SYNOPSYS®
Silicon to Software™

Choosing The Right Optical Design Software

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Introduction: Maximize Your Return on Investment

As a decision maker responsible for making the right choices for your company's bottom line, you understand that the return on any engineering tool investment is a crucial part of your business' growth and profitability. Why would you choose CODE V® when there are potential solutions available with lower up-front costs? Because when the quality of your optics is critical to your product, the return on investment in CODE V is much greater than the cost, and far superior to the return from other solutions.

CODE V is the proven and trusted optical design tool of numerous companies, government agencies, research labs, and universities worldwide. CODE V can help you save time, money, and your company's reputation. CODE V reliably produces better optical designs in less time—designs that are often cheaper to fabricate than those produced with other software. That's why our customers continue to subscribe to CODE V year after year, despite the other choices available.

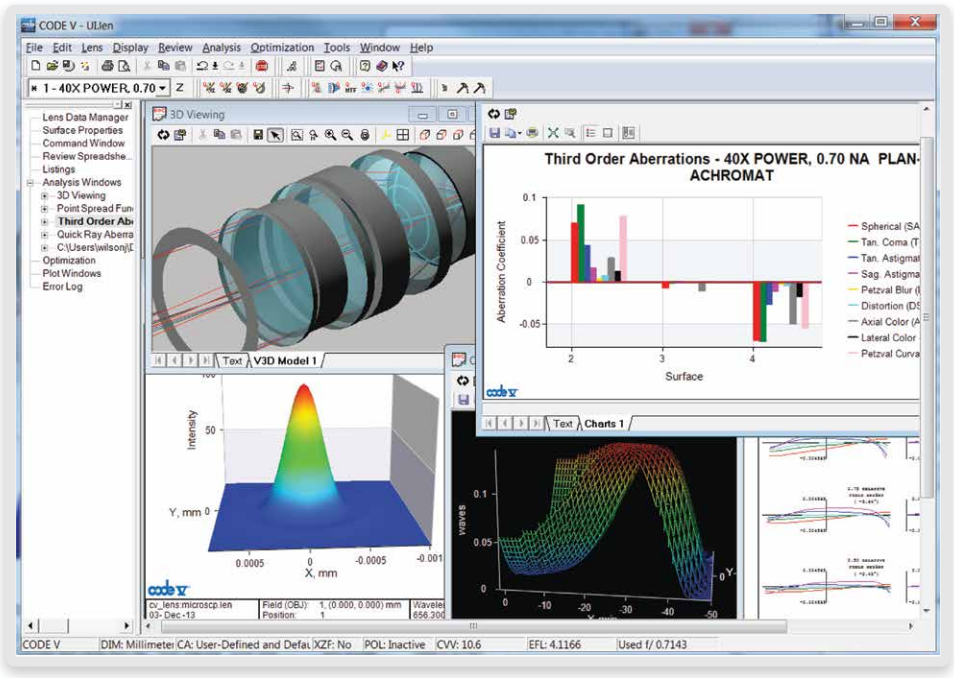

Figure 1. CODE V Graphical User Interface (GUI)

Feature list comparisons will not help you choose the right software for your company. The return on investment is completely dependent on the superiority of the algorithms and the implementation details, and depends little on the feature name. CODE V customers have done design study comparisons with competitive optical design software that prove the time-to-market and cost-to-manufacture savings CODE V can provide. Our customers found that the CODE V optimizer yields better, more manufacturable designs. They found that CODE V's fast wavefront differential tolerancing consistently predicts results that match measured performance, and can be computed in a fraction of the time compared to other tolerance approaches. They also found that their engineers produce better designs, faster. Invest in CODE V and you will save your organization money.

A Team You Can Rely On

Choosing the right optical design software is about more than just the software. You need a team you can rely on year after year. The Synopsys Optical Solutions Group (OSG), formerly Optical Research Associates (ORA®), has been providing world-class support to our CODE V customers for over 40-years. CODE V is developed and supported by a team with extensive technical know-how, including:

- The industry's largest software development staff devoted to commercial optical engineering software
- A customer support staff with over 50 person-years of engineering experience, who are dedicated to helping customers use our products successfully. This is their full-time job, not just an added responsibility
- Software development processes that have been formalized using state-of-the-art software configuration management methods to ensure an environment that produces innovative algorithms delivering high quality, reliable, and accurate results
- Staff of professional software testers. Our testing personnel construct and evaluate thousands of test cases run daily on code under development
- Our in-house Engineering Services group validates each version of CODE V on cutting-edge, real-world engineering applications
- Our staff includes three Fellows of the SPIE. Synopsys OSG engineers have published over 300 articles and are listed as inventor or co-inventor on nearly 100 patents related to optical systems

We are organized to produce the best optical engineering software products available. Here are some of the ways that this dedication to being the best can help your organization.

Produce Superior Designs

The heart of any optical design software is its optimizer: it takes systems that don't perform well, or don't meet optical or mechanical constraints, and makes them better. Users have found that CODE V's optimization is unmatched in the variety of systems it can handle efficiently, its superior results, and the speed with which it delivers these results. CODE V can optimize some systems in a fraction of the time compared to competitive software—as demonstrated by customer benchmark studies.

Furthermore, CODE V's optimization delivers the design reliability and robustness required for the most demanding optical applications. That's why it is the primary optimization software used by the microlithographic industry to design the optical systems that produce integrated circuits.

No other commercial package handles optimization constraints as well as CODE V. Competitive packages force users to include constraints as weighted aberrations, which results in time-consuming cycles of adjusting weights and re-optimizing to achieve the desired balance. CODE V's default constraint handling for optimization uses a superior implementation of Lagrange Multipliers, which allows the performance merit function to converge in a least-constrained mode, while still meeting all packaging requirements.

CODE V's fast wavefront differential tolerancing algorithm has been embedded in its optimizer so that designers can optimize for the best as-built performance, including the impact of tolerances and compensators. When used with CODE V's global optimization feature, Global Synthesis®, (which uses a Synopsys-proprietary algorithm), CODE V can find hundreds of solutions with superior as-built performance, compared to simply analyzing the as-built performance for global optimization results based only on nominal performance:

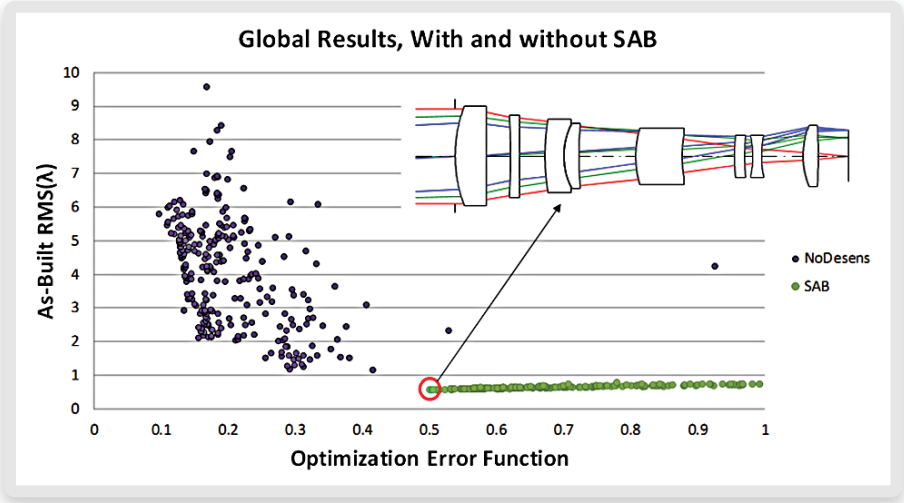

Figure 2: Each dot represents a different solution for an 8-element polychromatic lens, generated by Global Synthesis (GS). The X-axis is the optimization error function. The Y-axis is the field-averaged, as-built RMS wavefront error at a mean+2σ yield probability. If GS is run without any control on tolerance sensitivity (the purple dots), there is no correlation between a lower error function and better as-built performance. This represents wasted optimization and designer time. Once CODE V's unique tolerance desensitization is added to the error function, there are many solutions with superior as-built performance (green dots), and an excellent correlation between a lower error function and better as-built performance.

In addition, our optimization tools such as Asphere Expert and Glass Expert embed the expert knowledge of our optical engineers into our algorithms. Asphere Expert can determine which surfaces in the lens system would provide the greatest benefit when aspherized. The computation is incredibly efficient. The lens system could have four surfaces or four hundred, and the priority ranking of all the surfaces requires about the same time as a single cycle of optimization. Users can control the allowed slope departure for the aspheres, which will change the ranking appropriately.

Glass Expert automatically selects the best set of glasses for your system during the optimization process and achieves color correction more efficiently than alternative programs, saving hours of design time. It mimics the process that an expert optical designer, skilled in glass selection, would use. It will also make smart decisions about glass choice based on the lens construction. For example, if weight is a concern, Glass Expert might choose a high-density glass for a small, thin element, but avoid substituting that glass for a larger element or prism.

While CODE V has the fastest optimization algorithm in the industry, some systems can challenge the computation efficiency of damped least squares local optimization. CODE V includes a second, proprietary optimization algorithm called Step Optimization. It can dramatically speed up optimization convergence, reducing the time needed to find the best solution.

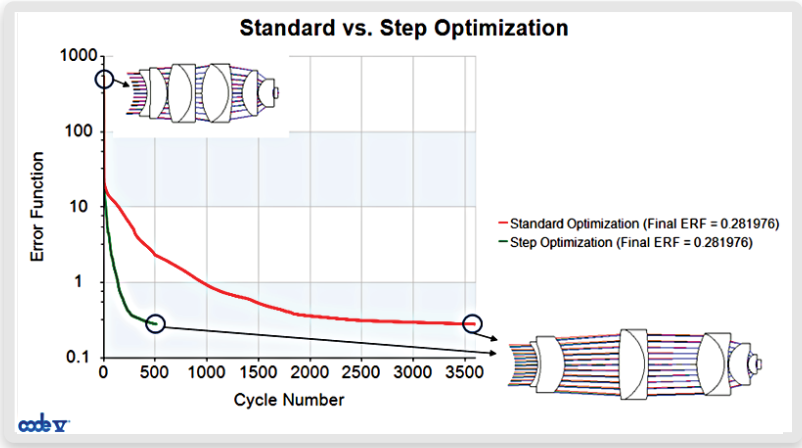

Figure 3. The Error Function value versus Cycle Number is plotted for two optimization runs, using an identical high-NA microscope objective starting lens. With standard optimization, it requires about 3600-cycles to reach the minimum value. With Step Optimization, the exact same solution is achieved in 510-cycles. The actual optimization time is approximately 7x faster using Step Optimization.

Manufacture with Confidence

Few designs end their life cycle on paper. They must be fabricated and meet performance specifications after assembly. Delivering the best performing as-built optical design with minimized recurring and non-recurring costs is one of the CODE V's greatest strengths, and many of its features are directed to this end.

CODE V's fast wavefront differential tolerancing feature is recognized in the industry as the most efficient tool for producing robust optical designs that will work when built. Its algorithm is just as accurate as Monte Carlo methods, yet it can be hundreds of times faster.[1] CODE V customers have reported situations where, when using other software, the measured performance of a system did not match the predicted as-built performance. The same tolerance analysis, when re-run in CODE V, agreed with the measured data.

The speed of CODE V's tolerancing enables it to be an integral part of the design process, rather than an end-of-the-design analysis. In fact, as mentioned earlier, the speed allows the calculation to be included as an optional component of the error function for optimization.

CODE V also supports a unique alignment optimization feature that can be used to automatically determine the appropriate hardware adjustments to correct misalignments in your assembled optics based on measured interferograms for your system. This feature has saved many organizations countless hours (and even days) of alignment time.[2]

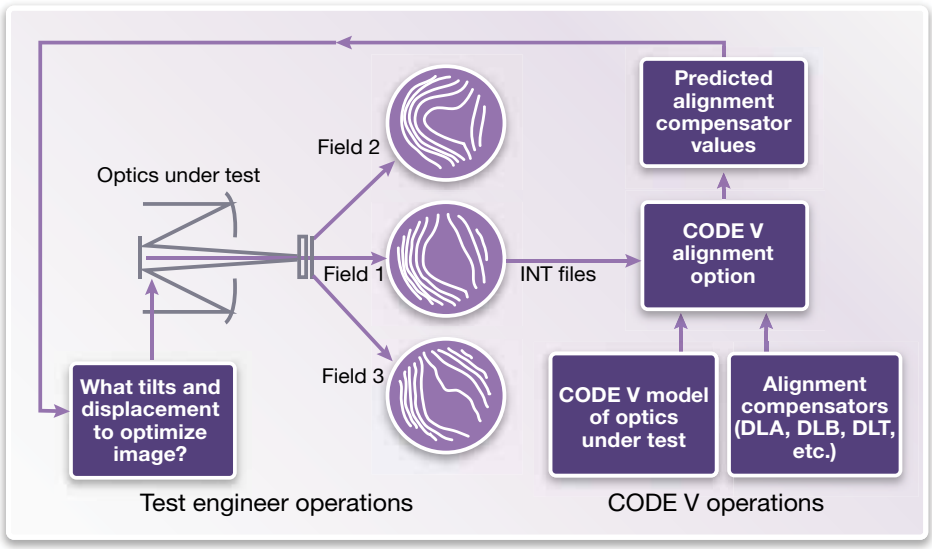

Figure 4. Schematic of the CODE V alignment optimization feature

Accurate Results You Can Count On

Errors in the design process can lead to missed schedules and extra costs, as unwanted redesigns are performed. It is critical for your optical modeling software to exceed the accuracy specifications that your own products must meet. CODE V utilizes the most accurate algorithms available and has the quality assurance processes in place to maintain this accuracy.

CODE V is known for providing intelligent, engineering-based defaults for its analysis and optimization features. In addition, if CODE V detects that a system may be violating some assumption of the analysis algorithm, it issues warnings. This means that your engineers can proceed with confidence, and often without extra setup work sometimes required in other software, to achieve useful and accurate results from CODE V.

As an example of CODE V's accuracy, NASA required the use of CODE V for the evaluation of all designs related to the corrective optics for the Hubble Space Telescope Servicing Mission. In fact, ORA's Engineering Services group developed the designs for the test optics for the WFPC2 camera and COSTAR corrective optics. The successful design of these test optics required the computation of individual Zernike coefficients to a minimum accuracy of 0.01 wave in a system model that included off-axis anamorphic aspherics (i.e., for COSTAR). The ultimate success of the servicing mission is clear in the stunning images now being returned by the Hubble.

CODE V also includes a generalized beam propagation feature, Beam Synthesis Propagation (BSP), that was initiated in response to a NASA-funded project requiring accuracy levels that were previously unobtainable in any commercial software. BSP sets an industry standard for accuracy, efficiency, and ease of use. Its beamlet-based wave propagation algorithm is designed to deliver extremely accurate modeling of the effects of diffraction throughout almost any optical system. A major benefit of BSP is its groundbreaking Pre-Analysis feature, which automatically recommends appropriate inputs based on the resident lens system and delivers an accurate answer in the shortest amount of time.

CODE V is also recognized as the only real choice for accurate results if polarization has an effect on your image performance. CODE V's polarization ray tracing capabilities allow accurate calculations of system performance, including the input polarization state and system-induced polarization effects.

Additionally, CODE V's partial coherence analysis feature allows the user to accurately predict aerial image structure assuming an object that is illuminated with light ranging from incoherent to fully coherent.

Get to Market Faster

CODE V's flexible user interface, faster algorithms, intelligent defaults, and features to support the manufacturing process all result in developing and assembling the best design, faster. Some examples worth noting:

- From user comparison studies, optimization runs are many times faster (seconds compared to minutes) than competitive software and converge in fewer cycles. There are optimization convergence control features that can speed up convergence on extremely complex systems by an additional two to four times[3]
- Nearly all functionality can be run via a Windows-standard graphical interface or command-line entry, allowing your engineers to use the program in the manner that is most efficient for them
- A fully functional macro capability is a very powerful tool to enable complex analyses to be run with an easy-to-use script
- There is also a COM Application Programming Interface (API), allowing users to create complex utilities and integrate CODE V with other COM-enabled tools

In addition, Synopsys' technical support staff is available five days a week, 10 hours a day to help your engineers if they have a question that requires some outside insight. This service has proved invaluable to customers to quickly overcome obstacles.

Seize the Competitive Advantage

Whether your application is micro-optics or large space-borne instruments working at wavelengths ranging from the extreme UV through the far infrared, CODE V has the capabilities and algorithms to help your design team develop, build, and deliver the best optical systems.

Remember that software functionality cannot be determined simply by comparing feature lists among competitive products. All algorithms are not created equal. CODE V gives you the best set of optical design tools available, and a dedicated, experienced team to back it up.

If optics are critical to your product, CODE V optical design software helps enable your success.

About Us

At https://www.synopsys.com/optical-solutions/codev.html, you can find detailed product feature information, white papers, and the CODE V brochure. Our Engineering Services group has used CODE V extensively in the 4,800 optical engineering projects they have successfully completed since 1963. Over 50 articles, presentations, and publications authored by our engineers are listed at https://www.synopsys.com/optical-solutions/learn/technical-papers.html. These articles cover a wide diversity of optical design and engineering applications, and are available for no charge, whether or not you are a CODE V customer.

References

[1] Synopsys Optical Solutions Group white paper, CODE V Tolerancing: A Key to Product Cost Reduction (2013).

[2] K. Sugisaki, et al., "Assembly and alignment of three aspherical mirror optics for extreme ultraviolet projection lithography," Proc. SPIE, Vol. 3997, pp. 751 – 758 (2000).

[3] Advanced Topics in CODE V training notes, "Advanced Optimization Techniques" (2013).

For more information, or if you would like a 30-day free-trial of CODE V, please contact Synopsys' Optical Solutions Group at (626) 795-9101, between 8:00 a.m.-5:00 p.m. PST, visit https://www.synopsys.com/optical-solutions.html, or send an e-mail to optics@synopsys.com.

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