

Cambridge University Press

978-1-107-05054-9 - An Introduction to Practical Laboratory Optics

J. F. James

Frontmatter

[More information](#)

---

## **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).

Cambridge University Press  
978-1-107-05054-9 - An Introduction to Practical Laboratory Optics  
J. F. James  
Frontmatter  
[More information](#)

---

Cambridge University Press

978-1-107-05054-9 - An Introduction to Practical Laboratory Optics

J. F. James

Frontmatter

[More information](#)

---

# An Introduction to Practical Laboratory Optics

J. F. JAMES



**CAMBRIDGE**  
UNIVERSITY PRESS

Cambridge University Press  
978-1-107-05054-9 - An Introduction to Practical Laboratory Optics  
J. F. James  
Frontmatter  
[More information](#)

CAMBRIDGE  
UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning and research at the highest international levels of excellence.

[www.cambridge.org](http://www.cambridge.org)

Information on this title: [www.cambridge.org/9781107687936](http://www.cambridge.org/9781107687936)

© J. F. James 2014

This publication is in copyright. Subject to statutory exception and to the provisions of relevant collective licensing agreements, no reproduction of any part may take place without the written permission of Cambridge University Press.

First published 2014

Printed in the United Kingdom by Clays, St Ives plc

*A catalogue record for this publication is available from the British Library*

*Library of Congress Cataloguing in Publication data*

James, J. F. (John Francis), author.

An introduction to practical laboratory optics / J.F. James.

pages cm

Includes bibliographical references.

ISBN 978-1-107-05054-9 (Hardback) – ISBN 978-1-107-68793-6 (Paperback)

1. Optical instruments—Handbooks, manuals, etc. I. Title.

QC371.J36 2014

681'.4—dc23 2014014037

ISBN 978-1-107-05054-9 Hardback

ISBN 978-1-107-68793-6 Paperback

Cambridge University Press has no responsibility for the persistence or accuracy of URLs for external or third-party internet websites referred to in this publication, and does not guarantee that any content on such websites is, or will remain, accurate or appropriate.

Contents

<i>Preface</i>	<i>page ix</i>
<b>1 Introduction: centred optical systems</b>	<b>1</b>
1.1 The common properties of optical instruments	1
1.2 Optical elements	1
1.3 Concepts in optical instrument design	3
1.4 Gaussian optics	11
1.5 Aberrations – a conspectus	13
<b>2 Telescopes and binoculars</b>	<b>15</b>
2.1 The visual telescope	15
2.2 Galilean telescopes	16
2.3 Keplerian refractors	17
2.4 Erecting telescopes	17
2.5 Binoculars	19
2.6 Applications of the refracting telescope	21
2.7 Reflecting telescopes	22
2.8 The Newtonian telescope	23
2.9 The Cassegrain telescope	23
2.10 Refractors versus reflectors	26
2.11 Focal reducers	27
2.12 Image rotators	29
<b>3 Eyepieces, eyes and colour</b>	<b>30</b>
3.1 Eyepieces	30
3.2 Eyepiece properties	32
3.3 Astronomical photography through an eyepiece	35
3.4 Visual observation	36

vi	Contents
3.5	The eye as an optical instrument 38
3.6	The perception of colour 39
<b>4</b>	<b>Cameras and camera lenses 43</b>
4.1	Introduction: the photographic lens 43
4.2	The double Gauss lens 44
4.3	Telephoto lenses 45
4.4	Wide-angle lenses 45
4.5	Fish-eye lenses 47
4.6	Zoom lenses 49
4.7	Practical aspects 49
4.8	Architectural photography 51
4.9	Schlieren photography 51
4.10	The optical transfer function 54
4.11	The Bores points of a lens 55
<b>5</b>	<b>The scientific CCD camera 57</b>
5.1	The traditional silver halide camera 57
5.2	Scientific digital photography 60
5.3	Calibration 62
5.4	Radioactive lenses 62
<b>6</b>	<b>Spectrometry 64</b>
6.1	The prism spectroscope 64
6.2	The direct vision spectroscope 69
6.3	Diffraction grating spectrometry 70
6.4	Grating mountings 71
6.5	Concave gratings 76
6.6	Illumination of a spectrometer 77
6.7	Grating ghosts 80
6.8	The alignment of a grating spectrograph 81
<b>7</b>	<b>Interferometers and their uses 84</b>
7.1	Interferometry 84
7.2	Oscillation, phase and phase-difference 84
7.3	Coherence 85
7.4	Division of wavefront 86
7.5	Division of amplitude 88
7.6	Interferometers 88
7.7	The Fizeau interferometer 90
7.8	The Michelson interferometer 91
7.9	The Fabry–Pérot étalon 93

7.10	The Mach–Zehnder interferometer	99
7.11	The Sagnac interferometer	101
7.12	Fine displacement measurement	102
7.13	Optical resonators	103
<b>8</b>	<b>Electro-optical effects and their practical uses</b>	<b>104</b>
8.1	Introduction: polarized light	104
8.2	Polarization effects	105
8.3	Polarizing elements	108
8.4	Laboratory uses of polarized light	109
8.5	Faraday effect	110
8.6	Kerr effect	111
8.7	Pockels effect	113
8.8	A practical example of applied polarizing effects	113
<b>9</b>	<b>Microscopes and projectors</b>	<b>116</b>
9.1	Projectors	116
9.2	The Fresnel lens	118
9.3	Microscopes	119
9.4	Köhler illumination	120
9.5	Travelling microscopes	122
<b>10</b>	<b>Siderostats and coelostats</b>	<b>124</b>
10.1	The celestial sphere	124
10.2	Equatorial telescope mountings	124
10.3	Coelostats	126
<b>11</b>	<b>The detection and measurement of radiation</b>	<b>130</b>
11.1	The geometry of radiation measurement	130
11.2	The detection of radiation	132
11.3	The classification of radiation detectors	133
11.4	The far infra-red	133
11.5	The middle infra-red	134
11.6	The UVOIR region	134
11.7	The far ultra-violet	136
11.8	Types of spectra	137
11.9	Black body radiation	138
<b>12</b>	<b>Practicalities</b>	<b>141</b>
12.1	Cleaning optical surfaces	141
12.2	Mounting optical parts	144
12.3	Optical filters	145

Cambridge University Press  
978-1-107-05054-9 - An Introduction to Practical Laboratory Optics  
J. F. James  
Frontmatter  
[More information](#)

viii	Contents	
<i>Appendix A</i>	<b>Gaussian optics</b>	149
<i>Appendix B</i>	<b>Optical aberrations</b>	162
<i>Appendix C</i>	<b>A brief introduction to Fourier optics</b>	174
	<i>Further reading</i>	181
	<i>Index</i>	183



Cambridge University Press

978-1-107-05054-9 - An Introduction to Practical Laboratory Optics

J. F. James

Frontmatter

[More information](#)

---

## 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.

Cambridge University Press

978-1-107-05054-9 - An Introduction to Practical Laboratory Optics

J. F. James

Frontmatter

[More information](#)

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.<sup>1</sup>

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

<sup>1</sup> '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.