

---

# Index

- Abelés method 134
- absorption coefficient 15
  - fine structure 16
- absorption constant 6
- amplitude attenuation 6
- analysis of reflectivity curves 201, 271
- asymmetric diffraction 40, 240
- atomic scattering cross section 6
- atomic scattering factor 6, 12
- autocorrelation function for surface roughness 122
  
- bandpass filter 233
- beam-splitting polarizers 161, 162
- beam splitters 161
- bidirectional reflectivity distribution function 119
- Born approximation 120
- Bose-Einstein statistics 68
- boundary roughness
  - autocorrelation function 216
  - Debye Waller factor 111
  - boundary roughness (*continued*)
    - from reflectivity 206, 207
    - from scattering 208, 209, 210, 211, 214, 216
    - growth models for thin films 216, 217, 219
    - Nevot Croce model 112
    - power spectrum 216
- Bragg condition
  - absorption correction 154
  - in momentum space 106
  - index correction 106
- Bragg diffraction 40
- BRDF=bidirectional reflectivity distribution function 119
- Brewster angle 162
- buffer layer 186
  
- classical states 73
- coherence area 65
- coherence conditions 60
- coherent Fresnel lens 56
- coherent noise 79

## 276 Index

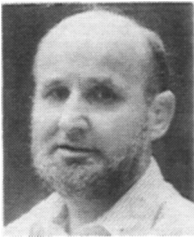
- coherent states 73
- coma 49
- contrast of interference fringes 62
- corona of sun 246, 249
  - emission lines 246
- critical angle 25
- critical momentum 25, 35
- critical wavelength 37
  
- Debye Waller factor 111
- degree of coherence 62
- deposition methods 170
- detector scan 209, 211
- dielectric constant 6
- diffraction efficiency
  - multilayer gratings 238
  - zone plates 88
- Drude model 11
  
- ellipsometry 194
- evanescent wave 28
- Ewald sphere 124
  
- Fabry-Perot resonator 157
- figure errors
  - correction with thin films 245
- filter 230
- filter materials 232
- form factor 107, 114
- free electron gas 7
- Fresnel equations 23
- Fresnel zones 8, 56
- Fresnel-Bragg optics 97
- fringe visibility 63
  
- grating equation 117
  
- high resolution imaging
  - comparison of systems 243
- high-reflectivity mirror
  - bandwidth 151, 152
  - design 140
- high-reflectivity mirror (*continued*)
  - material selection rules 147
  - maximum number of periods 146
  - minimum number of periods 145
  - optimum thickness ratio  $\gamma$  150
  - periodic and quasi-periodic design 149
  - phase shift of standing wave 153
  - quasi-periodic design 143
  - spacer layer 147
- image noise due to shot effect 244
- image reconstruction
  - in three dimensions 74
  - in two dimensions 74, 77
- imaging
  - amplitude addition 40
  - capillaries 43
  - effective surface 47
  - fabrication tolerances 41
  - field size 44
  - intensity addition 42
  - microchannel plates 43
  - sine condition 45, 46
- imaging with coherent illumination 74, 75
- imaging with incoherent illumination 74, 75
- in-situ analysis 171
- in-situ monitoring 194
- induced-transmission filter 144
- intensity fluctuations 64
- ion polishing 171, 181
  
- Kiessig fringes 271
- kinematical theory 108, 109, 110
  - Fourier transform 108, 109, 110
- kinetic energy of evaporant 172
- Kirkpatrick Baez optics 47
  
- laser plasma evaporation 171
- Laue diffraction 40
  
- Mandel's formula 67
- mass absorption coefficient 6

- modes of radiation field 60  
 modulation transfer function, MTF 77, 78  
 momentum space 117  
 momentum transfer 23  
 multilayer gratings 239  
 multilayer mirror monochromator 237  
 multilayer mirrors  
   deposition methods 170  
   material combinations 176  
   performance 177, 178, 179, 180, 181,  
     182, 183, 184, 185  
   spacer materials 174  
   testing 194  
 multilayer theory  
   Bragg reflection 104  
   computer programs 132  
   Darwin Prins model 104  
   Ewald's method 104  
   matrix method 134  
   recursive calculations 132  
   recursive method 105  
   rigorous theories 102, 104  
   vector or kinematical model 102
- nested telescopes 48  
 neutron beam guides 164
- offset scan 209  
 optical constants  
   for elements at 1.54Å 269  
   for neutrons 20  
   measurement 18
- Patterson pattern 202  
 phase retarder 163  
 phase shift near critical angle 30  
 photon bunching 68  
 photon counting statistics 67  
 photon occupation number for blackbody radiation 70  
 photon statistics  
   Bose-Einstein distribution 69  
   laser 69  
   Poisson distribution 69  
   photon statistics (*continued*)  
     thermal source 69  
 Poisson transform 67  
 polarizer for neutrons 164  
 power spectral density=PSD 117  
 PSD and autocorrelation function 122
- quarter-wave plate 163  
 quarter-wave stack 114
- radiation damage 251  
 radiation dose 251  
 random walk in complex plane 64  
 ratio  $\delta/\beta$  34  
 reflectivity at critical angle 28  
 refractive index 6  
 refractive index and atomic scattering factor 9  
 ring cavity 185  
 rocking curve 209, 211  
 ROSAT telescope 48  
 roughness  
   correlation between different boundaries 213, 214, 215  
   power spectral density 216, 218  
   replication 217  
 roughness from PSD (power spectral density) 119
- scattering 116, 120  
   Born approximation 120  
   calculation 215  
   for correlated roughness 122  
   for uncorrelated roughness 122, 124  
   in reciprocal space 210  
   influence of standing wave 214  
   interference structure 213, 214  
   measurement 209  
   Yoneda effect 120  
 scattering in reciprocal space 117, 210  
 Schwarzschild microscope 50, 51, 53  
 self supporting foils 230

## 278 Index

- sine condition 45
- Snells law 23
- soft x-ray spectroscopy 235
- soft x-ray telescopes 247
- spatial frequency 117
- speckle pattern 65
- sputtering and thermal evaporation 171
- standing wave
  - in Bragg reflector 140
  - in front of mirror 31
  - in optimized mirror 142, 143
  - in quarter-wave stack 140, 143
  - period 32
- standing-wave microscopy 153
- stepped mirrors 54
- structure factor 107
- superlattices 124
  - Ewald sphere 124
  - momentum transfer 125
  - reciprocal space 125
  - reflectivity enhancement 127
- supermirror 154, 155, 164
- surface-diffusion parameter 217, 218, 219
  
- tapered waveguides 159
- telescopes 247
- thickness errors 203, 204, 205
- Thompson scattering cross section 6
  
- uncertainty relations 60, 61
  
- Van-Cittert-Zernike theorem 66
- vector model 108, 109, 110
  - Fourier transform 108, 109, 110
  
- water window 179
- waveguide 33, 160
- waveguide modes 159, 160
- whispering gallery mirror 33
- Wolter optics 47
  
- x-ray diffractometer 198
- x-ray lithography 255
- x-ray microscope 250, 251, 252
  - imaging method 250, 251
  - phase contrast 252
  - scanning method 250, 251
- x-ray microscopy 250, 253
  - wet, living specimen 253
- x-ray projection lithography 255, 257, 258
- x-ray proximity printing 255
- x-ray reflectometer 198
- x-ray reflectometer 197, 200
  
- YOHKOH telescope 48
- Yoneda effect 120
  
- zone plates 40
  - aberrations 84, 86
  - diffraction efficiency 88
  - fabrication by sputtering/slicing 95
  - fabrication with electron beam 92
  - geometry 82
  - higher order images 83
  - holographic fabrication 94
  - on reflecting surfaces 97
  - parameters 90
  - ray tracing 85
  - resolution limit 86
  - spectral bandwidth 83





**Eberhard Spiller** received the Dipl. Phys. in 1960 and the Ph.D. in 1964 in physics from the Johann Wolfgang Goethe University of Frankfurt, Germany. He remained with the faculty in Frankfurt until 1968, joined the IBM Research Center in Yorktown Heights in 1968, and became IBM Emeritus 1993. His research interests in Frankfurt included lasers, holography, coherence, and speckle statistics. His early work at IBM was on the broadening of the picosecond pulses in laser mirrors and on the

characteristics of bistable Fabry-Perot resonators. In 1971 he discovered that multilayer mirrors useful for optical instruments should be possible in the vacuum ultraviolet and soft x-ray regions and started to work on their realization. He pioneered the use of synchrotron radiation for x-ray lithography and x-ray microscopy in 1975 and has initiated the development of normal incidence soft x-ray optics for astronomy. He has used multilayer mirrors for high-resolution soft x-ray imaging and has built several x-ray telescopes. These instruments have produced x-ray images of the solar corona with the highest resolution ever obtained. He continues to work in x-ray astronomy and precision optics as an IBM Emeritus.

Dr. Spiller has written book chapters on "X-Ray Lithography" (*Topics in Applied Physics*, Vol. 22, Springer-Verlag, 1977) and "Soft X-Ray Optics and Microscopy" (*Handbook on Synchrotron Radiation*, North-Holland, 1983), organized a conference on "High-Resolution X-Ray Optics" (Proc. SPIE 316, 1981), and given numerous invited talks and lectures on topics in x-ray optics. He is a fellow of the Optical Society of America and the American Association for the Advancement of Science, and a member of the Deutsche Physikalische Gesellschaft and SPIE.