



PREFERRED
RELIABILITY
PRACTICES

BINARY AND HYBRID OPTICS FOR SPACE APPLICATIONS

Guideline:

Binary (diffractive) optics combined with conventional (refractive) optics offer a significant potential for space optics reliability improvement.

Benefits:

Improved ruggedness, reduced size, and greater opportunity for redundancy are the potential benefits of using binary and hybrid optical systems for space applications. Hybrid optical systems can be designed that are less sensitive to color (or chromatic variations) and to temperature variations. When combined with conventional optics, binary optical systems can correct for spherical aberrations.

Center to Contact for More Information:

Marshall Space Flight Center (MSFC)

Implementation:

Binary Optics: Binary (diffractive) optics uses computer-aided design (CAD) tools and very-large-scale-integration (VLSI) electronic circuit manufacturing technology to create novel optical devices and to provide design freedom and new materials choices for optical elements. When combined with conventional (refractive) optical lens systems, binary optical systems cannot only provide athermalization and achromatization, but offer the opportunity for miniaturization, significant weight savings, and resulting opportunity for redundancy in aerospace telescope systems, sensors, vision systems, and microelectronic optical systems.

While in conventional optics lenses are polished to a desired profile, binary optics uses high resolution lithography (the design and replication process used in electronic circuit fabrication) to transfer a binary surface relief pattern to the optical element. This pattern is then etched into a surface using ion-beam etchers. A single etching step produces a two-level surface, thus the term “binary optics.” The etching process can be repeated with different etch depths to produce multi-level optical elements.

A binary coded set of lithographic masks can double the number of phase levels with each etching step. For example, four etching steps result in a 16-level optical element with a

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theoretical diffraction efficiency of better than 99 percent. The etch profile approximates a continuous phase surface.

Hybrid Optics: Hybrid diffractive/refractive lenses are being considered for NASA's Geostationary Earth Observatory (GEO) to reduce weight and increase reliability of its sensors, telescopes and imaging systems. Hybrid lenses can be built that weigh less than half of conventional lenses, offering the possibility of providing redundant systems. Since the color separation properties of binary optic lenses are opposite in sign to those of a traditional lens, achromatic, lenses can be constructed using combined diffractive/refractive elements.

Certain optical materials, particularly plastics and infrared materials, have optical and mechanical properties that may cause decreased performance over a wide temperature range. For space applications, the unique properties of diffractive lenses offer significant advantages in this regard when used in combination with traditional refractive or reflective systems. Temperature compensation may also be achieved in an optical system mounted in a housing that is subject to expansion or contraction in various thermal environments. It is possible to design an element that contains both refractive and diffractive surfaces such that the change in focal length with increasing or decreasing temperature is equal to the change in position of the image detector in relation to the lens. Optical technicians have developed an opto-thermal expansion coefficient that is used to design athermalized lenses that combine refractive and diffractive surfaces.

Opto-Electronics: Since binary optics are fabricated using the same equipment and techniques used to make semiconductor chips, the next step is to fabricate binary optics into the chips themselves, which results in opto-electronic assemblies with built-in processing functions. Micro-optic lens arrays can be integrated with semiconductor detector arrays to produce compact, lightweight, rugged, integrated imaging/detector systems. If the system is spaceborne, radiation resistance can be improved, since each smaller active detector element now presents less cross sectional area for gamma ray interactions.

Technical Rationale:

Binary and hybrid optics have created a revolution in the way lenses, and ultimately, opto-electronic systems are designed and manufactured. Hybrid optics combines the best features of diffractive and refractive optics technology. Many highly reliable types of hybrid lenses, filters, multiplexers, and diffractive coatings have recently become feasible. By applying a mixed optics approach to system design and fabrication, the number of series elements in a complex system can often be halved, improving reliability. The lower weight of the systems, in addition, offer the opportunity of increased redundancy through the use of multiple backup systems. Further evidence of the usefulness of these technologies should become evident as they are put into practice.

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Impact of Nonpractice:

Failure to apply binary and hybrid optics technology in space applications could result in higher weight, higher cost, less reliable systems than possible using these emerging technologies.

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