3.2. Glass quality of prisms

Especially when using large-sized prisms, the influence of the glass on the optical performance is remarkable. Optical homogeneity, striae, stress birefringence, bubbles and inclusions have to be within narrow tolerances. But even when the glass meets the highest precision levels and the surfaces and angles of the prisms are of highest accuracy, we still got varying transmission interferograms for different glass types. (Fig. 6 resp. Fig. 7) A prism as shown in Figure 7 cannot be used in high quality instruments. The tolerances for the single surfaces are better than 1(0,2)-, that means that the regular deviation from the ideal sphere is less than one fringe and the surface irregularity is better than 0,2.

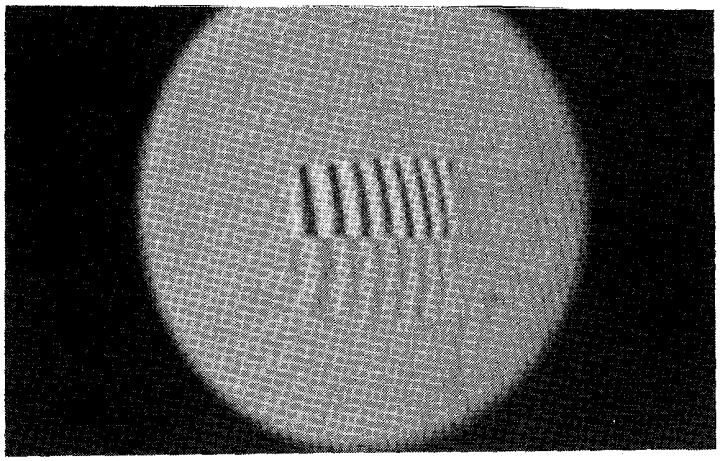

Fig. 6: Glass type A, transmission interferogram, accuracy of the single surfaces better than 1(0,2)-.

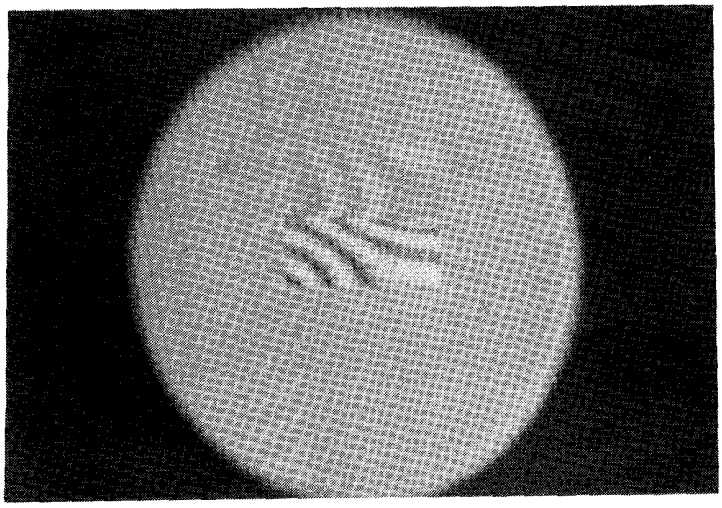

Fig. 7: Glass type B, transmission interferogram, accuracy of the single surfaces better than 1(0,2)-.

Our opinion is that the purity of the chemical elements and faults in production might be an explanation for the varying interferograms. Particles in the glass melt with diameters comparable to the wavelength of light can change the scattering behavior significantly[6].

3.3 Coating of prisms

3.3.1. Antireflection coating

Optimum transmission is one of the most important criteria for a high quality binocular. An uncoated optical surface causes a loss in transmission between 4% and 8%. Typically, in binoculars there are eight to fifteen glass-air transitions, so that multicoating of every surface is essential. The top models have transmissions of approximately 90%. Beside the loss of light coating reduces stray-radiation and therefore increases the contrast of the image. However, from our own observations and from literature[7] we know that antireflection coating can reduce contrast for instance when a Schmidt prism is used. In Figure 8 you can see that two surfaces are reflecting and entrance resp. exit surfaces at the same time.

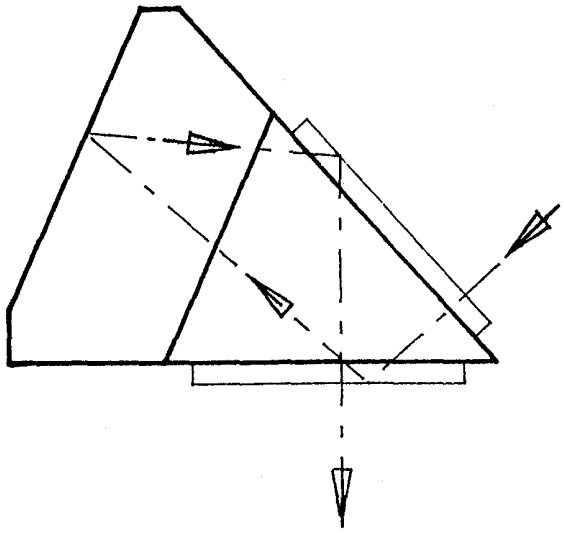

Fig. 8: Schmidt prism. Two surfaces act as reflecting and entrance resp. exit surfaces at the same time.

For the total internal reflection between glass and air an uncoated surface would be desirable; however, this is not desirable for maximum transmission.

You can see that the light has to pass through the antireflection coating six times and in addition, total reflection occurs twice at the film-air surface. To find the best compromise we measured the MTF, for four different types: one, two and three-layer coated prisms and an uncoated prism were measured, using the same objective. The results are shown in Figure 9.

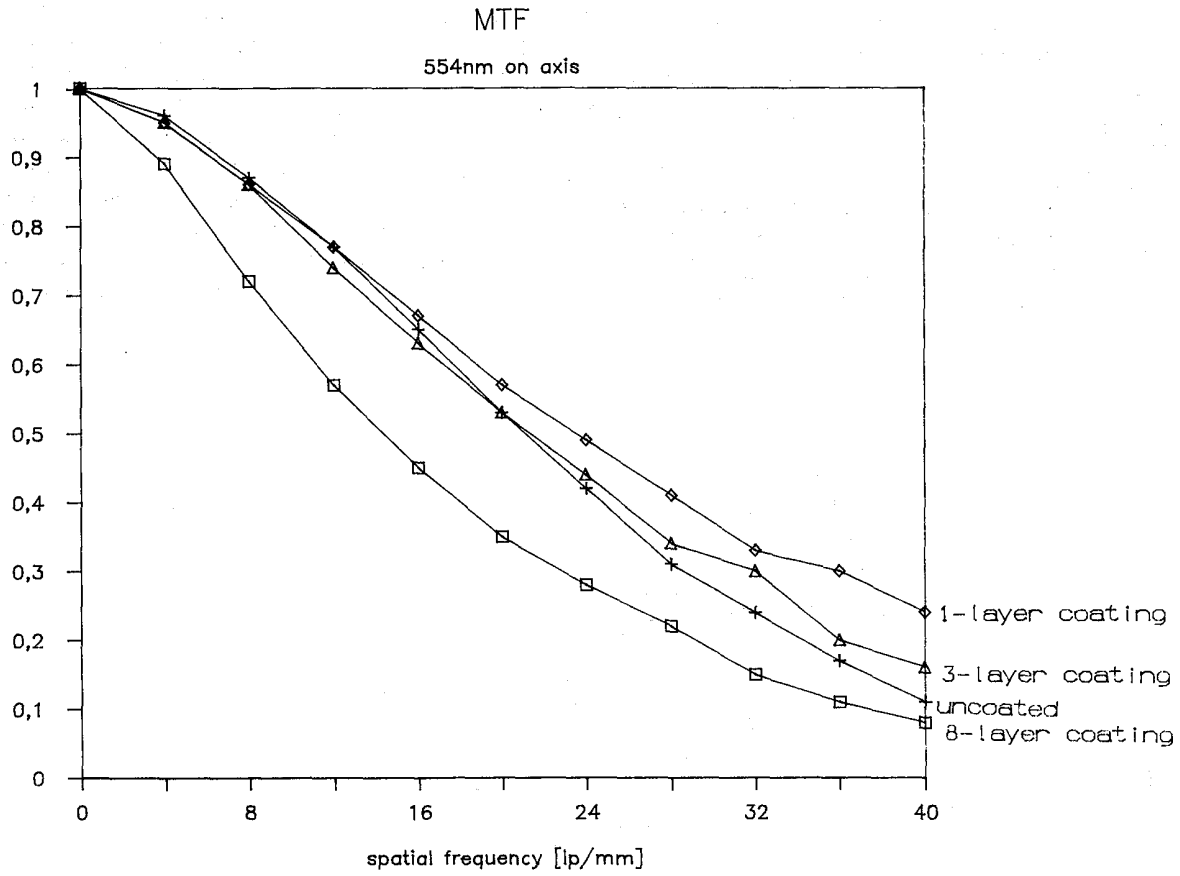

Fig. 9: MTF curves for different coatings.

Our conclusion from the measurements and from our visual observation was that a simple one-layer coating is the best compromise between contrast and transmission.

3.3.2 Phase correction coating for roof surfaces

Already in 1943 G. Joos pointed out that totally reflecting roof surfaces reduce image quality, unless they are coated properly[8]. Even if the surfaces of the prisms and the angles are manufactured extremely accurately, there is still a remarkable loss in contrast and resolution.

When the light wave is totally reflected, not only a change in direction occurs. Light waves vibrating parallel to the entrance plane are shifted in their phase against those vibrating vertically. The result is that the light is polarized elliptically[9]. At the roof prism the incident light is divided into two halves. Both halves are passed in a different sequence and get a different phase shift. By interference the light is partially extinguished and as a consequence of the energy principal this light is focussed beside the optimum geometric image point. The consequence is a reduced resolution and contrast in the direction perpendicular to the roof. The experienced and pretentious user of a binocular can observe the effect especially when viewing a point light source or very bright objects. The manufacturers of high quality binoculars therefore developed a special dielectric multicoating for the roof surfaces to compensate for the phase shift. Figures 10 to 12 compare MTF curves between coated and uncoated roof surfaces. The measurements were done with the same objective but with different orientations of the roof.

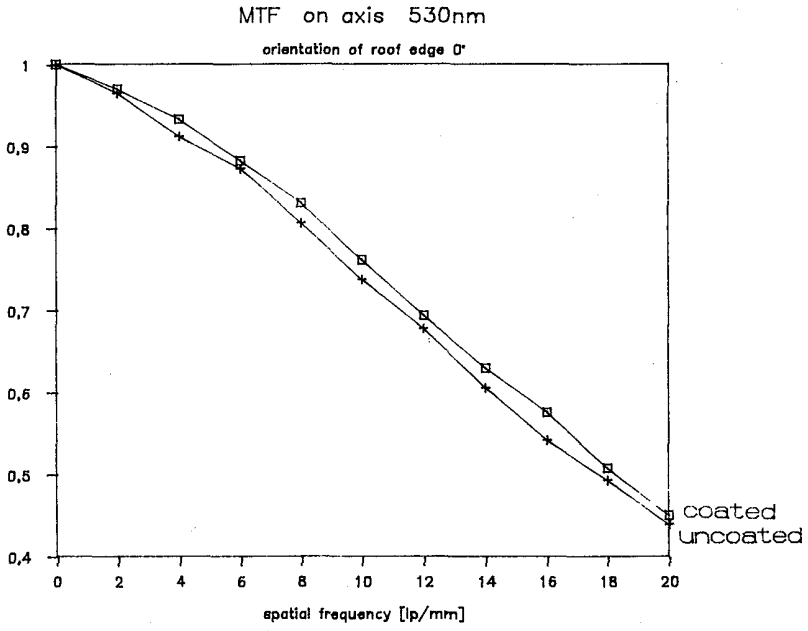

Fig. 10: MTF curves for phase-correction coated and uncoated roof surfaces for 0°.

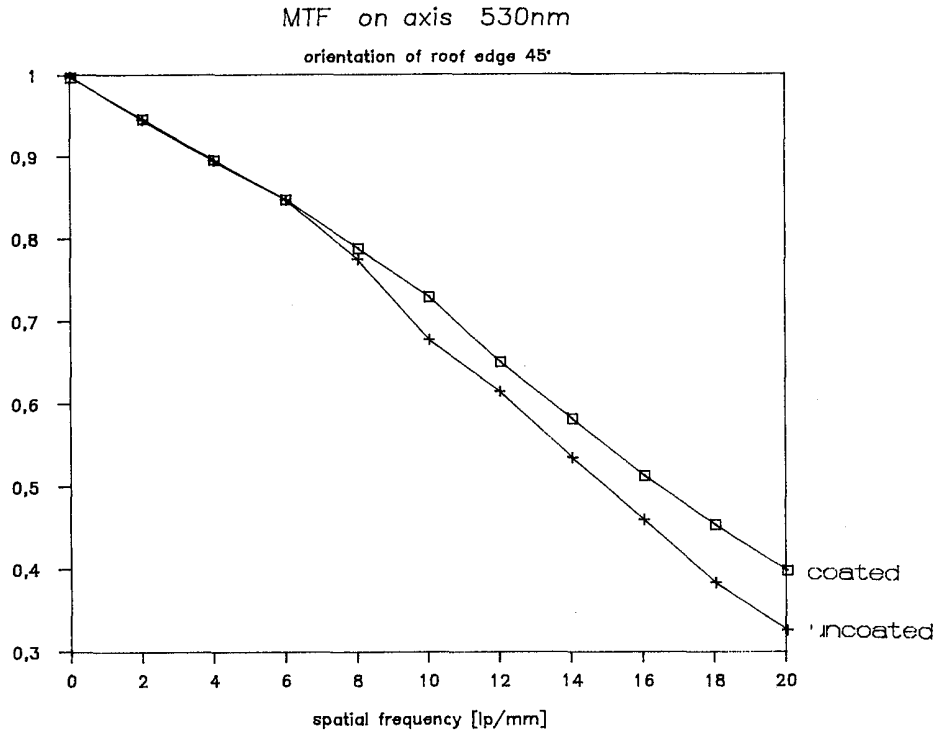

Fig. 11: MTF curves for phase-correction coated and uncoated roof surfaces for 45°.

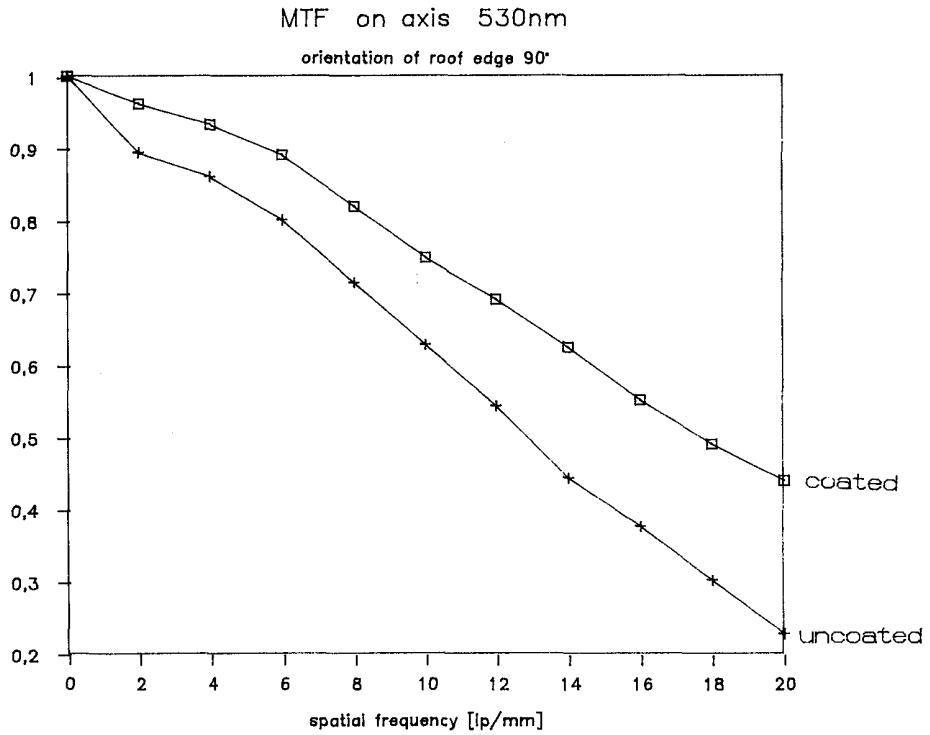

Fig. 12: MTF curves for phase-correction coated and uncoated roof surfaces for 90°.

Figures 13, 14 show interferograms of phase correction coated resp. uncoated roof surfaces. The interferograms are in good correspondence with the MTF curves.

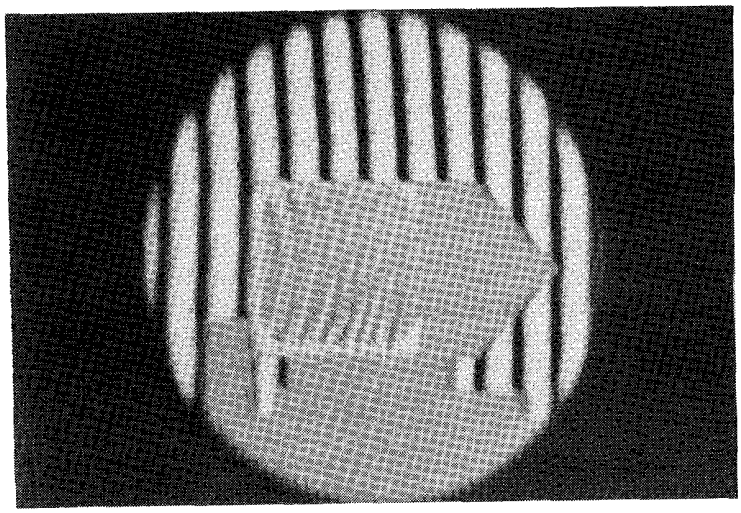

Fig. 13: Interferogram of phase correction coated roof surfaces.

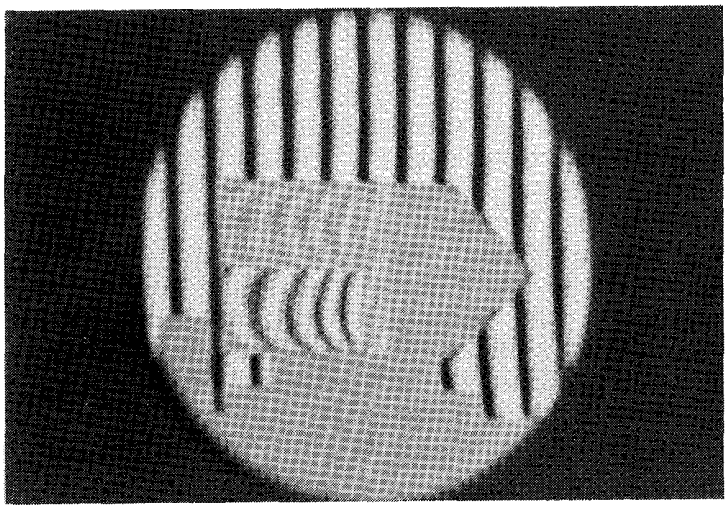

Fig. 14: Interferogram of uncoated roof surfaces.

4. CONCLUSION

The basic conditions to achieve high quality binoculars are an adequate lens design and production of optical and mechanical components within very narrow tolerances. For optimum performance the mounting of prisms and lenses, the quality of the glass and the different coatings of the prisms are essential.

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