DATASHEET

Asphere Design in CODE V

Q-Type Polynomials Enable Superior Design Optimization and Tolerancing

Features at a Glance

- Q^{bfs} polynomials for controlling aspheric slope departure
- Q^{con} polynomials for determining aspheric sag departure
- Basis members are independent (orthogonal)
- Offer many advantages over standard power-series formulation

Overview

Full support in CODE V® for aspheric surfaces based on mathematical formulations published by Dr. G.W. Forbes of QED Technologies enables superior design optimization and tolerancing, helping ensure a cost effective, manufacturable system.

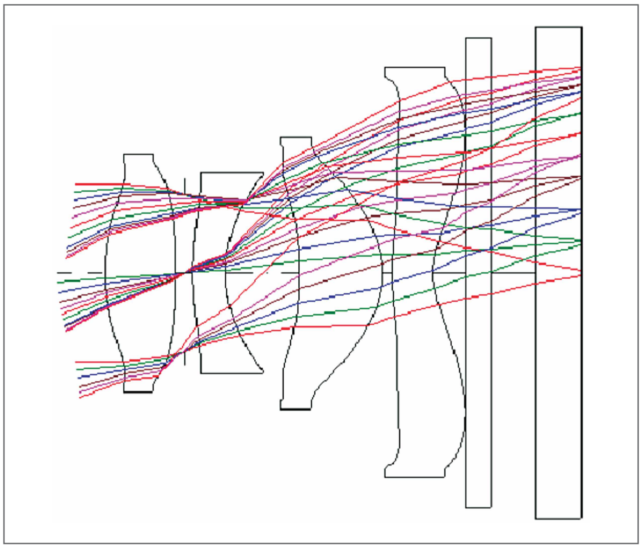

Figure 1: Cell-phone lens model containing aspheric elements

New Mathematical Formulations For Aspheric Surfaces

The use of aspheric surfaces in optical systems is becoming increasingly important as lens systems become more compact and complex, and image resolution becomes ever more critical. This increasing use of aspheric components is accompanied by an increasing need to control their production cost. Unfortunately, the traditional methods of aspheric design present inherent complications when it comes to manufacturing and testing of these components.

Dr. G.W. Forbes of QED Technologies has published new mathematical formulations for rotationally-symmetric aspherical surfaces that offer several advantages over the traditional polynomial-based aspheres (for example, CODE V's Asphere or ASP-type surface). Major advantages of these new forms over the classic power-series description include:

- The terms can be viewed in a physically significant way: the magnitude of the respective coefficient is directly related to slope or sag departure of the asphere from the base sphere or conic
- The formulations lend themselves to the use of optimization constraints, to substantially improve manufacturability and thereby reduce cost
- The introduction of slope constraints can also produce aspheres that can be tested without the use of expensive null optics
- The formulations convey the effective number of coefficients and require fewer digits of precision, which greatly simplifies the numerical burden placed on optical fabricators
- The formulations facilitate the determination of optimum placement of aspheric surfaces in an optical system
- The aspheric terms are orthogonal over a normalization radius, which makes each term unique and meaningful tolerancing of the terms possible
- The Q^{bfs} polynomial form defines a surface that is characterized by an RMS slope departure of the aspheric surface from a best-fit sphere. This provides a meaningful quantification of the testability of the surface. The RMS slope of this departure can be easily calculated, and is proportional to mean fringe density

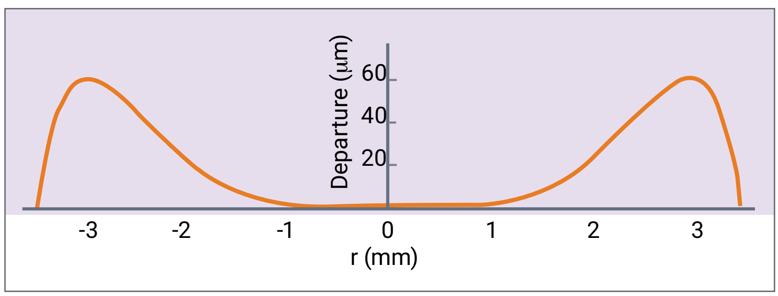

Figure 2: Deviation of sample Qcon aspheric surface from a conic section.
Figure courtesy of Dr. Greg Forbes, source cited below

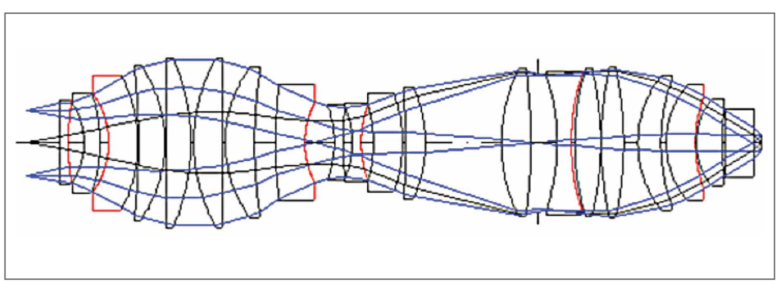

Figure 3: Lithography lens with aspheric surfaces shown in red

The Q^{con} form defines a surface that is characterized by the sag departure of the aspheric surface from a base conic. This formulation allows designers to determine the need for a particular term by inspection, thereby avoiding unnecessary complications for fabrication and testing, and reducing cost.

Q-Type vs. Zernike

Other methods have been employed over the years in an attempt to improve on the classic power-series method of modeling aspheric surfaces. Zernike polynomials constitute a widely used solution, and share some of the benefits offered by the Q-type polynomials. However, Zernike polynomials do not address critical manufacturability and testability issues, nor do the coefficients allow sag or slope departures from the base surface to be determined by visual inspection; the Q-type formulations excel at both. While Zernike polynomials remain extremely useful for many purposes, the Q-type polynomials offer a unique and innovative approach to aspheric design.

CODE V for Aspheric Design

An exclusive agreement with QED, signed in October of 2009, has supported efforts to integrate superior aspheric design and analysis capabilities in CODE V software, building upon the core analysis, optimization, and tolerancing strengths of CODE V. The Q^{con} and Q^{bfs} surface formulations are currently available in CODE V.

Additional Information

For additional background information, see G. Forbes, "Shape specification for axially symmetric optical surfaces," Opt. Express 15, 5218-5226 (2007), which is available online at the OSA Optics InfoBase website:

http://www.opticsinfobase.org/abstract.cfm?URI=OE-15-8-5218

Also see K. P. Thompson, F. Fournier, J. P. Rolland, and G. W. Forbes, "The Forbes Polynomial: A More Predictable Surface For Fabricators," in Optical Fabrication and Testing, OSA Technical Digest (CD) (Optical Society of America, 2010), paper OTuA6. The full-text PDF is available online at the OSA Optics InfoBase website:

http://www.opticsinfobase.org/abstract.cfm?URI=OFT-2010-OTuA6

For more information about CODE V, visit synopsys.com/optical-solutions.html or send an email to optics@synopsys.com.