
c) change of the forth curvature by 39.5%
d) change of the fifth curvature by 2.8%
e) change of the forth spacing by 0.4 mm

for the higher order aberrations of sagittal focus is too complex. In order to solve this problem the numerical estimations carried out for a series of optical systems of the most representative types were used. The formulae (11), (21) and (22) were programmed for the ODRA 1204 computer. The obtained results confirmed our suppositions, which seems to be very interesting for lens designers. A comparison of the numerical results for wave aberrations of sagittal focus calculated according to classical relations with those obtained from the formulae (11) and (12) confirmed their consistency within the computation error. To illustrate the above analysis a relation between the perturbing term and the higher order wave aberrations of sagittal focus defined as a difference of the expressions (22) and (21).

The calculations were carried out for a number of telescope, photographic and microscope objectives. The correlation of the perturbing term with the higher order wave aberrations of sagittal focus will be illustrated by some examples taken from most characteristic types of optical systems. All calculations were carried out for the systems of normalized focal length ($f' = 1$ mm).

In Fig. 4a a layout of a photographic objective of f-number 3 and the field angle $2\omega = 30°$ is pre-



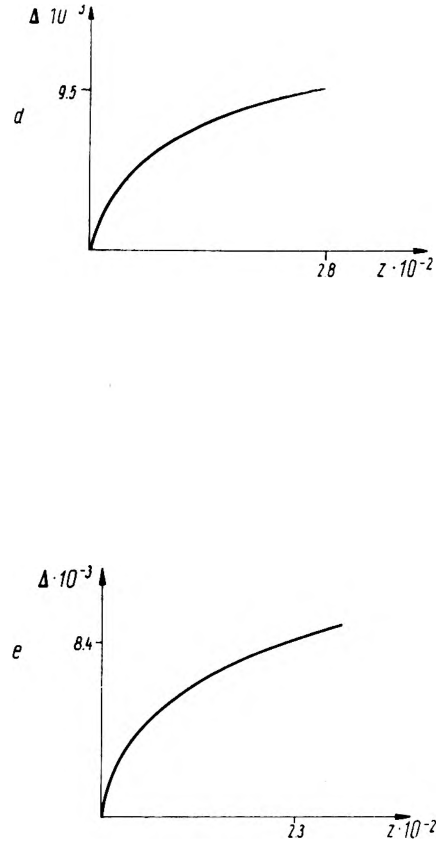


Fig. 19. Dependence of the higher order wave aberrations of sagittal focus $\bar{\Delta}$ on the perturbing term F when changing the planapochromatic microscope objective of magnification 20×

a) change of the first curvature by 10%
b) change of the second curvature by 8.5%
c) change of the sixth curvature by 15%
d) change of the third spacing by 0.4 mm
e) change of the fifth spacing by 0.05 mm

sented. In Fig. 4b astigmatism and field curvature is shown versus the field angle. In Fig. 4c a dependence of the higher order wave aberration of sagittal focus $\bar{\Delta}$ upon the perturbing term F is presented.

The remaining graphs concern the following optical systems: photographic objective, f-number 2, field angle $2\omega = 12°$ (Fig. 5a, b, c); photographic objective, f-number 3.5, field angle $2\omega = 40°$ (Fig. 6a, b, c); photographic objective, f-number 18, field angle $2\omega = 40°$ (Fig. 7a, b, c); photographic objective, f-number 22, field angle $2\omega = 180°$ (Fig. 8a, b, c); planachromatic microscope objective of magnification 5× (Fig. 9a, b, c); achromatic microscope objective of magnification 5× (Fig. 10a, b, c); planachromatic microscope objective of magnification 20× (Fig. 11a, b, c); achromatic microscope objective of magnification 20× (Fig. 12a, b, c); planachromatic microscope objective of magnification 40× (Fig. 13a, b, c); achromatic microscope objective of magnification 40× (Fig. 14a, b, c); telescope objective, f-number 4, $2\omega = 6°$ (Fig. 15a, b, c) and f-number 6, $2\omega = 6°$ (Fig. 16a, b, c). Independently, the influence of the design parameters variation on the dependence of the perturbing term upon the higher order aberrations of sagittal focus was also examined. This dependence is exemplified by changes in curvature of the refracting surfaces and thicknesses in a photographic objective symmetric aplanate of 1:3 clear aperture and $2\omega = 30°$ field of view (Fig. 17a, b, c, d), a planachromatic microscope objective of magnification $5\times$ (Fig. 18a, b, c, d) as well as a planapochromatic microscope objective of magnification $20\times$ (Fig. 19a, b, c, d, e).

As may be seen from the graphs, a well-defined regularity of the perturbing term correlation with the higher order wave aberrations of sagittal focus exists in all the cases in spite of the fact that the systems, under study, were of very different gabarite and correction types and the changes of design parameters were great. Moreover, this correlation proved to be almost linear within the whole range of field. As has been shown by a more exact analysis the deviation from rectilinearity for the field of view up to 90% did not exceed 8% (with the exception of few examples not exceeding 15% of the systems under test). This results seem to be so much encouraging for the optical lens designers that we started to work on analytical expressions, which would enable to examine the direct influence of the changes in design elements on the perturbing term and to utilize the results obtained in the optimizing procedure.

Corrélation entre le terme de perturbation et les aberrations d'onde d'ordre supérieur du foyer sagittal

On a examiné la relation entre le terme de perturbation et les aberrations d'onde d'ordre supérieur du foyer sagittal. On a analysé cette relation pour une série de systèmes de différentes conditions de gabarit et de construction. On a décrit aussi l'influence de la variation des paramètres de construction sur les relations entre le terme de perturbation et les aberrations d'onde d'ordre supérieur du foyer sagittal.

Корреляция возмущающего члена с волновыми аберрациями сагиттального фокуса высших порядков

Исследована зависимость возмущающего члена от волновых аберраций сагиттального фокуса высших порядков. Эта зависимость анализировалась для ряда систем с различными в принципе габаритными и конструктивными условиями. Описано также влияние изменений конструктивных параметров на зависимость возмущающего члена от волновых аберраций сагиттального фокуса высших порядков.

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