

Contents

Preface — VII

Introduction — 1

Chapter 1

Foundations of geometrical optics — 3

- 1.1 Electromagnetic waves in a homogeneous medium: the refractive index — 3
- 1.2 Inhomogeneous medium: eikonal equation and mirage formation — 6

Chapter 2

Fermat's principle: light reflection and refraction — 10

- 2.1 Changing the light trajectory at the boundary between two media — 11
- 2.2 Total internal reflection of visible light — 16
- 2.3 Total external reflection of X-rays — 18

Chapter 3

Fermat's principle: focusing of visible light and X-rays — 21

- 3.1 General approach — 21
- 3.2 Spherical lenses — 25
 - 3.2.1 Focusing X-rays by a void — 26
- 3.3 Focusing by reflection — 27
 - 3.3.1 Focusing and defocusing by a parabolic mirror — 28
 - 3.3.2 Kirkpatrick-Baez mirrors for focusing the synchrotron radiation — 29
- 3.4 Thin lenses — 31
- 3.5 Limitations of Fermat's principle — 35
- 3.6 Conventional light microscope — 37
 - 3.6.1 Köhler illumination and Abbe theory of image formation — 38

Chapter 4

Refractive index in anisotropic crystals — 42

Chapter 5

Polarization, birefringence, and related phenomena — 49

- 5.1 The Brewster angle for visible light and X-rays — 49
- 5.2 Birefringence in anisotropic crystals — 51
- 5.3 Producing polarized light — 56
- 5.4 Circular polarization and rotation of the polarization plane — 62

- 5.5 Induced birefringence — **66**
- 5.6 Optical activity — **67**
- 5.6.1 Faraday effect — **69**
- 5.6.2 Magnetic circular dichroism and circular polarization of X-rays — **69**
- 5.7 Polarization microscopy — **70**
- Appendix 5.A Fresnel equations — **74**
- Appendix 5.B Light ellipsometry and X-ray reflectivity — **77**

Chapter 6

Strong frequency effects in light optics — 83

- 6.1 Skin effect in metals — **86**
- 6.2 Light reflection from a metal — **87**
- 6.3 Plasma frequency — **89**
- 6.4 Negative materials and metamaterials — **91**

Chapter 7

Interference phenomena — 97

- 7.1 Newton's rings — **99**
- 7.2 Interference in thin films — **101**
- 7.3 Structural colors — **104**
- 7.4 Lippmann's color photography — **106**
- 7.5 Gabor holography — **109**
- 7.6 Cherenkov radiation — **112**

Chapter 8

Light and X-ray interferometers — 114

- 8.1 Michelson interferometer — **114**
- 8.2 Fabry-Pérot interferometer — **116**
- 8.2.1 Stimulated light emission — **120**
- 8.3 Mach-Zehnder interferometer — **125**
- 8.4 Bonse-Hart X-ray interferometer — **129**

Chapter 9

Phase-contrast microscopy — 133

- 9.1 Zernike microscope — **133**
- 9.2 Nomarski microscope — **135**
- 9.3 Modulation-contrast microscopy — **136**
- 9.4 Phase-contrast X-ray imaging — **138**

Chapter 10**Fraunhofer diffraction — 141**

- 10.1 Diffraction gratings — **141**
- 10.2 Kinematic diffraction of X-rays in the Bragg scattering geometry — **143**
- 10.3 Producing parallel X-ray beams with a Göbel mirror — **148**
- 10.4 Fraunhofer diffraction of light by a circular hole — **151**
- 10.5 Rayleigh criterion and diffraction limit of optical instruments — **155**

Chapter 11**Beyond diffraction limit — 159**

- 11.1 Confocal microscopy — **159**
- 11.2 Near-field microscopy — **166**
- 11.3 New ideas with negative materials — **170**

Chapter 12**Fresnel diffraction — 172**

- 12.1 X-ray scattering amplitude from an individual crystallographic plane: the Fresnel zone approach — **172**
- 12.2 Fresnel zone construction in transmission geometry — **176**
- 12.3 Light and X-ray focusing by Fresnel zone plates and Bragg–Fresnel lenses — **181**
- 12.4 X-ray microscopy — **183**
- 12.5 The Talbot effect — **190**
- 12.5.1 Employing diffraction gratings for phase-contrast X-ray imaging — **194**

Chapter 13**Optics of dynamical diffraction — 196**

- 13.1 Wave propagation in periodic media from symmetry point of view — **196**
- 13.2 The concept of reciprocal lattice and quasi-momentum conservation law — **199**
- 13.3 Diffraction condition and Ewald sphere — **201**

Chapter 14**Dynamical diffraction of quantum beams: basic principles — 205**

- 14.1 The two-beam approximation — **207**
- 14.2 Novel interference phenomena: Pendellösung and Borrmann effects — **213**
- 14.3 Diffraction profile in the Laue scattering geometry: extinction length and thickness fringes — **218**
- 14.4 Diffraction profile in the Bragg scattering geometry: total reflection near the Bragg angle — **223**

Chapter 15

Specific features of dynamical X-ray diffraction — 229

- 15.1 Dynamical X-ray diffraction in two-beam approximation — **234**
- 15.1.1 Taking account of X-ray polarization — **235**
- 15.1.2 The four-branch isoenergetic dispersion surface for X-ray quanta — **238**
- 15.1.3 X-ray extinction length — **240**
- 15.1.4 Isoenergetic dispersion surface for asymmetric reflections — **241**
- 15.2 The phase-shift plates for producing circularly polarized X-rays — **245**
- 15.3 X-ray beam compression using highly asymmetric reflections — **248**
- 15.4 The use of multocrystal diffractometers for phase-contrast X-ray imaging — **249**

Chapter 16

Optical phenomena in photonic structures — 255

- 16.1 Key ideas — **255**
- 16.2 Light localization in photonic structures — **257**
- 16.2.1 Helmholtz and paraxial wave equations — **258**
- 16.3 Slowing light — **260**
- 16.4 Photonic devices — **264**

List of scientists — 271

Index — 281