Manx Precision Optic

Fresnel Reflectivity

Why are Anti-Reflection Coatings useful?

The term 'Fresnel Reflectivity' is named after the French Engineer Augustin-Jean Fresnel (1788-1827). Based on experimental observations (many of them undertaken by Thomas Young), Fresnel deducted the so-called Fresnel Equations that allow the calculation of the reflected and transmitted electric field amplitude in relation to the initial electric field for electromagnetic radiation incident on dielectric material.

Going into the detailed derivation of the Fresnel Formulas would go well beyond the scope of this technical note, but looking at normal incidence (0º), the reflectivity (R) and transmission (T) of light on the interface between two dielectric media is given by:

$$R=[(n_2-n_1)/(n_2+n_1)]^2 \qquad T= 4n_2n_1/(n_2+n_1)^2$$

In these formulas, n_1 is the refractive index of the incident medium (n_1=1 in air) while n_2 represents the refractive index of the exit medium.

From these formulas it follows that the reflectivity per surface at 0º incidence increases with the difference in the refractive index of the media. In air as incident medium, the so-called 'Fresnel Reflection' per surface can reach significant values.

Examples are listed in Table 2014-03a below:

Material	Refractive index at 589nm	Fresnel Reflection per surface at 0º incidence
Crown Glass	1.517	4.22%
Fused Silica	1.458	3.47%
Water	1.333	2.04%
Zirconia	2.19	13.92%
Diamond	2.417	17.20%

Table 2014-03a: Fresnel Reflection of various materials

The above values naturally depend on the wavelength and are therefore, while accurate at 589nm, only approximations as far as the overall visible spectrum is concerned.

However, the high refractive index of diamond and the resulting Fresnel reflectivity explains the 'fire' that a well cut diamond displays (and why experts can easily distinguish it from cheaper Zirconia gemstones).

For technical applications, the Fresnel reflectivity does have serious implications. In modern lens systems (a camera lens, for example) it is not uncommon to find 10 or more optical surfaces. If each surface in the system was to reflect approx. 4% of the incident light, the total amount of reflected light would be about 40%. This is indeed the case in older camera lenses (with uncoated optics) and results in images that show lower contrast, especially when the photo is taken in a sunny environment.

Modern coating technology allows to significantly reduce the reflectivity of a surface. So-called anti-reflection ('AR') coatings can, depending on circumstances, reduce the reflectivity of a surface to less than 0.1%. They are generally available for single and multiple wavelengths (where, for example, the application involves discrete laser wavelengths) or entire spectral wavelength bands (for camera lenses, for example).

An AR coating can be made up of a single layer (MgF_2 is by far the most common) or of a system of multiple layers, which generally gives much better anti-reflection properties. Manx Precision Optics offers a range of standard AR coatings, but where a specific specification is required, the company will work with the customer to find the best solution.

Image 2014-3a below illustrates the performance of a single- and multilayer AR coating compared to an uncoated surface of a BK7 substrate at 589nm.

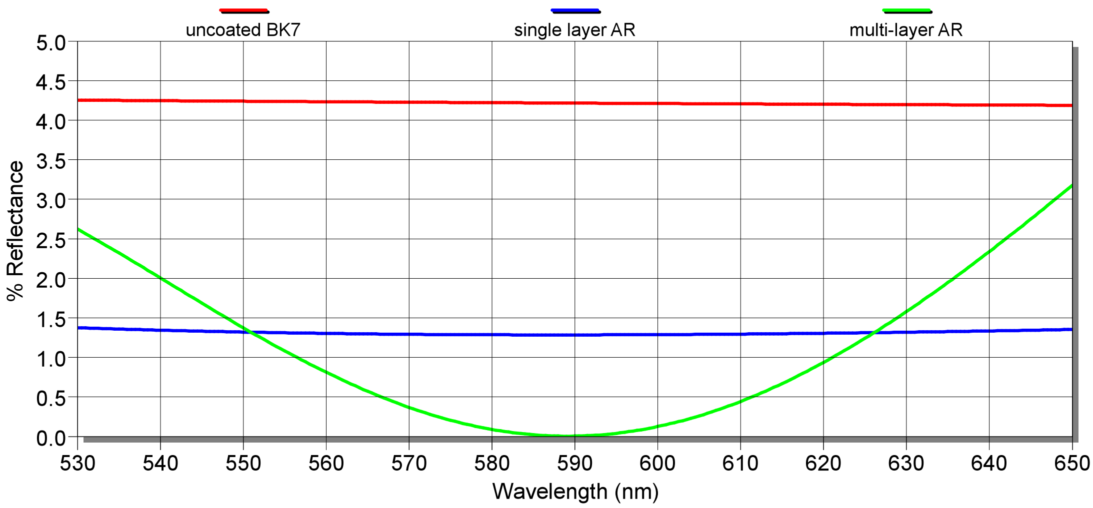

Image 2014-3a: AR-coating performance on BK7 at 589nm

References:

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