OPTICAL ENGINEERING SOFTWARE

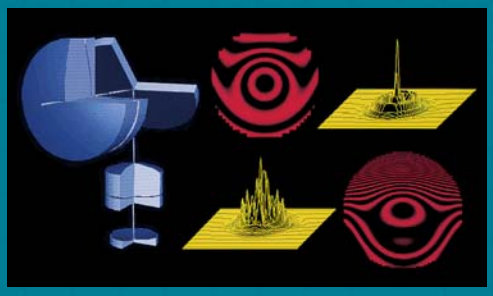
code V®

IMAGING OPTICS

DESIGN

ANALYSIS

FABRICATION



OPTICAL RESEARCH ASSOCIATES

Optical Research Associates (ORA®) was founded in 1963 to provide optical design services. Since then we have evolved to become the largest and leading supplier of imaging and illumination design/analysis software: CODE V® and *LightTools*.® ORA's Engineering Services group has also become the largest independent supplier of optical system design with more than 4,000 completed projects in imaging, illumination, and optical systems engineering.

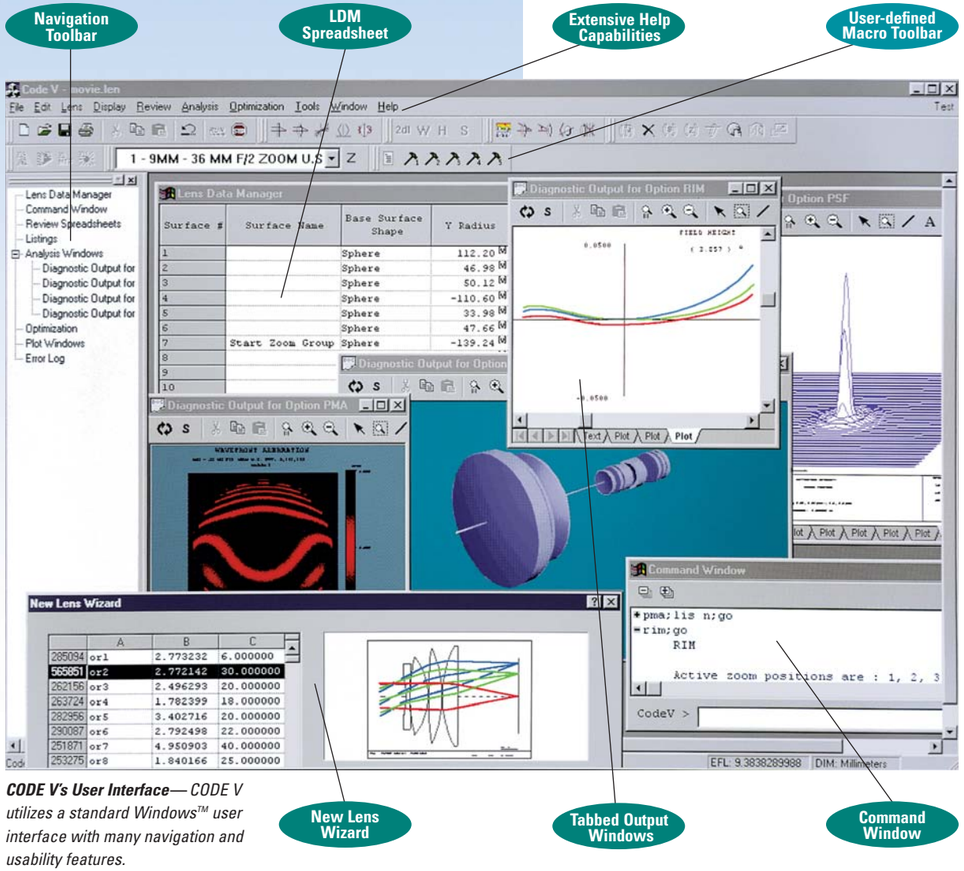
Since its worldwide introduction in 1975, CODE V has been instrumental in the development of advanced optical systems, sometimes with profound effects on business and culture. It has been used in the development of revolutionary applications such as the compact disk. CODE V algorithms are a key and dominant technology in the design of the microlithographic lenses that permit the imaging of ultra-fine lines on computer chips—a necessary ingredient in the continuing improvement of computer speeds.

CODE V software has contributed significantly to important technological advances across a wide spectrum of fields such as projection displays, medical instrumentation, advanced military technology, and space exploration.

Because of its established reputation for excellence and quality performance, CODE V is the software of choice when optics are critical to the success of a product or project.

More reasons to choose CODE V:

Customer Service: When you lease CODE V, you receive much more than the highest rated optical design/analysis software available. You also get access to more than 50 person-years of industry optical engineering experience through ORA's customer service staff. Whether you choose e-mail, facsimile, or our toll free phone number to request assistance, degreed optical engineering professionals are ready to answer your questions, including on-site and off-site CODE V training. Our tutorial and reference materials are complete, easy-to-use and include many examples.



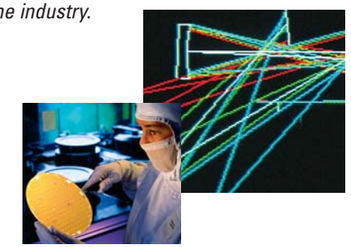
CODE V's User Interface— *CODE V utilizes a standard Windows™ user interface with many navigation and usability features.*

Program Updates: Extensive program updates are issued approximately once a year to add major new features. Periodic releases with minor improvements and fixes provide solutions to customer reported problems. All updates are included in our standard license.

Pre-tested & Pre-approved: One of ORA's most important strengths is the synergy between our engineering services and software development efforts. Our engineers provide ideas, guidance, testing, and feedback for the development of CODE V. Most importantly, before you use the latest version of CODE V for engineering problem solving, you can be confident that the software has been "put through its paces" by a dedicated team of engineers who work at the cutting-edge of optical technology.

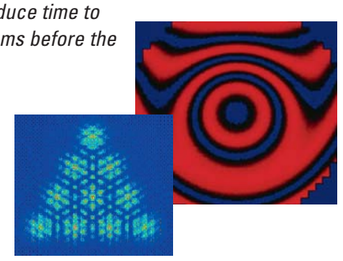
APPLICATION/DESIGN

From the deep UV to the far IR and from consumer products to government hardware, CODE V will handle your optical imaging applications. CODE V's award winning, proprietary optimization algorithms are simply the best in the industry.



ANALYSIS/FABRICATION

Comprehensive, accurate, and fast, you can have confidence in the performance predictions of CODE V. Extensive fabrication/tolerancing analysis capabilities reduce time to market and solve production problems before the design reaches manufacturing.

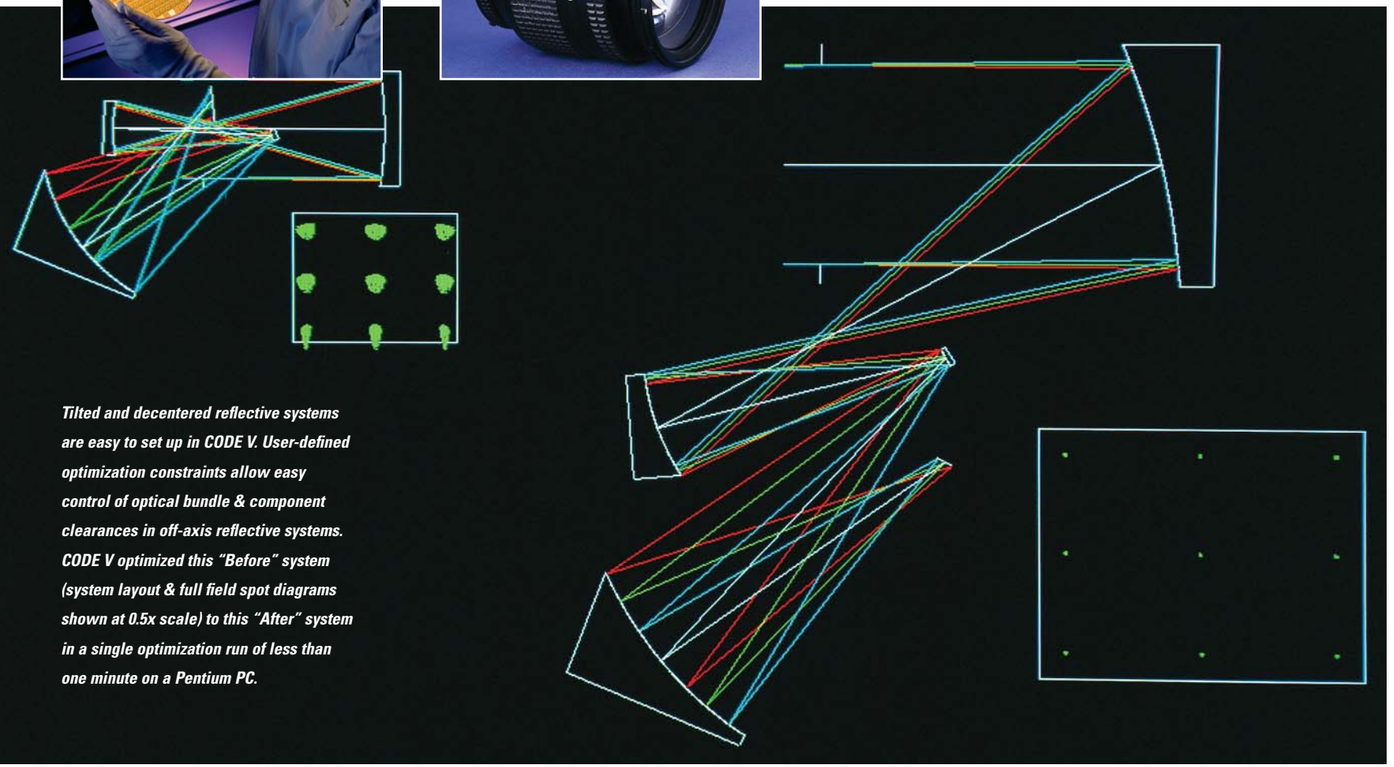


COMPREHENSIVE FEATURES

CODE V is the most powerful optical design and analysis software available and is continually being improved with new features and current feature enhancements.

***Microlithographic Systems**—CODE V is the dominant software of choice to meet the stringent optimization, analysis, and tolerancing demands of the integrated circuit manufacturing industry.*

***Zoom/Multi-configurations lenses**—CODE V optimization delivers the best possible zoom lens designs. Global Synthesis is highly effective for zoom lenses and excellent chromatic correction is possible with powerful glass optimization. CODE V includes specialized features for zoom lens analysis that help you build the best lens, not just design one.*



Tilted and decentered reflective systems are easy to set up in CODE V. User-defined optimization constraints allow easy control of optical bundle & component clearances in off-axis reflective systems. CODE V optimized this "Before" system (system layout & full field spot diagrams shown at 0.5x scale) to this "After" system in a single optimization run of less than one minute on a Pentium PC.

APPLICATIONS:

CODE V is the recognized leader when optics are critical to product success. Some of these applications and related CODE V features are:

- **Injection molded plastic lenses**—environmental analysis and material tolerances
- **Grating spectrometers**—wavelength dependent multi-configuration features
- **Digital camera lenses**—tolerance and fabrication analysis features
- **LCD projection systems**—polarization ray tracing
- **Reconnaissance lenses**—glass optimization with partial dispersion control
- **Telescopes & other visual systems**—true afocal modeling
- **Space-borne systems**—environmental analysis
- **Laser scanning systems**—diffraction beam propagation analysis
- **Infrared & UV systems**—special material characterization
- **Fiber optics systems**—fiber coupling efficiency computations
- **Segmented aperture systems**—non-sequential ray tracing features

Whatever your application, CODE V's state-of-the-art algorithms, user-friendly interface, and intelligent defaults will reduce time to market while maximizing the quality of your optical solution.

DESIGN:

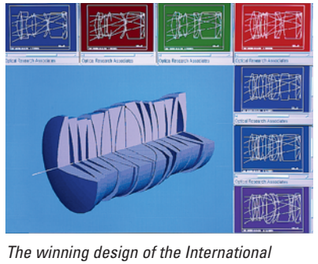
Optimization capabilities are often the most important consideration when choosing optical design software. ORA's award-winning, proprietary optimization algorithms are considered unsurpassed by industry leaders. Features include:

- The best, most effective global optimization algorithm available (see inset)
- RMS blur, Wavefront variance, MTF, fiber coupling efficiency, and/or a fully user-defined error function
- Zernike coefficient optimization
- Intelligent optimization defaults and general constraints
- Effective variable glass optimization
- Effective exact constraint handling
- Easy definition of user-defined constraints
- MTF optimization that is fast and accurate

Like other optical design programs, CODE V's local optimization (i.e., optimizing to find the local minimum of the error function) is based on damped least squares. However, ORA has implemented several proprietary enhancements that make CODE V's optimization algorithm the most effective available. CODE V's exact constraint handling, using Lagrange multipliers, removes control of constraints from the error function, so that the error function optimization does not stall while attempting to hold heavily weighted constraints. The user can develop the best solution—with the correct specifications—that fits the space available.

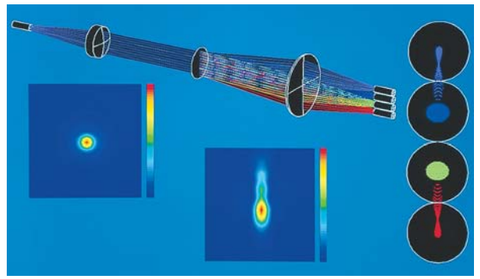
CODE V's Global Synthesis® algorithm is the most effective "global optimization" algorithm available for finding multiple unique configurations for systems with a large number of variables and constraints (including zoom lenses). GS uses a directed search (not a random hit-or-miss approach) to seek out new valleys in merit function space. While other methods may work on simple textbook examples, CODE V's Global Synthesis solves real world optical design problems.

CODE V's intelligent optimization defaults work well for the vast majority of systems, but can be overridden if desired. CODE V's RMS blur, Wavefront variance, and MTF error functions cover the majority of applications, but users can define their own merit function if desired. CODE V offers smart defaults, with as little or as much control as users require and consistently yields the best designs. This efficiency results in more freedom for users to perform useful engineering work instead of time-consuming tweaks of the error function.

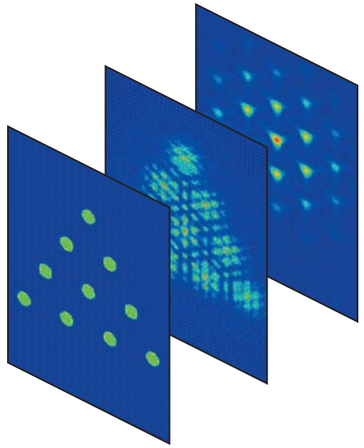


The winning design of the International Optical Design Conference "Camera in a Can" lens design contest was optimized using Global Synthesis.

***Photonics Systems**—Some useful features include gradient index materials, polarization ray tracing, lens arrays, & diffractive optical elements.*



***Beam Propagation**—Predicts intensity, amplitude, and phase characteristics of the diffracted optical beam anywhere in the system.*



ANALYSIS:

Optical Research Associates analysis algorithms are recognized for their accuracy and speed. Over tens of thousands of fabricated customer designs, more than 150 person-years of in-house engineering experience, and thousands of daily development test cases assure the quality of CODE V performance predictions—even on the most complex optical systems.

CODE V's extensive suite of analysis capabilities include:

- Many diagnostic evaluation options (e.g., Transverse ray aberration or OPD curves)
- Many geometrical and diffraction based image evaluation options (e.g., Spot diagrams and MTF)
- Non-sequential ray tracing
- Polarization ray tracing including birefringent material modeling
- General diffraction beam propagation
- Partial coherence 1-D and 2-D image analysis
- Fiber coupling efficiency
- Illumination analysis
- Scanning infrared narcissus analysis

CODE V's beam propagation analysis takes into account diffraction effects resulting from multiple aperture clipping and spatial or phase structure near a focal plane. Partial coherence analysis can predict image structure of one or two-dimensional objects based on fully coherent to fully incoherent illumination through an optical system. For photonic systems, fiber coupling efficiency of a diffraction image into a single mode fiber can be predicted, including the effects of misalignments and fiber tip cleavage angles.

For specialized or custom analysis, CODE V provides Macro-PLUS™—a powerful macro programming language including support of advanced mathematical functions such as a Fast Fourier Transform (FFT) operation and database access to a broad range of CODE V maintained and calculated data.

Most CODE V analysis option inputs can be customized, but the user isn't burdened with making all the choices. Intelligent input defaults are provided in all options, based on the ORA's software knowledge of the computational algorithm and engineering knowledge about the appropriate defaults for real world problems. Users can have confidence in the results CODE V provides.

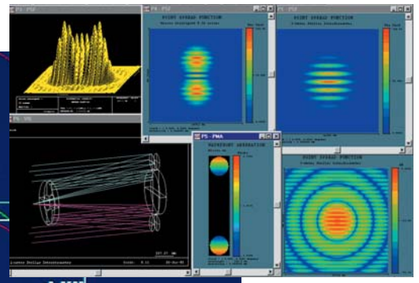
FABRICATION:

CODE V is used to design optics destined for hardware, and has many advanced capabilities to reduce time-to-market and solve production problems *before* the design reaches manufacturing. Features include:

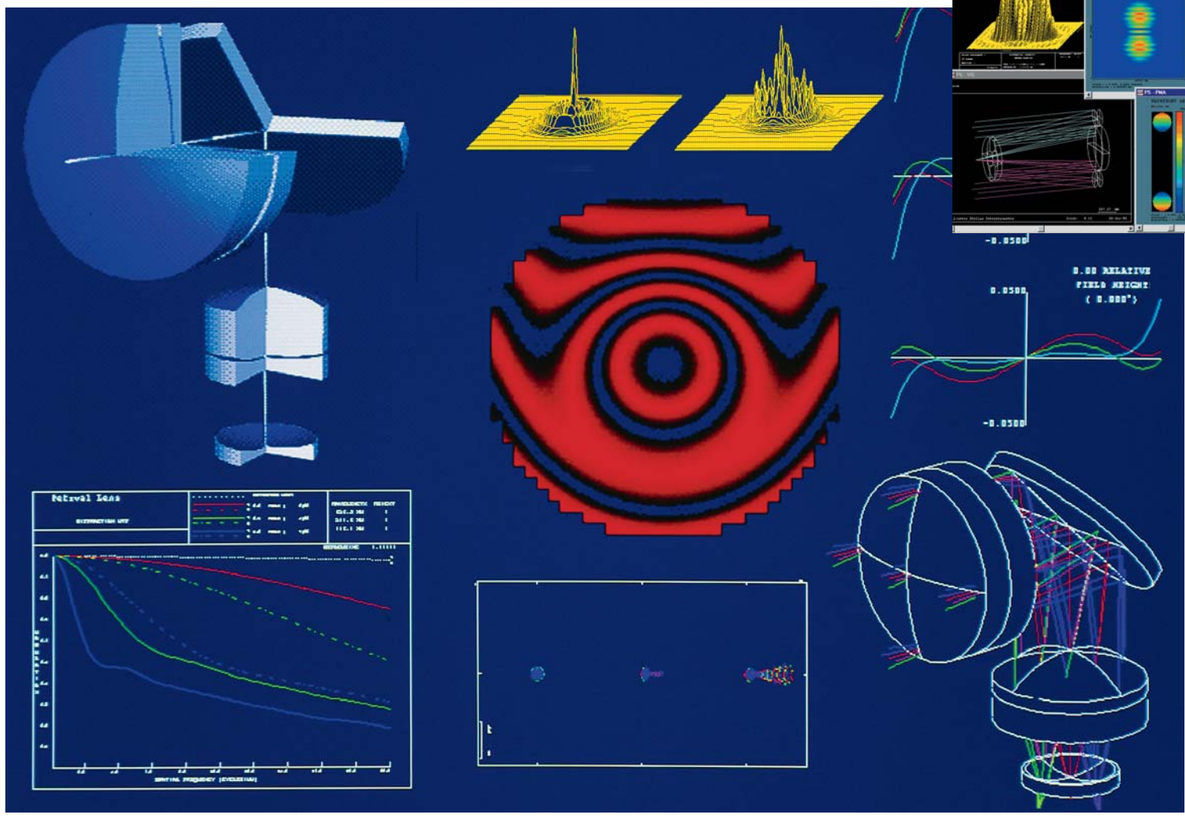
- Fastest and most accurate MTF and RMS wavefront error tolerancing via proprietary algorithms
- More than 40 built-in tolerance types, including glass inhomogeneity
- Automatic error budgeting, tolerance sensitivity analysis and compensator prediction
- CAD export using IGES, SAT, or STEP file format
- Interferogram interface for applying measured interferograms to the system model
- Automatic system alignment optimization based on as-built interferogram analysis
- Mechanical zoom lens CAM computation
- Lens element cost analysis (material and fabrication costs)

CODE V's sensitivity and inverse sensitivity (i.e., automatic error budgeting) tolerancing capabilities are based on measurable performance metrics such as RMS wavefront, MTF, and distortion. Multiple compensators can be defined and if desired, restricted to compensating sub-sets of tolerances. Boresight compensation can also be included. For specialized systems, CODE V includes user-defined tolerancing capabilities that allow a sensitivity analysis for any performance metric that CODE V calculates.

CODE V's interferogram interface allows measured surface deformation or system wavefront data to be imported into CODE V and included as part of the lens model. CODE V's alignment optimization is used to automatically guide the alignment of an as-built optical system using measured wavefront data. Whether your hardware is for the consumer, commercial, or government markets, if you are planning to build your optical designs, then CODE V's integrated design, analysis, and fabrication support features make it the best optical software for the job.



***Diffraction Analysis**—A stellar interferometer showing interference fringes produced from separated apertures using non-sequential surface ray tracing and diffraction analysis features.*



***Imaging System Analysis**—Transverse ray aberration curves, pupil maps, spot diagrams, MTF curves, and Point Spread Function plots are just a few of CODE V's suite of analysis features (shown above for a basic Petzval lens, US Patent 2,076,190.)*

code V®

COMPREHENSIVE FEATURES

User Interface Components

- LDM spreadsheet
- Surface properties window
- System data window
- Custom review spreadsheets
- Wizards
- Navigation toolbar
- Standard menus and tool bars
- Customizable toolbars (including user macros)
- Tabbed output windows
- Undo/Redo functionality
- Extensive help features
- UI simplification features
- Command line entry window

Lens Entry & Editing (LDM)

- Spreadsheet entry or command entry
- Supplied examples and patent lens search
- Off-the-shelf components
- Built-in Prims models
- "Black Box" lens modules
- Pickups and Solves
- Zoom/Multi-configuration systems
- Decentered/tilted systems
- Array elements
- Non-sequential surface modeling
- True afocal modeling
- Built-in glass catalogs (including IR/UV materials)
- Diffractive properties
- Gradient Index materials
- Multilayer coatings
- Pupil apodization
- Inteferogram data on surfaces and pupils: Grid, Zernike, and user defined
- Linear polarizers and retarders
- Birefringent materials
- Special surface types
  - Cylinders and toroids
  - Conics and superconics
  - Radial, XY, and anamorphic aspherics
  - Fresnel lens surfaces
  - And many more
- User programmable features support for surface shape, surface properties, and others

Diagnostic & Analysis Options

- Paraxial ray trace
- Real ray trace
- Aberration plots
- Gaussian beam trace
- Third, Fifth and Higher order aberrations
- Astigmatism & Distortion Field Curves
- 2D distortion grid
- Pupil map
- Field map (including Zernike polynomial terms)
- Footprint (beamprint) analysis

Optimization

- Ray, wavefront, MTF, fiber coupling efficiency, and/or user defined error function
- Local optimization or Global Synthesis
- Exact constraint control
- Over 60 standard constraint types
- User-defined constraints
- Effective glass optimization, including UV and IR bands
- Zernike coefficient optimization

Image Evalution Options (*including polarization)

- Spot diagrams
- Geometrical radial energy
- Quadrant detector analysis
- Biocular analysis
- RMS wave error
- MTF (vs. frequency, vs. focus)*
- Point Spread Function*
- Line Spread Function*
- Encircled Energy*
- Detector Energy*
- 1-D and 2-D Partial Coherence analysis*
- Fiber Coupling Efficiency
- Polarization dependent loss
- General Diffraction Beam Propagation

Fabrication & Tolerancing Options

- Lens display:
  - General lens plots (2D, etc.)
  - Lens element/component drawings
  - Interactive 3D model visualization, including surface selection and editing
  - Gaussian beam plot
- Tolerance analysis
  - MTF/RMS based
  - Distortion based
  - Primary aberrations
  - Fiber coupling efficiency/ polarization dependent loss
  - User defined tolerancing
- CAD Export – IGES, STEP, and SAT
- Sag tables
- Cost analysis
- Weight/Center of Gravity analysis
- Automatic testplate fitting
- Zoom CAM design
- Automatic alignment analysis

Other Features

- Powerful Macro-PLUS programming language
  - Many ORA-supplied macros
  - Built-in FFT and other mathematical functions
- Environmental analysis including temperature and pressure
- Illumination analysis
- Multilayer coating design/analysis
- NASTRAN interface macro
- Spectral analysis
- Transmission analysis
- Ghost image analysis
- Narcissus analysis
- User-defined graphics
- COM API interface that links with other COM-enabled software, such as MATLAB® or Microsoft® Excel

OPTICAL RESEARCH ASSOCIATES

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