Compensation for Phase Anisotropy of a Metal Reflector

A multilayer dielectric coating would introduce an opposing phase anisotropy.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method of compensation for the polarization-dependent phase anisotropy of a metal reflector has been proposed. The essence of the method is to coat the reflector with multiple thin alternating layers of two dielectrics that have different indices of refraction, so as to introduce an opposing polarization-dependent phase anisotropy.

The anisotropy in question is a phenomenon that occurs in reflection of light at other than normal incidence: For a given plane wave having components polarized parallel (p) and perpendicular (s) to the plane of incidence, the phase of s-polarized reflected light differs from the phase p-polarized light by an amount that depends on the angle of incidence and the complex index of refraction of the metal. The magnitude of the phase difference is zero at zero angle of incidence (normal incidence) and increases with the angle of incidence.

This anisotropy is analogous to a phase anisotropy that occurs in propagation of light through a uniaxial dielectric crystal. In such a case, another uniaxial crystal that has the same orientation but opposite birefringence can be used to cancel the phase anisotropy. Although it would be difficult to prepare a birefringent material in a form suitable for application to the curved surface of a typical metal reflector in an optical instrument, it should be possible to effect the desired cancellation of phase anisotropy by exploiting the form birefringence of multiple thin dielectric layers. (The term "form birefringence" can be defined loosely as birefringence arising, in part, from a regular array of alternating subwavelength regions having different indices of refraction.)

In the proposed method, one would coat a metal reflector with alternating dielectric layers having indices of refraction n_1 and n_2, and thicknesses d_1 and d_2, respectively. To obtain form birefringence, the thickness of each spatial period ($d = d_1 + d_2$) must be much less than the shortest wavelength of light for which compensation is sought. For special case $d_1 = d_2 = d/2$ shown at the top of Figure 2, the resulting ordinary and extraordinary indices of refraction (n_o and n_e, respectively) would be given by

$$n_o = \left[\frac{(n_1^2 + n_2^2)}{2} \right]^{\frac{1}{2}}$$

and

$$n_e = n_1 n_2 \left[\frac{2}{(n_2^1 + n_2^2)} \right]^{\frac{1}{2}}.$$

The magnitude of the compensatory phase anisotropy would be proportional to the thickness of the compensator. In choosing the thickness, one must take into account that incident light would pass through the dielectric layers, be reflected from the mirror surface, then pass through the dielectric layers again and, hence, the phase accrual through the compensation layer must therefore be doubled before being added to the reflection phase.

The free design parameters for a given application would be the choice of constituent dielectric layers (with their indices of refraction and dispersion characteristics), the thickness of the compensator (equivalently, the number of spatial periods), and the relative thickness of each constituent layer. In a typical design optimiza-

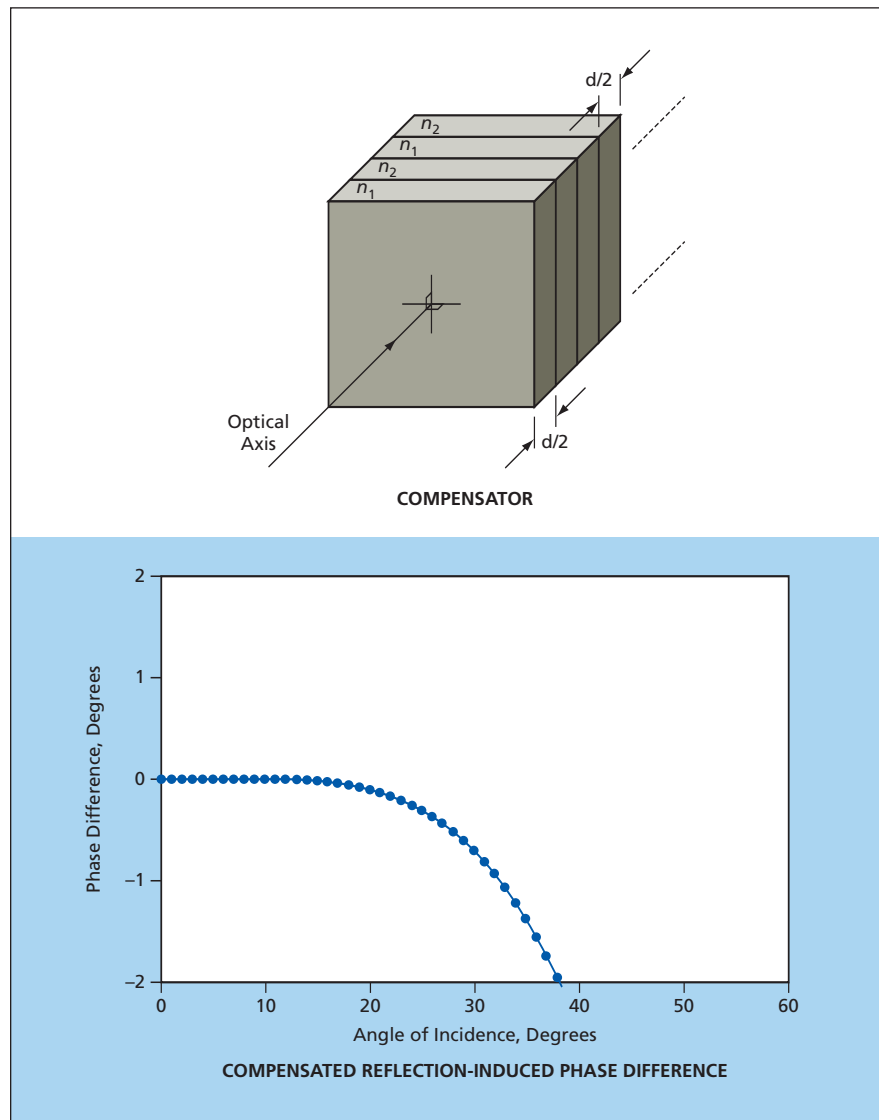**COMPENSATOR**

COMPENSATED REFLECTION-INDUCED PHASE DIFFERENCE

Figure 2. A **Coating Comprising Alternating Thin Dielectric Layers** having different indices of refraction would exhibit form birefringence that could be exploited to compensate for anisotropy like that of Figure 1.

tion, one would adapt the parameters to the reflector at hand and seek to keep the phase deviation below some maximum allowable value across the range of angles of incidence for the field of view of the instrument of which the reflector is a part. To obtain compensation over a spectral band, it would be desirable to perform a wider optimization involving the bandwidth of the light and the dispersion characteristics of each dielectric layer.

The lower part of Figure 2 illustrates an example of compensation for the anisotropy of Figure 1 for monochromatic light. In this case a combination of $n_o = 1.5$, $n_e = 1.45$, $d_1 = d_2 = d/2$, and an overall thickness of 0.5676 wavelengths was chosen to satisfy a requirement to keep the maximum phase anisotropy below 0.0075° at angles of incidence as large as 13°.

Optical Characterization of Molecular Contaminant Films

A theoretical model is correlated with measured spectral transmittances and VUV exposures of spacecraft optics.

Lyndon B. Johnson Space Center, Houston, Texas

A semi-empirical method of optical characterization of thin contaminant films on surfaces of optical components has been conceived. The method was originally intended for application to films that become photochemically deposited on such optical components as science windows, lenses, prisms, thin-film radiators, and glass solar-cell covers aboard spacecraft and satellites in orbit. The method should also be applicable, with suitable modifications, to thin optical films (whether deposited deliberately or formed as contaminants) on optical components used on Earth in the computer microchip laser communications and thin-film industries.

The method is expected to satisfy the need for a means of understanding and predicting the reductions in spectral transmittance caused by contaminant films and the consequent deterioration of performances of sensitive optical systems. After further development, this method could become part of the basis of a method of designing optical systems to minimize or compensate for the deleterious effects of contaminant films. In the original outer-space application, these deleterious effects are especially pronounced because after photochemical deposition, the films become darkened by further exposure to solar vacuum ultraviolet (VUV) radiation.

In this method, thin contaminant films are theoretically modeled as thin optical films, characterized by known or assumed values of thickness, index of refraction, and absorption coefficient, that form on the outer surfaces of the original antireflection coating on affected optical components. The assumed values are adjusted as needed to make actual spectral transmittance values approximate observed ones as closely as possible and to correlate these values with amounts of VUV radiation to which the optical components have been exposed.

In an initial study, the method was applied in correlating measured changes in transmittance of high-purity fused silica photochemically coated with silicone films of various measured thicknesses and exposed to various measured amounts of VUV radiation. In each case, it was found to be possible to select an index of refraction and absorption coefficient that made the ultraviolet, visible, and infrared transmittance changes predicted by the model match the corresponding measured transmittance changes almost exactly.