distances for the particular waves, it is easy to notice that the system may be considered as being corrected in the whole range of the superachromatic correction because $|\Delta s_{max}| = 0.008$. The general conclusion is that condition (1) is a sufficient and not necessary one. Thus there are some more three-lens combinations applicable to superachromatic correction beside those admissible by Herzberger condition. The problem is being examined in detail and the results will be published in the next paper.

References

[1] Gaj M., Nowak J., Optik 25, 1967, 203.
[2] Gaj M., Nowak J., Optica Applicata 1, 1971, 51.
[3] Gaj M., Nowak J., Optica Applicata (in print).
[4] Herzberger M., Mc Clure N. R., Applied Optics 2, 1966, 553.

Maciej Rafałowski *

On an Attempt of Automizing the Lay-out Calculation on Computer

In the paper an attempt has been made to apply a computer to the automation of the lay-out calculation of optical systems.

The lay-out computing for more complex systems and particularly for those of variable magnification are usually tedious and give no guarantee of resulting in an optimal variant. Thus, it may be temptative to try to make the computer to do the job partly. An automation of the analytic evaluation of the optimal system parameters, after having it developed, have to be considered as possible in principle.

Among the discouraging factors appearing by any automation trial the following are to be mentioned in the first line: the great variety of requirements, with may be met in particular systems, the difficulties in determining any reliable criteria for the system quality evaluation at this stage of the design as well as the fact that the decisions taken during the lay-out calculation influence essentially the later correction procedure. For this reason a wide possibility of designer's intervening during the process of computing would be very helpful.

To adjust the calculation to the particular computer the properties of the optical system have been described by a merit function of the form

$$F = \sum \left(\frac{A_{i0} - A_i}{T_i}\right)^2 \tag{1}$$

i.e. by a sum of the squared deviations of the real properties A_i devided by their respective tolerances; the latter playing the role of the importance measure of the particular features (the inessential properties are eliminated by assuming the corresponding $T_i = 0$ in the data deck). The above function has to be minimized.

*) Instytut Konstrukcji Przyrządów Precyzyjnych i Optycznych Politechniki Warszawskiej, Warszawa, ul. Koszykowa 75, Poland.

The lay-out calculations are based on considerable simplification of both the system parameters (thin lens approximation, no treatment errors included) and the calculation accuracy requirement. The formulation of the requirements for the system is usually reduced at this stage as well. For the purpose of programming the following magnitudes have been accepted as the system parameters: thin lens powers, spaces, glass parameters (n and ν). Their values have to be optimized with respect to some gabarite properties chosen from among the following: focal length, maximal admissive length of the system, distance from the object to the image, position of the object, of the image and of the pupils with respect to the first and the last element of the system, both the longitudinal and lateral chromatism. Petzval's curvature and maximal diameters of the lenses, while the values of the magnification, image height, vignetting coefficient and aperture are being kept constant ($\tan u_{max}$, N, or D_z). It is a characteristic feature of the lay-out computing that the ranges of parameters to be changed are limited (for instance by the design conditions) as well as that of the required properties of the system are onesidedly limited. This results in discontinuity of the merit function and diminishes the effectivity of the interaction procedures.

For the purpose of programming a gradient method for the merit function minimizing has been applied because of both its simplicity and calculation speed and, last but not least, its less sensitivity to the merit function discontinuities.

The programme enables to restrict or to block the variability of the majority of the parameters. The dumping of the particular parameters variability has also been applied by normalizing them with the help of the elementary increases (the same that were used to the estimation of the merit function derivatives as a ratio of finite differences).

The said programme was carefully tested. During examination as a standard system to compare with an enlarger objective ($f = 55$), consisting of three lenses, has been chosen. In systems to be examined only those features were corrected which were important for the enlarger objectives, i.e. the focal length, the chromatic aberrations and the Petzval curvature.

The results of three trials are presented in table. In variant 1 the original system was badly aberrated so that the variation of all the parameters was needed. As a result of 10 iterations a new system was obtained which requires some further correction, in particular, because of too great field curvature and longitudinal chromatism. However, a possibility of simplifying the preliminary calculation when designing a system, has proved to be a real one.

	f	C_w	C_p	Petz.	FO
Required value	55.0	0.00000	0.00000	0.30000	0.000007
Variant I original value	992.670	0.00005	−28.796	0.3548	2.46115
final value	56.197	0.00072	−1.1240	0.68575	0.00067
Variant II original value	51.094	−0.00087	−0.62824	0.67780	0.00040
final value	56.335	−0.00271	−0.15103	0.36924	0.00002
Variant III original value	56.088	−0.00029	−0.11809	0.35360	0.000012
final value	55.394	−0.00054	0.01343	0.35814	0.000006

f — focal length
C_w — chromatism of magnitude
C_p — chromatism of position
Petz. — Petzval curvature
FO — merit function value

In variant two the starting system was of arbitrarily accepted powers of particular elements, the other (fixed) parameters being identical with those of the standard system.

In variant three the quality of the standard system has been improved after a short correction, resulting in a merit function twice less than the original one.

The programme may be easily generalized by introducing some additional parameters (for instance lens radia or other shape parameters) and adding some other conditions to the merit function (for instance, including the estimation of the geometrical aberrations) to make it more useful for further correction. Also, there exists a possibility of introducing the expression characterizing systems of variable magnification. When computing system of these types the advantage of automizing the lay-out calculation may by succesfully exploited.

Miron Gaj, Anna Magiera, Leon Magiera *

Application of the Higher Order Aberration to the Optical System Calculation

Wave aberrations are a basis for a number of image quality criteria. One of the estimation methods of the wave aberrations exploits an existing dependence between transversal aberrations and wave aberrations. Practical realisation of the method consists in expressing the coefficients of the wave function development into series by the transversal aberration coefficients. It is convenient to use the expressions for the transversal aberrations in the form given by H. A. Buchdahl [1] and the developement of the wave function as proposed by Nijboer [2]. Clearly, the accuracy of the calculations depends on the aberration order. Juan L. Rayces and Hsiao-Hung Hsieh [3] gave a relation between the Nijboer coefficients and those due to Buchdahl, taking account of contributions to the aberrations of third order and fifth order, only (first and second order due to Buchdahl). As for many systems such an accuracy is insufficient, the formulas for Nijboer coefficients taking account of the contributions coming from the seventh order terms, in addition to the lover order terms, have been derived in the following form

$$-RN_{20} = \frac{2\sigma_3+\sigma_4}{2}H^2 + \frac{\mu_{10}+\mu_{11}}{4}H^4 + \frac{\tau_{18}+\tau_{19}}{4}H^6$$

$$-RN_{22} = \frac{\sigma_3}{2}H^2 + \frac{\mu_{10}-\mu_{11}}{4}H^4 + \frac{\tau_{18}-\tau_{19}}{4}H^6$$

$$-RN_{31} = \sigma_2 H + \frac{\mu_7}{2}H^3 + \frac{\tau_{15}+\tau_{16}+\tau_{17}}{4}H^5$$

$$-RN_{33} = \frac{\mu_8-\mu_9}{6}H^3 + \frac{2\tau_{15}+2\tau_{16}-3\tau_{17}}{24}H^5$$

$$-RN_{40} = \frac{\sigma_1}{4} + \frac{\mu_4}{4}H^2 + \frac{8\tau_{11}+3\tau_{12}-3\tau_{14}}{23}H^4$$

*) Instytut Fizyki Technicznej Politechniki Wrocławskiej, Wrocław, Wybrzeże S. Wyspiańskiego 27, Poland.