Optical Design with Free Form Surfaces

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Budget constraints and testing challenges have historically limited the choice of surfaces available for the design of reflective optical instruments. Typical options include spherical and conic mirrors, as well as the occasional polynomial asphere with modest spherical departure. For future space-flight science instruments, however, more degrees of freedom are necessary to meet greater demands in imaging performance and packaging requirements. These instruments will be composed of aspheres located far off-axis with large spherical departure, and some designs will require asymmetric or "freeform" surface profiles.

Fortunately, recent advances in optical manufacturing have significantly increased the ability to fabricate such optics with high surface quality at a reasonable cost. This trend opens new degrees of freedom available to the optical designer, adding more "tricks" to the designers tool kit to solve a given problem. As the departure from symmetry for optical surfaces increases, the "old school" approach of paraxial design of optical systems becomes invalid, and new paradigms must be considered for optical design.

This paper surveys various approaches for optical design using freeform surfaces, and its purpose is to educate a general audience of non optical engineers on the method of optical design. Standard first and third order approaches of aberration correction are covered, as well as parabasal optics for asymmetric systems. Hamiltonian methods are also discussed, along with differential equation solutions for aplanatic imaging systems. Finally, a review of existing surfaces available in standard lens design software is reviewed.