

An Introduction to Practical Laboratory Optics

Aimed at laboratory workers and students taking laboratory courses in experimental optics, this book introduces readers to optical instruments and their uses.

The book explains the basic operation of lenses, mirrors, telescopes in the laboratory and under field conditions, how to use optical instruments to their maximum potential and how to keep them in working order. It gives an account of the laws of geometrical optics which govern the design, layout and working of optical instruments. The book describes the interactions of polarized light with matter and the instruments and devices derived from this, and discusses the choice of spectrometers and detectors for various spectral regions, with particular attention to CCD cameras.

The emphasis throughout is on description, with mathematical precision confined to the appendices, which explain the ray transfer matrix and outline the Seidel theory of optical aberrations. The appendices also introduce Fourier methods in optics and Fourier transform infra-red spectrometry.

J. F. JAMES has held teaching positions at The Queen's University, Belfast, and the University of Manchester, and is one of the pioneers of Fourier spectroscopy. He is the author of *A Student's Guide to Fourier Transforms*, now in its third edition, and *Spectrograph Design Fundamentals* (Cambridge University Press, 2011 and 2007 respectively).

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J. F. JAMES



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Preface

The most famous and illustrious mis-user of an optical instrument is Sherlock Holmes. There is an iconic figure of him with Inverness cape, deerstalker hat and calabash pipe, peering through a magnifying glass, the latter held at arm's length, to inspect a possible blood stain.

This is the wrong way to use a magnifying glass – which incidentally should always have a plano-convex lens rather than the biconvex lens with which many cheap versions are provided. The glass should be held close to the eye, plane side facing, and the object brought in until it is in clear focus at a comfortable distance for viewing. This gives the clearest image, the widest field and the minimum of optical aberrations. It is the attention to small detail like this which helps ensure success. Watchmakers do it properly, with a *loupe*, a lens held, like a monocle, in the eye socket.

In experimental science, especially in physics laboratories, it is sometimes found, when beginning a new piece of basic research, that no appropriate apparatus exists and that it is necessary to improvise. The traditional laboratory stand-and-clamp then comes into its own, followed, after some experimentation, by a properly designed system with an optical bench or table with lenses, mirrors and other basic optical elements for measuring and analysing radiation. Skills in the design and assembly of such provisional devices are part of the true experimenter's art.

In any field of science, a large part of experimentation involves light, be it photography, photometry, polarimetry, microscopy or spectroscopy, and the proper selection and application of optical elements and devices may have a great effect on the satisfactory outcome of experimental work. Much can be done with standard, versatile 'common-user' instruments such as cameras and microscopes, but all too often there is a particular measurement to be made where apparatus must be designed and constructed before the experiment can be done.

No mention is made here of individual manufacturers of optical equipment. Even famous firms come and go or are swallowed by other, bigger fish. But they advertise in the various scientific journals and their catalogues provide valuable information about their products and much useful background information on optics generally.

What follows here is an account of the basic principles of common optical instruments, the elementary laws of optics affecting them and descriptions of some of the ingenious devices which have been invented over the last few centuries and which are of particular use in the laboratory, in the workshop and in the field.¹

I make no apology for presenting theorems and useful equations without proof. This is a handbook, not a treatise, and there are many learned works on library shelves which will supply the deficiency if a more thorough explanation is needed. The list of further reading at the end of this book will point the inquirer in the right direction.

Finally, a warning! Geometrical optics is a dangerous subject and I have left it to the end. For most sensible people it is a miserably boring agglomeration of tedious, elementary calculation, arithmetic and geometry, but to others it is an obsession like chess or golf or computer programming. The victim is sucked into a quagmire of invention, ingenuity and improvement, forever trying to achieve the perfect lens or telescope or whatever. The lucky designer is the one who knows when to stop calculating and start building. Yet there is an immense sense of achievement when the last element of the new system is put in its place, the last adjustment is made, and one's final fears evaporate as a clear, sharp image appears in its proper place, just as calculated. This is invention at its most satisfying.

Beppu, Japan

Beppu, Japan, October 2013

J. F. James

¹ 'Field', here, is the usual euphemism for mosquito-ridden swamp or bare, windswept mountain-top where some deranged scientists choose to do their data-gathering.