Preface

Astronomical Optics and Elasticity Theory is intended to serve both as a text and as a basic reference on *"active optics methods."* Mainly elaborated for astronomy, and following a conceptual idea originated by Bernhard Schmidt, the first developments of active optics began in the 1960s. These methods allow one to transform by a highly continuous process a spherical surface into the desired *aspherical* surface, as well as to correct tilt and decentering errors between telescope mirrors, to control the focal position by curvature variation, etc, so as to achieve diffraction-limited performance. The recent spectacular increase in telescope sizes, active image correction of telescope errors and atmospheric degradation, and the advent of detectors having nearly perfect quantum efficiencies has led to remarkable progress in observational astronomy, whose large telescopes now currently operate with active optics.

The first chapter concerns optical design and elasticity theory; I thought it useful to introduce these two topics by brief historical accounts. Most of the following chapters are dedicated to the generation of axisymmetric aspheric mirrors, as well as non-axisymmetric mirrors. Active optics methods are investigated for corrections of focus, and for aberrations of third and higher orders. Optical aberration modes that can be superposed by elastic flexure belong to a subfamily that I called Clebsch-Seidel modes. Such aberration correction modes are generated by multimode deformable mirrors. Depending on the adopted thickness class – constant or variable – various active mirror configurations are discussed using the so-called *tulip, cycloid, vase, meniscus*, and *double-vase mirrors*. Two chapters are dedicated to optical designs with the Schmidt concept; the first includes my 1985 high-order analysis of the axial wavefront reflected by a spherical mirror, the system resolving power for each option – with either a refractive, a reflective, or a diffractive corrector – and the optimal corrector shape for each design type; in the second, active optics aspherization methods of the corrector element are developed for catadioptric or all-reflective telescope types and for aspherized grating spectrographs. Another chapter on large mirror support systems treats the minimization of flexure against gravity and in situ active optics control on large telescopes. A short chapter concerns the flexure of thin lenses when bent by a uniform load; this is useful to produce stigmatic singlet lenses by active optics. Grazing incidence X-ray telescopes can also greatly benefit from the ripple-free active aspherization process for various two-mirror designs and particularly for a mirror pair strictly satisfying the sine condition; a theory of weakly conical shells is proposed in a special chapter where the aspherization of the mirrors is obtained by pure extension (or contraction).

The book provides a foundation for finding a mirror thickness geometry and an associated load configuration which can generate one or several fixed surface optical modes – this in the most practicable conditions. Computational modeling, the third branch of science which bridges analytical theory and experimentation, is the ultimate method for accurately solving the deformations of a solid for any configuration of equilibrium-force sets. In the final design stage for an active optics mirror, finite element analysis of the three-dimensional deformations allows optimizing its thickness geometry to obtain the desired mirror figure. However, geometrical optimizations with such codes must require sufficient user knowledge in elasticity theory, and a preliminary analytic solution of the problem by a first approximation theory. This preliminary approach with the theory – the aim of this book – is all the more necessary since there are generally several alternatives for generating a given surface type – as, for instance, with the various solutions presented here for *variable curvature mirrors*.

The beautiful theory of axisymmetric shallow shells, elaborated by Erik Reissner in 1946, is one of the greatest analytic achievements in elasticity theory. In the axisymmetric flexure case, this theory is here used for the aspherization of fast f-ratio mirrors. In addition, a convergent iteration vector which acts towards the required flexure is implemented for determining the thickness distribution of *meniscus-, vase-*, and *closed-form mirror shells*. The method has proved sufficiently accurate that no significant corrections were found necessary from finite element analysis. Active optics aspherizations of primary and secondary telescope mirrors were carried out by the *Laboratoire d'Optique de l'Observatoire de Marseille* (LOOM). The results of stress figuring or in-situ stressing of all the axisymmetric mirrors directly designed from Reissner's theory – as for instance with the modified-Rumsey anastigmatic telescope presented here – show that the axial wavefront correction errors are within conventional diffraction limited criteria.

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