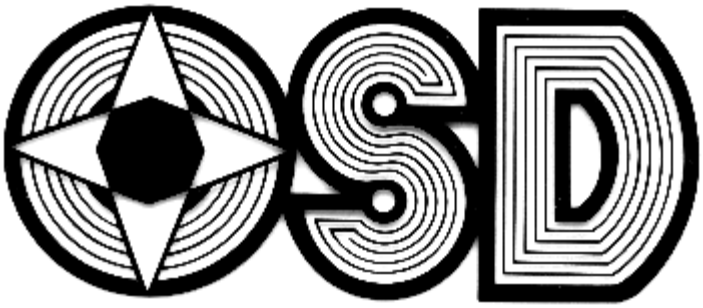
SYNOPSYS™

OPTICAL DESIGN PROGRAM

User's Manual



Optical Systems Design, Inc.

Quick Jumps into the Table of Contents:

1.0 INTRODUCTION
2.0 BASIC CONCEPTS
3.0 LENS DATA INPUT
4.0 LENS DATA OUTPUT
5.0 UTILITY FEATURES
6.0 LENS ANALYSIS ROUTINES
7.0 LENS ANALYSIS ROUTINES -- PLOTTED
8.0 IMAGE ANALYSIS ROUTINES -- BASIC SET
9.0 IMAGE ANALYSIS ROUTINES -- SPECIAL SET
10.0 AUTOMATIC DESIGN PROGRAM
11.0 TOLERANCING PROGRAM (TOL)
12.0 BUDGET TOLERANCE PROGRAM (BTOL)
13.0 INTERACTIVE FEATURES
14.0 ENVIRONMENTAL ANALYSIS PACKAGE
15.0 ARTIFICIAL INTELLIGENCE FEATURES (AI)
16.0 THIN-FILM PROGRAM
17.0 POLARIZATION
18.0 NONSEQUENTIAL RAYTRACING
Appendices

Table of Contents

1.0 INTRODUCTION

2.0 BASIC CONCEPTS

2.1 Input Commands
- 2.1.1 AI Command Format
- 2.1.2 Command-level Input
- 2.1.3 Character Set

2.2 Notation Conventions

2.3 Log Number

2.4 Coordinate systems
- 2.4.1 Surface location options
  - 2.4.1.1 Relative position
  - 2.4.1.2 Global position
  - 2.4.1.3 Local position
  - 2.4.1.4 External coordinates
- 2.4.2 Analysis in other coordinate systems

2.5 Sign conventions
- 2.5.1 Reflections
- 2.5.2 Intersections
- 2.5.3 Radii
- 2.5.4 Ray Angles

2.6 Stops – Pupils – Vignetting
- 2.6.1 Real Pupil Option
- 2.6.2 Vignetting
- 2.6.3 Wide-Angle Pupils (WAP)
  - 2.6.3.1 Setting Expected Pupil Vignetting (VFIELD)
- 2.6.4 CSTOP Option
- 2.6.5 FILLSTOP Option
- 2.6.6 Summary of Pupil Options
- 2.6.7 Display of Vignetted Pupil

2.7 OPD -- Numerical Considerations

2.8 (Topic deleted)

2.9 Modes of Operation (ON, OFF) MSS
- 2.9.1 Reset Modes (RESET)

2.10 Version number

2.11 Project name

3.0 LENS DATA INPUT

3.1 RLE Data -- System Input
3.1.1 Object Input Description
3.1.1.1 Noncircular Pupil
3.1.1.2 Implied Pupil
3.1.2 Gaussian Input Beam Definition (OBG) MUT
3.1.3 Lambertian Object (OBL)
3.1.4 Gaussian input profile
3.1.5 Waveguide Object(OBW)
3.1.6 Illumination Array (OBI)
3.2 RLE Data-Optional System Input
3.3 RLE Data -- Surface Input
3.3.1 Special Surface Options
3.3.1.1 Clear aperture input
3.3.1.2 Other Special Surface Options
3.3.2 Curvature Options
3.3.2.1 Spherical Surfaces
3.3.2.2 Aspheric Surfaces
3.3.2.2.1 Conic Sections
3.3.2.2.2 Power-series Aspherics
3.3.2.2.3 Toric Surfaces
3.3.2.2.4 Biconic Surfaces
3.3.2.2.5 Spline Surfaces
3.3.2.2.6 Zernike Polynomial Surfaces
3.3.2.2.7 Biradial Conics
3.3.2.2.8 Aspheric Toroids
3.3.2.3 Fresnel Surfaces
3.3.2.4 Holographic optical elements (HOEs)
Examples of HOE input
3.3.2.5 Gratings
3.3.2.6 Noncircular-zone surfaces (NCZONE)
3.3.2.7 Unusual surface shapes USS)
3.3.2.8 Diffractive optical elements (DOEs)

3.3.3 Thickness Options
3.3.4 Index Options
3.3.4.1 Gradient-Index (GRIN)
Example of GRIN input
3.4 Notes on Using Pickups and Solves
3.5 Examples of RLE Data
3.6 Changing a lens
3.6.1 The CHG file
3.6.1.1 Inserting and deleting surfaces
3.6.1.2 Lens Truncation (MXSF)
3.6.1.3 Removing Aperture Data (CFREE)
3.6.2 Lens editing (LE)
3.6.3 Lens initialization (NLENS, SLENS)
3.7 Storing and Retrieving Lens Data
3.7.1 The Lens Library MLB
3.7.2 SAVE, FETCH MWL
3.8 Asymmetrical Data: -- Tilts and Decenters
3.8.1 Relative
3.8.1.1 Examples of tilt and decenter input
3.8.2 Global Coordinates
3.8.2.1 Coincident
3.8.3. Local Coordinates
3.8.4. External Coordinates
3.9 Prism Library
3.9.1 Prism definitions
3.9.1.1 Right-angle prism (RANGLE)
3.9.1.2 Amici prism (AMICI)
3.9.1.3 Porro prism (PORRO)
3.9.1.4 Penta prism (PENTA)
3.9.1.5 Dove prism (DOVE)
3.9.1.6 Schmidt prism (SCHMIDT)
3.9.1.7 Pechan prism (PECHAN)
3.9.1.8 Penta-roof prism (PROOF)
3.9.1.9 Roof mirror (MROOF)
3.9.1.10 Abbe erector (ABBE)
3.9.1.11 Double Porro (DPORRO)

3.9.1.12 Pechan roof (PCR)
3.9.1.13 Double Dove (DDOVE)
3.9.2 Examples of prism input
3.10 Edge Descriptions
3.11 Lens Arrays

4.0 LENS DATA OUTPUT

4.1 Lens Specifications (SPEC) **MLL**
4.1.1 DWG with SPEC (DSPEC) MLL
4.3 Lens File Output (LEO) **MLL**
4.4 Print Options (POP) **MLL**
4.5 OUT
4.6 Print Asymmetries (ASY) **MLL**
4.6.1 Tilts and Decenters (TDC)
4.6.2 Special Surface Data (SSD)
4.7 Specifications, with Element Power (SPC) **MLL**
4.8 (Topic deleted)
4.9 Refractive index data (RIN) **MLL**

5.0 UTILITY FEATURES MUT

5.1 Surface Shape Routines (SAG) **MUT**
5.1.1 Surface Profile (SPROFILE)
5.2 Element Weight Calculation (WGT) **MUT**
5.3 Flux Calculation (FLUX) **MUT**
5.4 Narcissus (NAR) **MFT**
5.5 GHOST
5.5.1 Analyzing a Ghost Image with PGHOST
5.5.2 Analyzing a Ghost Image with RGHOST
5.5.3 Plotted Ghost Image Features (GHPLOT)
5.6 GLASS
5.7 DEF -- ZERNIKE Deformation Fit
5.8 SCALE MUT
5.9 Thermal Soak Program (THERM)
5.10 Annotating output ($, TEXT, MSG)

5.11 Lens Reversal (REVERSE) MUT
5.12 Gaussian Beam Trace (BEAM) MFT
5.13 Buried Ghost Image (BGI) MFT
5.14 Combine Two Lenses (COMBINE)
5.15 Time and date (TIME)
5.16 Closest-fitting sphere (ADEF)
5.17 Object point search (OCALC, FCALC)
5.18 Aligning components along a ray (AIM)
5.19 FOLD, UNFOLD
5.20 Custom Glass Table
5.21 Adjusting Magnification (MSET)
5.22 Flipping a Range of Surfaces (FLIP)
5.23 Insert Real Glass (IRG)
5.24 Creating a VFIELD (FVF)
5.25 Print Glass Attributes (PGA)
5.26 ASAP Input File (ASAP)
5.27 Inserting, Deleting surfaces and elements
5.28 GRIN Statistics
5.29 WAIT
5.30 DOE fringe Pattern DMASK
5.31 Search for Best Glasses (GSEARCH)
5.32 F/number Calculation (FN)
5.33 V-number Calculation (VNUM)
5.34 Glass transmission (GTRANS) MTR
5.35 DOE OPD table (DSAG)
5.36 Transmission along a ray (RTRANS) MRR, MTR
5.37 Illumination systems
5.38 Clocking Element Wedge Errors
5.39 T/number Calculation (TN) MTR
5.40 Lens Blank Cost (GCOST) MUT
5.41 Lens Spacer Length (SPACERS) MUT
5.42 Zemax Input File Converter (ZMCONVERT)
5.43 Duplicate and Mirror (DMIRROR)
5.44 Slope Analysis (SLOPE) MUT
5.45 Fresnel Transmission Loss (FTRANS) MTR

6.0 LENS ANALYSIS ROUTINES

6.1 Paraxial Raytrace (PXT) **MFT**

6.2 Clear Aperture Programs

6.2.1 CAP MLL

6.2.2 Edge Thickness (EDGE) MUT

6.3 Raytrace (RAY) **MRR**

6.3.1 Targetted Raytrace (TARGET) MRR

6.3.2 Global Raytrace (GRAY) MRR

6.3.3 External Raytrace (ERAY)

6.4 Ray Fans (SFAN, TFAN, FANS) **MRR**

6.5 First-Order Analysis (FIRST) **MFT**

6.6 Third-order Analysis (THIRD, NTHIRD) **MFT**

6.7 Fifth-order analysis (FIFTH) **MFT**

6.8 Feathering Point (FEATHER) **MUT**

6.9 Strain Evaluation (STRAIN)

7.0 LENS ANALYSIS ROUTINES – PLOTTED

7.1 Lens drawing (DWG) **MPL**

7.1.1 Zoom lens drawing (ZDWG)

7.2 Perspective Drawing, Solid Model (PER, RPER, SOLID) **MPE**

7.3 Ray Fans, Plotted (RPT, RPO) **MRR**

7.3.1 Short-form input

7.3.2 Long form input

7.4 Field Curvature (FCV) **MRR**

7.5 Distortion Curve (DIS) **MRR**

7.5.1 AFOCAL distortion

7.6 Plot Utilities (saving, EPL)

7.7 Lens Element Drawing (ELD) **MPL**

7.8 Edge description file (EFILE, ELIST)

7.9 Three-Parameter Plots (PA3)

7.10 Combining Lens Drawings (CDWG)

7.11 Graphical System Summary (GSS) **MGS**

7.12 Grid Distortion (GDIS) **MRR**

7.13 Adding Tolerances to your Drawings

7.14 Longitudinal Spherical Aberration (LSA) **MRR**
7.15 Forward Scattering (FSC) **MFS**

8.0 IMAGE ANALYSIS ROUTINES – BASIC SET

8.1 Dialog-driven Image Analysis Features
8.2 Multicolor Analysis
8.3 Influence of Apertures on Image Analysis
8.4 Footprint Options **MFP**
8.4.1 Footprints with other drawing programs
8.4.2 Examples of Footprint Analysis
8.5 Geometric Analysis **MGI**
8.5.1 Spot Diagrams MGI
8.5.1.1 Spot Diagram (SPT) MGI
8.5.1.2 Through-focus Spot Diagram (TFS) MTS
8.5.2 Knife-edge Trace (KNI) MGI
8.5.3 Geometric MTF (GMTF) MOP, MFM
8.5.4 Through-Focus Geometric MTF (TFG) MTG
8.5.5 RMS Focusing (FOCUS) MGI
8.5.6 RMS Spot Size MGI
8.5.7 Image Model (GMODEL) MMO
8.5.8 Examples of Geometric Image Evaluation Input
8.5.9 Field Blur
8.5.10 Multi-field Geometric MTF (MGMTF)
8.5.11 Foucault Knife-edge Tool (MFK)
8.5.12 Illumination Pattern (IPAT)
8.6 Diffraction Analysis
8.6.1 Exit Pupil Wavefront Map (PUPIL) MDI
8.6.1.1 Interferogram plot
8.6.2 Point-Spread Function (PSPRD) MDI
8.6.3 Diffraction MTF
8.6.3.1 Convolution MTF options (MTF, ZMTF, MFF, MZMTF) MOP
8.6.3.2 Single field of view convolution MTF MOP
8.6.3.3 Multifield MTF plots (MFF) MMF
8.6.3.4 Fourier-transform diffraction MTF (DMTF, M2F) MOP, MFM
8.6.3.5 Through-focus diffraction MTF (TFMTF) MTM

8.6.3.6 MTF over field (MOF) MOP
8.6.4 Diffraction Image Model (DMODEL, WMODEL) MMO
8.6.5 Diffraction Pupil Function (DPF)
8.6.6 Coefficients of Wavefront Polynomial (COE)
8.6.6.1 Zemike Wavefront Polynomial (ZCOE)
8.6.7 Partial Coherence Analysis MPA
Theory
8.6.8 Wavefront Variance (VAR), VFOCUS MDI
8.6.9 Perturbed Exit Pupil (GPP)
8.6.10 Through-focus PSPRD (TFP) MTP
8.6.11 Over Field PSPRD (OFP) MOF
8.6.12 Variance-MTF Relationship (VMR)
8.7 Generic Image Analysis
8.8 Mapping Function (MAP) MMA
8.8.1 Examples of MAP input

9.0 IMAGE ANALYSIS ROUTINES -- SPECIAL SET

9.1 Generating the Image Model
9.1.1 Composite image model
9.1.2 Image model coordinate Systems
9.2 IFOV-Detector Efficiency (DETECTOR)
Examples of **DET** input
9.2.1 Find Detector Size (FDS)
9.3 Image Dissection (FOR...) MFO
Examples of **FOR** Input
9.4 Diffraction Program (DIFF) MDF
9.4.1 Prompted **DIFF** input
9.4.2 Examples of **DIFF** input
9.5 Image Illumination (ILLUM) MGI, MTR
9.6 Diffractive Propagation (DPROP)
9.7 Extended Image Analysis (EIA)

10.0 AUTOMATIC DESIGN PROGRAM MOM

10.1 Mathematical Method

10.1.1 Metric Input, Variable Metric
10.2 Parameter Input (PANT)
10.3 Aberration Input (AANT)
10.3.1 Ray Aberrations, settings
10.3.1.1 Automatic generation of ray aberrations
10.3.1.2 User-specified ray aberrations
10.3.1.3 (Topic deleted)
10.3.1.4 Wavefront coefficient aberration
10.3.1.5 Ghost image control
10.3.2 Paraxial aberrations
10.3.2.1 Paraxial section aberrations
10.3.2.2 Third- and fifth-order aberrations
10.3.2.3 Section third- and fifth-order aberrations
10.3.3 Construction parameter aberrations
10.3.3.1 Holographic Optical Element Parameters
10.3.4 Extended format
10.3.5 Limit and Correction Input
10.3.5.1 Limit input
10.3.5.2 Correction input
10.3.6 STA -- GTA (storing aberration set)
10.3.7 Edge feathering control (AEC)
10.3.8 Center thickness control (ACC, ACM)
10.3.9 MTF Aberrations
10.3.10 Composite aberrations
10.3.10.1 Zn parameters in optimization
10.3.11 CLINK command link to aberrations
10.3.12 Surface slope control (ASC)
10.3.13 Critical-angle control (ACA)
10.3.14 Automatic aperture control (AAC)
10.4 The SYNOPSYS Command
10.5 Modes of Operation of SYNOPSYS
10.5.1 Derivatives
10.5.2 Evaluate only
10.6 Examples of Lens Design Input
10.7 ZOOM Lenses, Multiconfigurations
10.7.1 ZFILE zoom lenses

10.7.1.1 Optimizing ZFILE zoom lenses
10.7.1.2 CAM curve calculation
10.7.2 Alternate Configurations
10.7.2.1 Examples of Multiple Configuration Input
10.8 Comments about the SYNOPSYS Optimization Program
10.8.1 Initial evaluation
10.8.2 Derivative calculation
10.8.3 High-order aspherics
10.8.4 When correcting OPD's
10.8.5 When "OPTIMUM" is not good enough
10.8.6 Altering a good design
10.9 Final Results
10.9.1 Summary of optimization
10.9.2 Change summary
10.10 Automatic Testplate Matching (TPM) **MMT**
10.11 Naming aberrations: the AFILE, ALIST
10.12 Simulated Annealing
10.13 Tolerance Desensitization
10.14 Design Search (DSEARCH) MDS
10.15 Automatic Aspheric Assignment (AAA)
10.16 Automatic Element Deleting (AED)
10.17 Saddle-point Build (SPBUILD, AEI) MDS

11.0 TOLERANCING PROGRAM (TOL)

11.1 Examples of Tolerancing Input

12.0 BUDGET TOLERANCE PROGRAM (BTOL)

12.1 BTOL Input -- General Format
12.1.1 Variable attributes
12.1.1.1 Cemented elements and BTOL
12.1 2 BTOL Adjustments
12.1.2.1 Fabrication adjustment with REOPTIMIZE
12.1.2.2 Finding the best adjustments
12.1.3 BTOL Quality descriptors

12.1.3.1 BTOL Wavefront quality descriptor
12.1.3.2 BTOL Spot size quality descriptor
12.1.3.3 BTOL Strehl ratio quality descriptor
12.1.3.4 BTOL MTF quality descriptor
12.1.3.5 Additional quality descriptors
12.1.4 Multiconfiguration BTOL analysis
12.2 BTOL Image quality evaluation
12.3 Statistical considerations
12.3.1 Segmented tolerancing
12.4 BTOL example
12.5 Monte-Carlo tolerance analysis
12.5.1 Example Monte-Carlo run
12.5.2 Including other quantities in MC
12.5.3 Fabrication Adjustment with FAMC
12.6 Lens Tolerancing Today
12.7 BTOL Format Summary

13.0 INTERACTIVE FEATURES

13.1 Help Files
13.1.1 Instant HELP
13.1.2 ToolTip Help
13.2 The MACro Editor
13.2.1 Startup Macro (SYSTART.MAC)
13.2.2 Other MACro commands
13.3 The SketchPAD
13.3.1 SketchPAD graphics
13.3.2 The WorkSheet program
13.3.3 The LE Lens editor
13.3.4 SnapShot
13.3.5 The Glass Table
13.3.6 The Y-YBAR diagram
13.4 BELL command
13.5 Graphics tools
13.6 Interactive Directory (DIR)
13.7 The SYNOPSYS menu dialog tree

13.8 Rotating drawingS (RPER, RSOLID)
13.9 Saving a plot as an HPGL, DXF, or Postscript file
13.10 Capturing printout (PON, POFF)
13.11 Command Window options (CCW, NCW, PCW)
13.12 Output toggle (QUIET, LOUD)
13.13 Scrolling to recently-typed commands
13.14 Displaying several plots on a single page
13.15 Displaying error messages
13.16 Program updates
13.17 Lens cell editor
13.18 UNDO and REDO
13.19 License utility
13.20 The TrayPrompt
13.21 The Format Coach
13.22 Dual Monitor Support
13.23 Annotation Strings (ASn)

14.0 ENVIRONMENTAL ANALYSIS PACKAGE

14.1 Thermal-Optical-Structural-Program (TOSP)
14.1.1 Generating the perturbation table
14.1.2 Creating TOSP data with separate programs

15.0 ARTIFICIAL INTELLIGENCE FEATURES (AI)

15.1 Natural Language Processing
15.1.1 Grammatical Considerations
15.1.2 Parametric Plots, Listings
15.1.2.1 Do MACro Commands
15.1.2.2 The AIParameter
15.1.2.3 Automatic Output File (FILE)
15.1.2.4 Replotting the same data (AGAIN)
15.1.2.5 Loop Searching
15.1.3 Symbol Substitution
15.1.3.1 Passing values with the AIParameter
15.1.4 Calculating with AI

15.1.4.1 Composite aberrations in AI
15.1.4.2 The Zn parameters
15.1.4.3 Passing parameters with the Zn array
15.1.4.4 Examples of Zn calculations
15.1.5 Other Lens Changes in AI
15.1.5.1 Matching Vendor-Supplied Elements
15.1.5.2 Inserting and Deleting a Given Lens With AI
15.1.5.3 Replacing a Lens With AI
15.1.5.4 Moving an Element with AI
15.1.5.5 Selecting A Catalog with AI
15.1.5.6 Changing Wavelengths in AI
15.2 AI Primer
15.2.1 Basics
15.2.1.1 Question Verbs
15.2.1.2 Nouns – Subjects
15.2.1.3 Conditions
15.2.1.4 Change Verbs
15.2.1.5 Looping in AI – Loop Verbs
15.2.2 AI Possibilities
15.3 Expert Systems
15.3.1 Initializing the example file
15.3.2 Starting a lens from scratch
15.3.3 Using XSYS with a starting lens
15.3.4 Entering lens requirements
15.3.5 Alternate starting points
15.3.5.1 Rating potential matches
15.3.5.2 Selecting a potential match
15.3.5.2.1 Lens matching modes
15.3.6 Optimizing the selected match
15.3.7 XSYS example

16.0 THIN-FILM PROGRAM

16.1 Common Mode
16.2 Analysis Mode
16.3 Design Mode

16.4 Example FILM Input

17.0 POLARIZATION

17.1 Polarization Raytracing (PRAY) MRR, MTR
17.1.1 Object polarization
17.2 Modeling Surface Coatings
17.2.1 Standard coatings
17.2.2 Custom coatings
17.2.2.1 Dummy custom coatings
17.2.3 Transmissive coatings
17.2.4 Reflective coatings
17.2.5 Mirror materials
17.2.6 Polarization-active components
17.2.7 Surface coating output
17.3 SYNOPSYS Features Utilizing Polarization
17.4 Example polarization input
17.5 Birefringent Materials
17.5.1 Birefringent raytracing
17.5.2 Quarter-wave, half-wave plates

18.0 NONSEQUENTIAL RAYTRACING

18.1 Nonsequential surfaces
18.1.1 LOOSE surfaces
18.1.2 CAPTURE surfaces
18.1.3 ILOOSE surfaces
18.1.4 Other nonsequential surfaces
18.1.5 RECTIFY surfaces
18.1.6 MBOUNCE surfaces
18.2 Aperture Considerations in Nonsequential Tracing
18.3 Examples of Nonsequential Raytracing
18.3.1 Telescope mirror with inside aperture
18.3.2 Segmented aperture system
18.3.3 Segmented mirror
18.3.4 A more general nonsequential system

18.3.5 Cavity
18.3.6 Ghost Image Analysis with Nonsequential Rays

(Topic deleted)
Appendix B Mode Switch Data
Appendix C Formulation of Conic Sections
Appendix D Third, Fifth-Order Aberrations
Appendix E Example SYNOPSYS Files
Appendix F Glass Model Calculations
Appendix G Glass Tables
Schott
Ohara
Hoya
Unusual
Corning France
Chinese Guangming
Russian LZOS
Appendix H Lens Vendors