Preface

A very wide selection of excellent books are available to the reader interested in geometric optics. Roughly speaking, these texts can be divided into three main classes.

In the first class (see, for instance, [1–14]), we find books that present the theoretical aspects of the subject, usually starting from the Lagrangian and Hamiltonian formulations of geometric optics. These texts analyze the relations between geometric optics, mechanics, partial differential equations, and the wave theory of optics. The second class comprises books that focus on the applications of this theory to optical instruments. In these books some essential formulae, which are reported without proofs, are used to propose exact or approximate solutions to real-world problems (an excellent example of this class is represented by [26]). The third class contains books that approach the subject in a manner that is intermediate between the first two classes (see, for instance, [15–21]).

The aim of this book, which could be placed in the third class, is *to provide the reader with the mathematical background needed to design many optical combinations that are used in astronomical telescopes and cameras*.[1] The results presented here were obtained by using a different approach to third-order aberration theory as well as the extensive use of the software package ***Mathematica***®.

The third-order approach to third-order aberration theory adopted in this book is based on Fermat's principle and on the use of particular optical paths (not rays) termed *stigmatic paths*. This approach makes it easy to derive the third-order aberration formulae. In this way, the reader is able to understand and handle the formulae required to design optical combinations without resorting to the much more complex Lagrangian and Hamiltonian formalisms and Seidel's relations. On the other hand, the Lagrangian and Hamiltonian formalisms have unquestionable theoretical utility considering their important applications in optics, mechanics, and the theory of partial differential equations. For this reason the Lagrangian and Hamiltonian optics are widely discussed in Chapters 10–12.

[1]A professional textbook in astronomical optics is [22].

The use of *Mathematica*® to design optical combinations is shown to be very convenient. In fact, although the aberration formulae are obtained in an elementary way, their application in the design process necessitates a lot of calculations. Using *Mathematica*® it is possible to implement programs that allow us to realize the third-order optics of all the astronomical combinations described in this book. Although experience has shown that a design based on third-order optics is not always acceptable, this approach can be used as a starting point of any optimization method available in professional softwares, like ***Oslo*** and ***Atmos***, the simplest versions of which can be freely downloaded from the Internet. However, we must bear in mind that the optimization methods will only give correct results if the data used in the approximate design are very similar to those determined in final project. These methods must be handled with great care, since they will very often lead to a new design that is worse than the original one. The reason is that the function to be minimized contains many minima which are very close to each other and do not correspond to an effective improvement in the optical combination. For this reasons the author, with the help of A. Limongiello, developed the software ***Optisoft***, working under *Microsoft Windows*, which allows the *final* forms of all the optical combinations considered in this book to be obtained.

In the first chapter, the essential aspects of an optical system $\mathbb{S}$ with an axis of rotational symmetry are introduced. Moreover, we analyze all the data supplied by optical software in order to *check* whether a given optical system $\mathbb{S}$ is acceptable or not. In Chapter 2 Gaussian optics is developed from Fermat's principle. In this chapter the Gaussian characteristics of $\mathbb{S}$ are described: conjugate planes, magnification, focal and nodal points, principal planes and optical invariants. The matrix form of the Gaussian approximation is presented in detail. All of the Gaussian data for an optical system can be derived using the notebook ***TotalAberrations***.[2] Finally, the approach via Fermat's principle is compared with a more traditional presentation of Gaussian optics.

In Chapter 3 a new approach to the third-order monochromatic aberrations that is based on both Fermat's principle and *stigmatic paths* is described. Here it is shown that these optical paths can be used in Fermat's principle instead of the real rays, with the advantage that the stigmatic paths are completely known, since they are determined by Gaussian optics. A new section contains the evaluation of third-order aberrations in the exit pupil. The third-order aberrations for any optical system can be obtained in mathematical form using the notebook ***TotalAberrations***. It should be noted that the symbolic formulae are so dense for optical systems containing many elements with finite thicknesses that they are not practical to apply.

Chapter 4 contains a brief introduction to fifth-order aberrations and their classification. It is also shown that third-order aberrations contribute to fifth-order aberrations. Finally, a proposal is presented to evaluate the fifth-order aberrations starting from the third-order ones in the image plane and exit pupil.

[2] A programm written with ***Mathematica***® can be implemented as notebook or package.

Chapter 5 contains an analysis of the Newtonian and Cassegrain telescopes based on conic mirrors. In Chapters 6 and 7, we study photographic cameras containing lenses and mirrors (Schimdt, Wright, Houghton, Maksutov) as well as the corresponding catadioptric Cassegrain telescopes. Finally, the third-order design of achromatic doublets or apochromatic doublets and triplets is discussed in Chapter 8. Some other interesting optical devices, including the Klevtsov combination, the Baker–Schmidt flat-field camera, the Buchroeder camera, the Baker–Nunn camera, and the Petzval objective optical combinations with sub-corrector are studied in Chapter 9.

Finally, the Lagrangian and Hamiltonian formulations of geometric optics and Seidel's third-order aberration theory are treated in Chapters 10–12. Optics in anisotropic media is sketched in Chapter 13.

Each optical combination analyzed in the book is accompanied by a notebook that automates its third-order design. All these notebooks work in version 10.x, 11 of *Mathematica*® and may be downloaded from the publisher's website at: http://extras.springer.com. These notebooks represent an integral part of the book for many reasons. First, they contain many calculations that appear in the book and many worked exercises. Moreover, many other exercises can be carried out by the reader him- or herself. Finally, carefully studying the programs contained in the notebooks could provide a good way for readers to learn how to program with *Mathematica*®.

We conclude by noting that amateurs with sufficient knowledge of mathematics may find it interesting to learn how to derive the formulae listed in many manuals from the general laws of geometric optics. On the other hand, amateurs who are not interested in learning the mathematical background of optics can use the notebooks contained in the book to rapidly obtain the third-order designs of many cameras and telescopes used in astronomy.

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