Pushing the Envelope in Optical Design Software

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This special issue in *Optical Engineering* began with a conversation at Photonics West last year with Dr. Donald O'Shea. We were discussing the capabilities of current optical design programs. In his role as an educator, Dr. O'Shea introduces his students not only to the art of optical design, but also to the software tools which are available to be used, or misused, to aid in the design of optical systems.

Optical design programs have expanded in scope significantly over the last 10 to 20 years. The speed of computers has been a significant factor. Many of you may remember when computer programs could trace all of one ray surface per second, but this was still a marked improvement over hand calculations. When programs reached ray tracings speed on the order of 20,000 ray surfaces per second, optical design software had ''arrived.'' Now ray trace speeds can easily exceed 1,000,000 on some designs.

This increase in ray tracing speed has led to several changes in how optical design is performed. The first result is that an optimized design form can be determined in a shorter time. It also can provide designers the opportunity to explore other regions of solution space. The options available for constructing merit functions allow almost any requirement to be considered throughout the entire lens design process.

Experienced optical designers can design and analyze tolerance complex systems more efficiently and effectively than ever before. The basic functionality of the design program more than meets the needs of most design projects. Properly constructed and constrained merit functions can be used to direct the program to one or several possible solutions in a relatively short time frame. Included tolerancing capabilities can be applied to determine the best design candidate in terms of performance as well as manufacturability.

Additionally, the design codes are also becoming more powerful. Calculations, which may have been neglected previously because the amount of time and computer resources required, can now be readily performed. The functionality of current software, in many ways, goes well beyond simple geometric ray tracing and aberration calculation. Many of these new capabilities have been added to the various programs to try to keep up with needs of designers who need to ''push the envelope'' of the available software to reach the desired goals.

During my chat with Dr. O'Shea, I mentioned that, in my view, about 90 of the features of most of the design programs go virtually unused. In part, this is legitimately due to the fact that many designs do not require many of these capabilities. Much about the process of optical design today is very similar to that done long before the arrival of the computer and userfriendly design codes. It is very possible that one of the reasons designers do not take full advantage of the programs is that often we do not have the time to simply explore the new software releases as they arrive. We simply look at the changes that are applicable to our current designs, fully intending to fully read the documentation when the time is available. This leads to the reasons for having this special issue. The first is to allow optical designers to show other designers the issues that have been dealt with in new ways. The second is to let everyone look at optical design programs in new ways.

Papers were submitted concerning several aspects of ''pushing the envelope'' including user-defined or other special surface shapes, specialized analysis capabilities, interactive calculations, and others.

The first paper by Descour et al. discusses using single value decomposition to determine the alignment sensitivity of extreme ultraviolet lithography projection cameras. In this case, software was written to modify the design to include the desired misalignment modes, and then to take information returned from the design program for use in an external application. The paper by Stone describes a geometric method for modeling many aspects of interferometric systems. The goal is a method that allows interferometers to be modeled as actually used. The paper by Rolland discusses the design of head-mounted displays, including the use of specialized analysis tools to model accommodation and distortion. These are important to analyze the system from the perspective of usability. The paper by Rayces and Rosete-Aquilar discusses a method for designing an optical system that can be used to duplicate the wavefront errors of another optical design over the entire field of view. This is a very powerful tool which can be used to generate corrector optics which work over the entire field-of-view of the original optical system. The next paper, by Rogers, discusses the tolerancing of null lenses as part of the end-use design. This provides a correlation between the tolerancing of the null lens and the performance of the system under test. The paper by Wang, Aikens, and English, Jr. shows a method of using zoom positions to simultaneously optimize a design for near field and far field performance. This process is well suited to laser systems that often require aberrations be controlled in the pupil as well as the field. The paper by Lerner and Sasian discusses the use of implicit functions to describe highly aspheric surfaces. Recent advances in technology have significantly reduced the cost factors associated with aspheric optics, but in many instances the standard aspheric surface shape fails to meet the design requirements. The paper by Dewald describes using a special optical surface to model digital micromirror devices. The paper by Thibault describes a method for representing astigmatic laser diode sources that can be used to accurately determine coupling efficiency. The paper by Rodgers discusses using nodal aberration theory to design tilted-component systems having symmetric performance. It also discusses using Zernike coefficients as the driver in the optimization process to reduce unwanted aberrations. The paper by Tesar considers the impact of the variety of glass available in an optimization process to the final system performance. This is a continuation of the long-standing discussion of how many glass types are really necessary. The paper by Sparrold et al. describes using counter-rotating Zernike phase plates in a conformal optical system to reduce the aberration effects of the conformal optical dome. The paper by Cassarly et al. describes a method of optimizing the output from faceted reflectors in illumination systems. Forkner's paper describes a simple technique for generating null masks to be used in Ronchi testing of highly aberrated elements. The paper by Tesar, Liang, and Mansuripur combines optical design with further diffraction analysis in lithographic systems.

My goal was to include papers that would be educational to optical designers of all experience levels. Many of the techniques described here may lead others to look at optical design and at the design programs from a new perspective. Although this is a special section, please remember that *Optical Engineering* always has room for papers on optical design. The journal would gladly accept for review any papers submitted on this topic. I would like to thank all of those who contributed to this special section as well as all of the reviewers. The prompt response from everyone made this an enjoyable process. I would also like to thank Dr. O'Shea for providing this opportunity and the staff at *Optical Engineering* for all their help and support.

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