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J. F. JAMES
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SPECTROGRAPH DESIGN FUNDAMENTALS

In recent years enormous changes have occurred in the field of optical spectrometry. The classical spectrometer has become obsolete and the spectrograph, in combination with the CCD detector, now offers a vastly superior approach. Although the basic optical principles remain unchanged the design considerations are very different, and in many cases more demanding. However, developments in computer ray-tracing and computer-aided design have coped with these extra impositions and have allowed the construction of a new generation of spectrographs.

The book covers the general principles of spectrographic design, and the practical and engineering aspects of a broad range of spectrographs and spectrometers. This allows the reader to make an informed choice of instrument. It will be of particular use when none of the immense array of manufactured spectrographic and spectrometric instruments is suitable for a specialised task. The book deals with materials and methods of construction and includes suggestions for the choice of optical table, the design of slit mechanisms, and adjustable mirror, grating and lens mounts, with suggestions for the alignment and calibration of the finished instrument.

Spectrograph Design Fundamentals describes the design and construction of optical spectrographs. It will be a valuable resource for academic researchers, graduate students and professionals in the fields of optics, spectroscopy and optical engineering.

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Preface

Thirty-eight years ago, together with my colleague the late Robert Sternberg, I wrote a book entitled *The Design of Optical Spectrometers*. It described the state of the art as it was at that time after the great advances which had come in the previous ten years, and it was intended for people who wished to build a spectrometer tailored to a specific purpose, where perhaps one of the commercial designs was inadequate, unsuitable, unnecessarily cumbersome, or expensive.

When at last the time came to consider a new edition it became clear that the technology had changed so much that the classical optical spectrometer, in the sense of *monochromator*, was more or less obsolete and that later developments such as the desktop computer and the charge-coupled device had restored the spectrograph to its former eminence. The restoration in no way annulled the optical improvements of the previous 30 years but new constraints posed new problems in design. These problems are now solved and the solutions are presented here.

The fundamentals of optical design have not changed, but the constraints are now all different, and such properties as flat fields are needed where before they could be largely ignored; and focal ratios matter again when previously we could design everything so that such trivia as spherical aberration and coma could be neglected.

There is, as always, a gap to be bridged between the elegant theory presented in the undergraduate textbooks and the practical spectroscopic instrument standing on the laboratory bench or bolted to the Cassegrain focus of an astronomical telescope. The gap is partly in the limitations imposed by the curse of non-linearity in geometrical optics and the contumacious aberrations it produces, and partly in the sometimes obstinate physical properties of the materials of construction. As always in scientific instrument making, the art is in knowing what must be precise and exact and what can be left go hang at a crude level. There are tricks in this trade just as in any other. The traditional engineer's description of a physicist is 'someone who designs a box that must be screwed together from the inside'. (There is a parallel physicist's definition of an engineer: someone who, when asked 'what is three times four?' will get out a slide rule and answer 'about twelve'.) There is an element of truth in this and some of the hints in these pages may help to refute the calumny.

This work is thus intended for the new generation of researchers who desire high efficiency in an instrument tailored to their own particular purpose, and who have access to a mechanical workshop of moderate size where an instrument of their design can be constructed. There has been no attempt to venture into the new fields of optical resonant scattering spectroscopy, tunable laser spectroscopy or other specialised techniques and so the book is directed to chemists, astronomers and aeronomers as much as to physicists.

Manufactured spectrographs are in no way deficient, but are necessarily compromises, both in performance and cost, and are often intended for teaching or dedicated to a routine task such as sample analysis. A specially designed instrument has no difficulty in excelling them for a particular investigation, particularly in academic research fields where new areas are being explored and where no established technology yet exists.

It is to the basic optical design and construction of such individual instruments that this book is dedicated. I also take the opportunity of acknowledging my late good friends and colleagues, Dr H. J. J. Braddick, Rob Sternberg and Larry Mertz, from whom I learned so much.

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