

# Index

1951 USAF target, 101

## A

$A\Omega$  product, 32  
Abbe number, 136, 139  
abrasive compound, 141  
acid resistance, 138  
active lap, 143  
Airy disk, 49, 53, 93  
Airy pattern, 48, 100, 102, 107  
aliasing, 196  
alkali resistance, 138  
anamorphic system, 74  
angular resolution, 100  
aperture stop, 10, 28  
apical radius, 122  
aspheric surface, 123, 142, 195  
astigmatism, 67, 75, 95, 160, 162, 190  
autocollimation technique, 153  
autocollimator, 147  
autocorrelation, 112  
autostigmatic microscope, 151  
axicon, 125  
azimuthal frequency, 79

## B

back focal distance, 5, 39  
barrel distortion, 73, 97  
bayonet mount, 40  
best-fit sphere, 127  
biconic surface, 74, 133

## C

C mount, 40  
calcium fluoride, 140  
cardinal points, 24, 43, 154–156  
cat's eye position, 151  
Cauchy formula, 139  
CCD, 13  
centration, 158  
chief ray, 12  
circle of least confusion, 70, 95  
classical Fizeau interferometer, 181  
climatic resistance, 138  
CMOS, 13  
coherence, 181, 184  
color code, 137  
coma, 65, 75, 82, 160, 163, 190  
computer-generated holograms, 198  
conic constant, 122  
conjugate, 7  
conoid, 121  
constringence, 136  
contrast, 110, 180  
contrast reversal, 114  
coordinate system, 1, 50  
Crown glass, 136, 149  
CS mount, 40  
curvature, 3  
cutoff frequency, 113  
cylinder axis, 134  
cylinder function, 47  
cylindrical surface, 134

**D**

defocus, 60, 62, 83, 94, 170, 188–189  
density, 137  
depth of field, 38  
depth of focus, 37  
deterministic microgrinding, 143  
diffraction-limited system, 100, 113  
dimming, 138  
dispersion, 136  
dispersion formulas, 139  
distortion, 72, 97  
dynamic range, 166

**E**

eccentricity, 122  
EF mount, 40  
effective focal length, 4  
encircled energy, 107  
ensquared energy, 107  
entrance pupil, 28, 43  
étendue, 32  
even asphere, 125  
exit pupil, 28, 43  
eyepiece, 34

**F**

$f$ -number, 35, 101  
 $f$ -stop ( $f/\#$ ), 35  
F mount, 40  
F $\theta$ -lenses, 98  
field of view, 39  
field stop, 13  
five-step algorithm, 193  
Flint glass, 137  
focal collimator, 154  
focal length, 4, 30, 156  
focal planes, 25, 156  
focal points, 4, 43, 153, 156  
focimeter, 153  
focometer, 153  
Forbes Q polynomials, 126, 135, 197  
Foucault test, 158, 162–163  
four-step algorithm, 192

Fourier series, 76  
Fraunhofer lines, 135  
freeform surface, 135  
Fresnel diffraction, 45  
fringes, 175, 178, 182–183, 188–189, 196  
front focal distance, 39  
front focal length, 4  
front focal point, 25  
front nodal point, 25  
front principal plane, 25  
full field of view, 39

**G**

gallium arsenide, 140  
Gaussian imaging equation, 7, 15, 30, 152  
Geneva gauge, 149  
germanium, 140, 143  
grindability, 138  
grinding, 141  
grinding pits, 141

**H**

half field of view, 39  
Hartmann screen test, 163  
homogeneity, 188  
hyperboloid, 122

**I**

injection molding, 144  
interference, 181  
interferograms, 189  
interferometry, 177  
International Glass Code, 137  
interval of Sturm, 70  
ion beam figuring, 144  
isoplanatic patches, 109

**K**

keystone distortion, 74, 98  
knife edge, 158  
Knoop hardness, 138  
Kronecker delta, 77

**L**

Lagrange invariant, 32  
laser Fizeau interferometer, 184  
lateral shearing interferometer,  
188  
lead zirconate titanate (PZT), 192  
least-squares fit, 86, 130, 172  
lens clock, 149  
lens gauge, 148  
lens measure, 148  
lenslet array, 164  
Lensmaker's equation, 10  
lensmeter, 153  
lensometer, 153  
line spread function, 114  
linear-shift-invariant system, 109  
long-wave infrared (LWIR), 140  
longitudinal magnification, 31

**M**

Mach-Zehnder interferometer,  
186  
magnetorheological finishing, 143  
magnification, 155  
Maréchal criterion, 103  
marginal rays, 11  
mean square slope, 128, 197  
mechanical tube length, 35  
medial focus, 70, 95, 190  
microscope objective, 34  
mid-wave infrared (MWIR), 140  
MIL Number, 137  
modal method, 171  
modulation, 110  
modulation transfer function, 110  
moiré deflectometry, 174

**N**

neutralization test, 152  
Newtonian imaging equation, 9  
Newton's rings, 120, 183  
nodal points, 43, 155–156  
nodal slide, 156  
normalized coordinates, 50

numerical aperture, 33, 35  
Nyquist limit, 196

**O**

oblate ellipsoidal surface, 121  
odd asphere, 125  
optical angle, 18–19  
optical flats, 119, 182  
optical invariant, 33  
optical path difference, 52, 179  
optical path length, 52  
optical testing, 177  
optical transfer function, 109, 179  
orthogonal functions, 75

**P**

*p* value, 122  
paraboloid, 122  
paraxial angles, 8  
paraxial raytracing, 16  
paraxial refraction equation, 18  
paraxial transfer equation, 19  
parfocal distance, 35  
peak-to-valley error, 103, 120, 142, 179  
percent distortion, 97  
Petzval surface, 72  
phase, 180, 192  
phase transfer function, 111  
phase unwrapping, 193  
phase-shifting interferometry, 191  
phosphate resistance, 138  
piezo-electric transducer, 192  
pincushion distortion, 73, 97  
piston, 58, 83  
pitch, 142  
plane waves, 177  
plastic optical materials, 138  
plastic optics, 144  
point source microscope, 151  
point spread function, 49, 53, 93  
polishing, 141  
power, 4, 30, 149, 153, 158, 175  
preforms, 144  
primary aberrations, 63

principal planes, 43, 155  
principal points, 25, 30, 157  
prisms, 120  
prolate ellipsoidal surface, 121  
pupil zone, 51

## Q

quatrefoil, 83

## R

radial order, 79  
radiance, 32  
radius of curvature, 3, 149–151  
ray scaling, 22  
Rayleigh criterion, 100, 103  
rear focal length, 5  
rear focal point, 25  
rear nodal point, 25  
rear principal plane, 25  
reciprocal magnification, 155  
reduced thickness, 19  
reference flat, 120  
reference sphere, 54, 61, 179  
reflection, 5  
refraction, 2  
relative partial dispersion, 137  
resolution, 100, 109, 148  
retroreflection position, 151  
RMS wavefront error, 104, 108  
Ronchi ruling, 162  
Ronchi test, 162–163

## S

sagittal depth, 120  
sagittal focus, 69, 95, 190  
sagittal plane, 68  
sampling, 196  
sapphire, 140  
Scheimpflug imaging, 74, 98  
Schott formula, 139  
secondary astigmatism, 83  
Seidel coefficients, 64  
Seidel coma, 96  
Sellmeier formula, 140

sensitivity, 167  
Shack–Hartmann sensor, 164  
shear plate, 188  
sign convention, 1, 50  
single-point diamond turning, 143  
slurry, 141  
sombbrero function, 48  
spherical aberration, 64, 83, 94, 160, 163, 190  
spherical surface, 3, 120  
spherometer, 150  
spot diagram, 55  
staining, 138  
star test, 93  
Strehl ratio, 102, 106, 179  
stressed lap, 142  
sub-Nyquist interferometry, 198  
subaperture stitching, 198  
subsurface damage, 142

## T

tangential focus, 69, 95, 190  
tangential plane, 68  
test plate, 121, 183  
thermal coefficient of expansion, 138  
thin lens, 10  
three-step algorithm, 192  
throat diameter, 40  
throughput, 32  
tilt, 59, 148, 158, 188  
tolerances, 120  
toric surface, 134  
transformation temperature, 144  
transverse magnification, 7, 16, 29  
transverse ray error, 54, 64, 159  
trefoil, 82  
Twyman–Green interferometer, 186

## U

unnormalized coordinates, 55

## V

V-number, 136

vertex, 3  
vignetting, 12  
visibility, 180

**W**

wavefront error, 53, 64, 158–159,  
179  
wavefront slope, 166  
wavefront variance, 104, 106, 128,  
179  
waves, 180  
wire test, 162–163  
working distance, 155  
working  $f$ -number, 37, 101

workpiece, 141  
wrapped phase, 193

**Y**

ynu raytracing, 16

**Z**

Zernike astigmatism, 82, 96  
Zernike coma, 82, 96  
Zernike defocus, 82  
Zernike polynomials, 78, 106  
Zernike spherical aberration, 83, 95  
zinc selenide, 140, 143  
zinc sulfide, 140



**Jim Schwiegerling** is a Professor of Optical Sciences and Ophthalmology & Vision Sciences at the University of Arizona. He has taught courses in visual optics, introducing engineers to the functioning of the human eye and ophthalmic instrumentation, as well as in optical specification, fabrication and testing, which examines the optical system design process from initial conception, through fabrication, to final testing. After training at the University of Rochester and the University of Arizona, he joined the faculty of the Ophthalmology Department in 1998 and the College of Optical Sciences in 2010. Dr. Schwiegerling's research interests include wavefront sensing and adaptive optics in the human eye, corneal topography, intraocular, contact, and spectacle lens design, instrumentation, optimization, and computational photography.