Optica Applicata, Vol. XIV, No. 1, 1984

A simple zoom objective, $f/1.8$, $R \approx 2$*

P. Kalló

Budapest Technical University, Department of Precision Mechanics and Optics, H–1025 Budapest, Kapy–u. 26/B, Hungary.

The zoom objective consisting of four lenses and featured by $f/1.8$ relative aperture has a focal lenght varying from 44 to 88 mm. The diameter of its image is 100 mm, with the image plane linearly compensated. According to Conrady's criteria, the image quality is good at the centre along the entire range of focal distances, good at the sides of the image field for short and long focal distances and it is still sufficient in the medium focal distance range.

It is a generally accepted fact that the design of a zoom objective becomes more difficult if: it consists of a small number of simple or cemented composite lenses, its image plane is stabilized by optical or linear compensation instead of a mechanical solution and the following parameters: ratio of maximum to minimum focal distances, relative aperture, field angle, image quality requirement, and wavelength range of chromatic correction are to be unusually large.

The above mentioned requirements, as well as the difficulty grade of fulfilling them are characterized by a three-step scale given in Table. The purpose of this work was to design a zoom objective of parameters marked in this Table with x, and characterized by: small number of lenses, image plane stabilized by linear compensation, small ratio of maximum to minimum focal distances, a larger relative aperture, small object field, good image quality and medium wavelength range of chromatic aberration correction.

In order to select a type of objective that might be expected to fulfil the above requirements, an attention has been paid to the objective having an inherent potential to provide optical compensation: zooms containing two moving components. Basic variants of these types of zooms, known from the literature, are illustrated in Fig. 1.

In variants 1 and 2 given in Fig. 1, the moving lenses being converging or dispersing lenses are of the same character. Consequently, the varying spherical aberration of the moving components should be compensated by the first lens. In this case, the spherical aberration may be compensated by the

---

* This paper has been presented at the European Optical Conference (EOC'83), May 30–June 4, 1983, in Rydzyna, Poland.

	Denomination	Symbol	Grade of job difficulty		
			High	Medium	Low
1	Number of lenses	i	x (Few)	(More)	(Several)
2	Image plane stabilization	Δ	(Optical compensation)	x (Linear compensation)	(Mechanical compensation)
3	Min/max focal distance ratio	$R = \dfrac{f_{max}}{f_{min}}$			x
4	Relative aperture	f/NO	x		
5	Field angle	$\pm \beta_c$			x
6	Image quality requirement		("Excellent")	x ("Good")	("Satisfactory")
7	Wavelength range	$\Delta\lambda$		x	

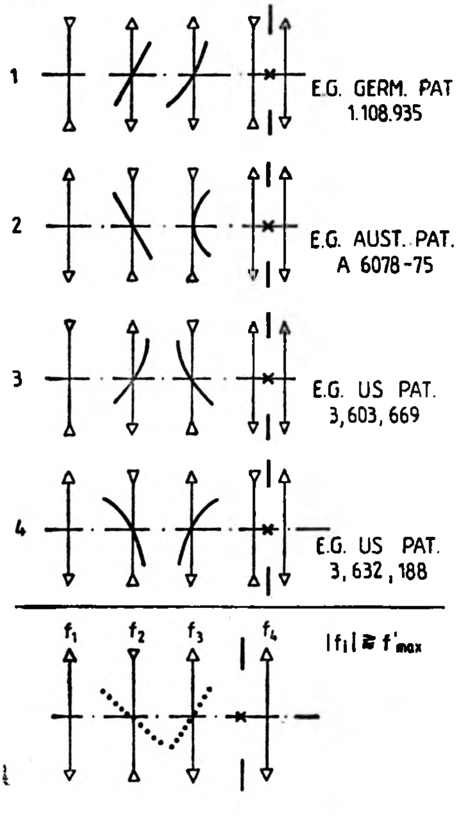

Fig. 1

first lens, the focal distance of which is substantially shorter in absolute value than that of the moving components. This property makes difficult the correction of field curvature or renders it impossible. From this viewpoint, the design of variant 2 is less difficult, but the recurving path of the second moving component is not favourable for linearization.

In variants 3 and 4 in Fig. 1 the varying spherical aberrations compensate each other in a good approximation. Therefore, it is not only possible but moreover necessary to apply the first lens with a large absolute value of focal length. Furthermore, in the case of a more severe requirement with respect to object field, variant 3 is more advantageous. It has, however, some shortcomings, namely, that the resultant focal distance of the last two lenses flanking the stop is nearly equal to that of the other lenses. In view of the above considera- tion and starting with the variant 4 (Fig. 1) attempts were made to solve the problem by selecting the type according to the one illustrated at the bot- tom of this figure and hoping that the path of the moving components can be linearized. In order to fulfil the requirement of a large relative aperture the absolute value of focal distance of each lens of the system had to approximate closely or even exceed the maximum focal length of the zoom objective. It was evident, however, that this task requires the extension of the structural length and the Petzvál-sum with the given low requirement of the object field (which was apparently permissible) to be increased.

After these preliminary assumptions investigations on the feasibility of linearization of the paths of the moving components of the selected system were conducted. This possibility was examined with the help of the gradient method and the results obtained were published in paper [1]. Since it turned out that linear compensation of the selected system was possible, further investi- gations on the correction possibilities of the system, whose focal distances are presented in Fig. 2 were performed. This system is not yet corrected.

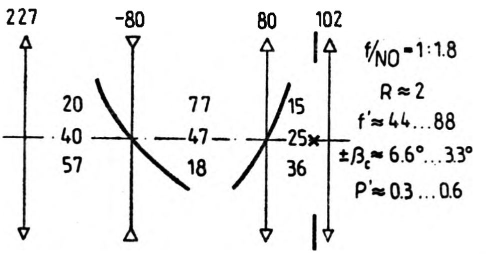

Fig. 2.

Imaging errors calculated with third-order approximation vs. the form factors of the lenses for minimum, medium and maximum focal dis- tances are plotted in Fig. 3. For sake of perspicuity, only the spherical aber- ration, the central coma and the meridional image field curvature are taken into account. (The distortion of the objective not shown here does not exceed $2^0/_0$). In the neighbourhood of form factors, pertinent to the indicating verti- cal lines drawn in Fig. 3, the zoom objective was apparently corrigible in third- order approximation. After performing the linearization of the paths of the moving components the system shown in Fig. 4 was obtained.

The correction of the zoom objective was performed in the following steps: i) by the iterative decreasing of the third-order and the trigonometrically calcula- ted image forming errors, and ii) by applying linear fine correction.

The correction of the spherical aberration was achieved by applying to the components of the first cemented composite lens glasses of different index

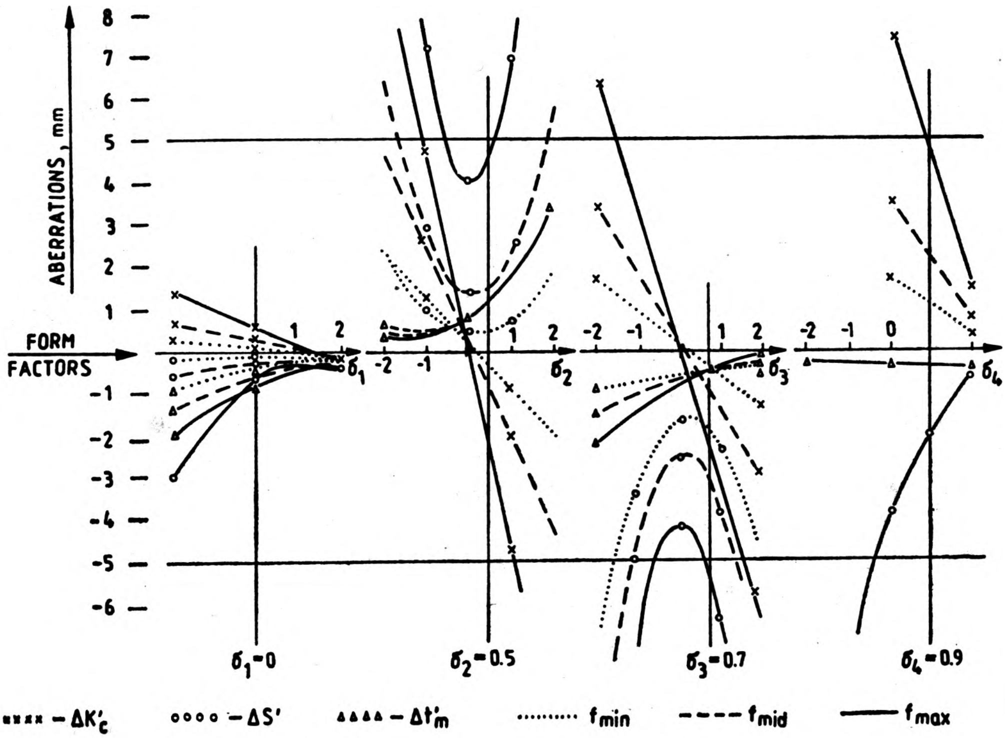

Fig. 3

of refraction. For the correction of chromatic aberration all the cemented lenses had to be composed of glass materials of different dispersion. (However, in the case of components of the first three lenses only the Abbé-numbers are different, the indices of refraction being the same).

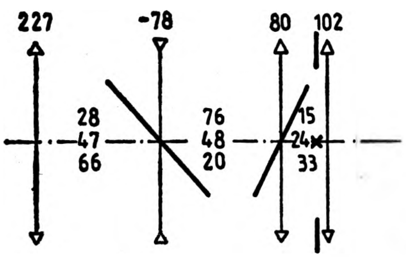

Fig. 4

The sectional diagram of the zoom objective is presented in Fig. 5. Figure 6 shows the conventional aberration graphs of the zoom objectives as well as the meridional dimension of spot diagram corresponding to arbitrarily selected points of the image field. It can be seen that, according to Conrady's criteria, the image quality is good within the whole image field and the entire

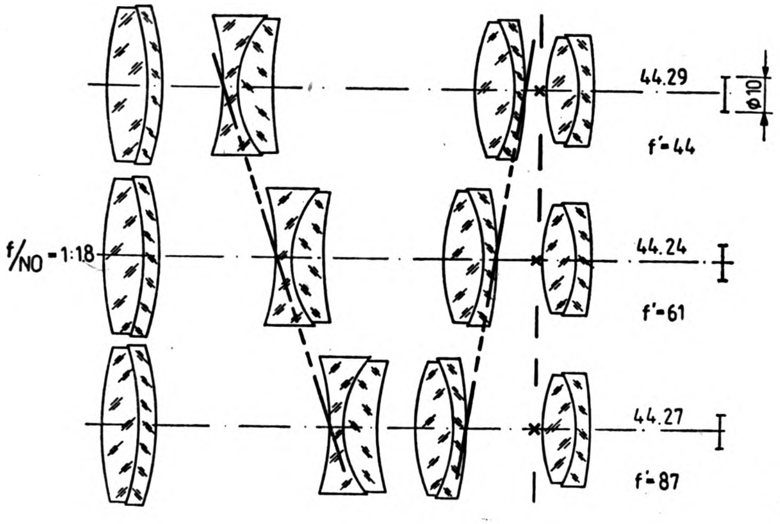

Fig. 5

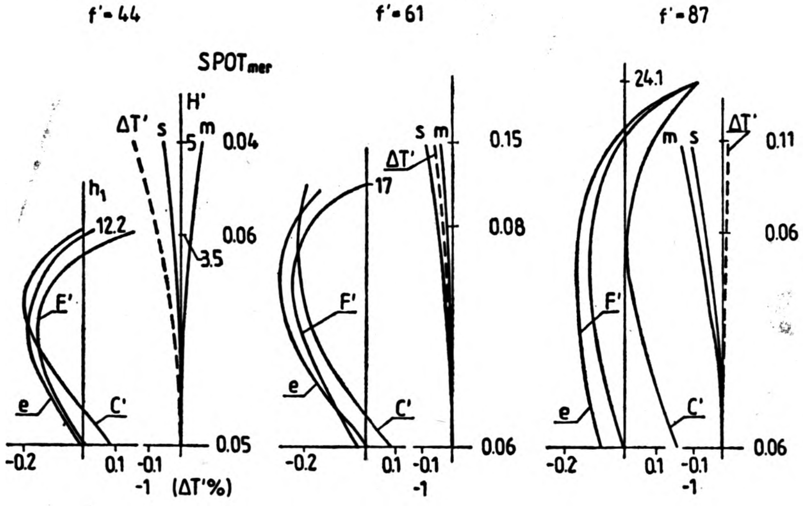

Fig. 6

range of the variable focal distance, except for the edge of the image field which, in case of medium focal distances, can be qualified as sufficient.

In conclusion, we may state that in the case of more severe optical requirements, for example, larger zoom range, larger relative aperature and image field, as well as even more improved image quality, they may be fulfilled by increasing the number of lenses and using the same design principles and methods.

Reference

[1] KALLÓ P., Optik **62** (1982), 39–43.

Received August 3, 1983