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Antireflection coating for high index cemented doublets

Ronald R. Willey

Opto Mechanik, Inc., P.O. Box 361907, Melbourne, Florida 32935.
Received 6 January 1990.
0003-6935/90/314540-02$02.00/0.

Uncoated surfaces of high index glasses when cemented to form lens doublets have inferior antireflection properties to doublets of low index glass. This can be overcome by the application of a single layer coating of aluminum oxide prior to cementing.

Normally lens doublets of 1.5–1.6 index of refraction are cemented with cements of whose indices are near 1.52. This gives an index match close enough for most glasses so that Fresnel reflections at the cemented interfaces are reduced to $\ll$1%. However, when doublets of glasses such as SF11 and LaF21 with indices of the order of 1.785 are cemented with cement of 1.52 index, the reflections are relatively high. This is shown in Fig. 1 where a thirty-wave optical thickness layer of cement is between surfaces of SF11 and LaK21. The actual interference maxima will vary with cement thickness, but the envelope for the maxima and minima will be the same as in Fig. 1. In many modern systems this is undesirably large. We have not been able to find available optical cements of higher index which could eliminate this reflection, and we have not found this problem dealt with in the usual texts on optical engineering or thin films.

The solution is somewhat obvious when the problem is considered. The index of refraction of the proper matching layer between the glass of index 1.785 and the cement of 1.52 is the geometric mean between the two or ~1.65. This is fortuitously represented by a practical coating material, aluminum oxide. If the surfaces to be cemented are first coated with a quarterwave optical thickness (QWOT) of the oxide, the residual reflection at the center wavelength will be practically zero.

Figure 2 shows what can be expected. Curve *A* is the reflection which would occur at each cemented surface of a glass such as SF11 (including dispersion effects) without any coating. Curve *B* would be the result at each surface if the usual single QWOT of magnesium fluoride were put on the glass. This incidentally makes a good visible AR coating for 1.785 glass in air because of the glass's high index but not

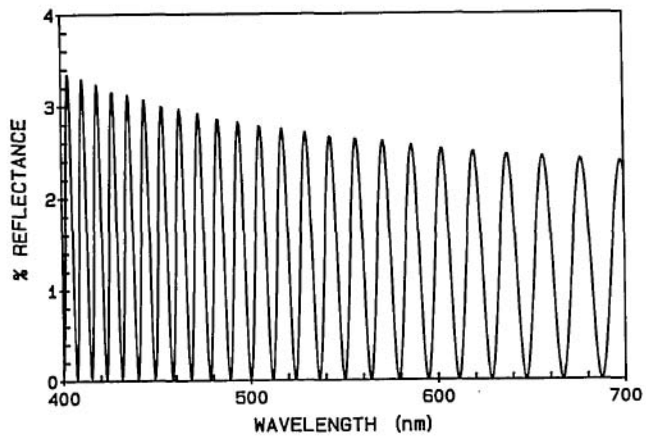

Fig. 1. Interface reflection of surfaces of high index (1.785) glasses SF11 and LaK21, which have been cemented with thirty waves of optical thickness 1.52 index cement.

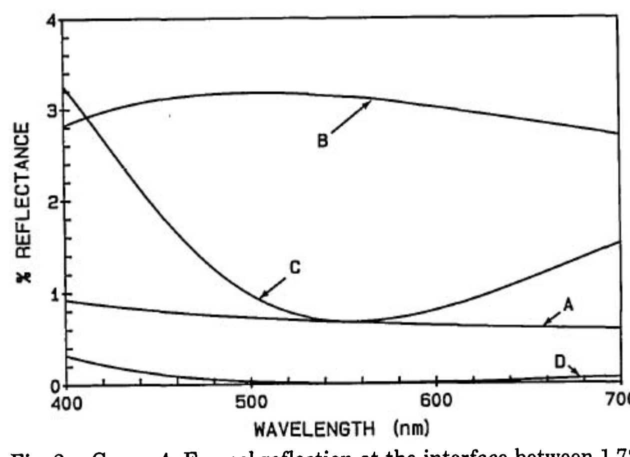

Fig. 2. Curve *A*, Fresnel reflection at the interface between 1.785 glass (SF11) and 1.52 cement. Curve *B*, reflection of the surface as in curve *A* if coated with one QWOT of magnesium fluoride. Curve *C*, reflection of the surface as in curve *A* if coated with two QWOTs of magneisum fluoride. Curve *D*, reflection of surface as in curve *A* if coated with one QWOT of aluminum oxide (1.64 index).

when cemented. Curve *C* shows that a halfwave of magnesium fluoride would be better than a QWOT but still inferior to the uncoated surface. Curve *D* would be the result of the interface between SF11 and 1.52 cement having been coated

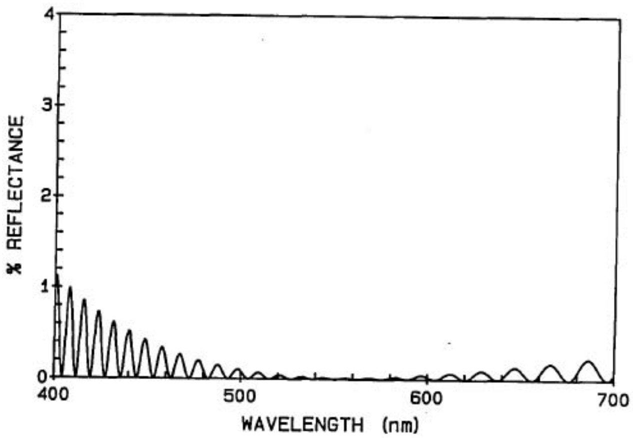

Fig. 3. Interface reflection of surfaces as in Fig. 1, which have been coated with a QWOT of 1.64 index at 550 nm prior to cementing.

with a QWOT of aluminum oxide. This would be the case also if a low index lens were to be cemented to a high index lens. The QWOT of 1.65 would be the proper stepdown layer from the high index glass to the cement of index of 1.52, which would in turn be a reasonable match to the low index glass.

When two high index lenses have the 1.65 coating and are cemented with 1.52 cement, at the design wavelength, the reflection is essentially zero. Figure 3 shows the result of such a case with thirty waves of optical thickness in the cement layer. The fact that the coating layers are not exactly a QWOT at wavelengths longer and shorter than the design wavelength (550 nm) causes some mismatch at the 400- and 700-nm ends, but this is seen to be a minor problem compared with Fig. 1.

We have used these coatings in practice and found the results consistent with the predictions. Guenther[1] discribed a potential problem with the use of aluminum oxide on some glasses. We have not observed any serious effects to date. If it were a problem requiring correction, a thin barrier layer of some other material could be used on the glass before the aluminum oxide. Alternatively, the layer could be approximated by two or more layers of higher and lower index materials as we described previously.[2]

We conclude that a QWOT coating of 1.65 index material (aluminum oxide) can be beneficially used to reduce the reflection losses of cemented surfaces whose index is >1.65.

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Determination of refractive index of a simple negative, positive, or zero power lens using wedged plated interferometer

R. P. Shukla, G. M. Perera, M. C. George, and P. Venkateswarlu

Alabama A&M University, Physics Department, P.O. Box 1268, Normal Alabama 35762.
Received 31 October 1989.
0003-6935/90/314541-03$02.00/0.

Measurement of the refractive index of a simple negative lens is presented. The technique is also useful for measuring the refractive index of a simple convex and zero power lens.

The measurement of the refractive index of a simple convex lens was reported by Munnerlyn[1] using a Twyman-Green interferometer. However, he has given no experimental details about the accuracy of the interferometer for measuring the refractive index. Kasana and Rosenbruch[2] devised a novel method for measuring the refractive index of a simple convex lens using a Murty interferometer,[3] but this method is not suitable for measuring the refractive index of a negative lens. In this Technical Note, we present a nondestructive technique for measuring the refractive index of a negative lens using a wedged plate interferometer.[3] The method is found to be useful for quick identification of the glass materials of the negative lenses. The method may also be useful for measuring the refractive index of a simple convex lens or a zero power lens.

A schematic diagram of the wedged plate interferometer for measuring the refractive index of a lens is shown in Fig. 1. A beam of light from a He–Ne laser is focused by means of a microscope objective at the focus of a good lens. A pinhole is placed at the focus of the microscope objective. A wedged plate of ~10 sec of arc is placed in the path of the collimated light so that the apex of the wedge lies in the horizontal plane. The light beam is reflected partly from the front surface and partly from the rear surface of the plate and two sheared wavefronts are obtained. The interference fringes are formed in the common area of the wavefronts. For a well collimated beam, the fringes are straight and horizontal. For measuring the refractive index, a focusing lens is mounted on a carriage and placed in the path of the transmitted beam. The lens under measurement is placed on the optical axis of the focusing lens. The focusing lens is moved back and forth to focus the laser beam on the front surface of the lens. The reflected beam from the front surface of the test lens is again collimated by the focusing lens, and horizontal straight fringes are obtained in the common area of the sheared wavefronts. This position (1) of the focusing lens is noted on the measuring scale attached to the carriage. The focusing lens is then moved toward the test lens to focus the laser beam on to the rear surface of this lens. When the beam is focused exactly on the rear surface, horizontal straight fringes are obtained. This position (2) of the focusing lens is again noted. The distance between these two positions gives an apparent thickness t_a of the test lens. Finally, the focusing lens is moved away from the test lens to focus the laser beam at the center of curvature of the front surface of this lens. As in this position, the laser beam is incident normally on the front surface of the lens, the horizontal straight fringes are observed again in the field of view. This position (3) of the focusing lens is noted. The distance between positions 1 and 3 gives the radius of curvature R of the front surface. The central thickness t of the test lens is