A/R Coatings for WIYN MOS Port Corrector

Analyses and Recommendations, David Vaughnn (7/12/93)

The wide field corrector for the WIYN MOS port is an air-spaced doublet made of fused silica. There are four air to glass interfaces which are evaluated in this report in terms of possible anti-reflection (A/R) coatings. The transmission of fused silica is very near 100% and does not effect the corrector transmission in any appreciable way. There are four principle ways to coat the optics:

1. **Do nothing:** In this case, the typical Fresnel losses will be such that the corrector transmission would be approximately 87% (see attached figure).
2. **Complex A/R coating:** The corrector will be used across the region 3500Å - 1μ. This represents a span of almost two octaves. Traditional broad-band A/R coatings are good for about one octave. In the last 10 years, advances in coating design and technology have made extreme broad-band coatings possible. These coatings are typically composed of 30 or more discreet layers. As such, they require a great amount of time, expertise, and difficulty to manufacture. However, one could expect a corrector transmission on the order of 96% if these coatings are realized. This was the method chosen for coating the Bench Spectrograph Camera optics. In all likelihood, this decision has carried with it a two year delay in that project. And, the corrector optics are significantly larger (more prone to problems) than the camera optics.
3. **Porous coatings:** Very porous and soft vitreous silica can be applied to the surfaces by dipping and baking out an organic solution. These coatings are sometimes referred to as *sol gel*. They have very good optical properties (one could expect a corrector transmission in excess of 98% with four of these coatings) and very poor mechanical properties. In fact, it would not be practical to coat the outer two surfaces of the corrector because of the enormous susceptibility to even an average environment. As a result, the transmission figure would need to be appropriately downgraded. On top of that, it would be difficult to find a suitable contractor to provide these coatings.
4. **Single-layer MgF_2 coatings:** These coatings are inexpensive, simple, durable, can be made relatively hard, are easy to manufacture, and have the advantage that a coated surface will never have a transmission less than the simple substrate. One can expect a corrector transmission of 91% (see attached figure) using these coatings. It is my recommendation that these coatings be used.

Design of Coatings:

A relatively flat transmission function may be obtained by peaking (or putting down a quarter wave on) three of the four coatings at 5040Å and peaking the fourth coating at 3550Å (this second coating will peak also at 9980Å). It is better to specify the coatings as desired peak wavelengths rather than physical layer thicknesses because optical monitoring is more accurate than crystal monitoring. Coatings will shift and reach a static profile within 24 hours after being exposed to the ambient environment due to water absorption. This effect can and should be compensated for.

The attached figure shows the composite of these four coatings. The dispersions of both the fused silica and MgF_2 have been modeled. An analysis was also made to check if the angle of incidence of the various converging beams created any loss due to polarization effects in addition to the Fresnel losses. The worse case degradation is .05%.

Recommended Specifications:

Parameter	Specification
Coating Type	Single-layer MgF_2
Peak wavelength 3 of 4 surfaces	5040 ± 20Å (after 24 hours)
Peak wavelength 1 of 4 surfaces	3550 ± 20Å (after 24 hours)
Quality and durability	Per MIL-C-675, Sections 3.4 & 3.8
Coating uniformity	Max deviation over surface ± 4% at peak
Clear apertures	Per construction drawings
Acceptance	Acceptance is subject to the results of inspection by WIYN. WIYN will provide enough 2" x 2" witness plates for initial trials (24 hour stability check) and to be coated along with the optics. For the latter, two witness plate will be coated the same as each element (coated on both sides) and four witness plates will be coated with each of the four coatings on one side. Delivery must include a copy of in-house quality assurance inspection sheets listing applicable coating conditions, date, and name and signature of coating technician.

Testing:

There are three ways to test the coating performance. The first way is to have the reflectance measured for the witness plates which are coated on one side. The uncoated side should be roughly ground and painted flat black. The coated side should (of course) be polished prior to coating. NOAO does not currently have the facilities to make this measurement (a suitable reflectometer). Some manufactures may do this as a matter of course with their quality assurance program. Otherwise, this testing may be contracted out. This is the only test of the three which can verify the performance of an individual coating.

The second method is to test the transmission of the two witness plates which share the coatings of each of the two sides of both elements. NOAO has the facilities to make this measurement (Perkin-Elmer Lambda-9). I suggest that these two witness plates be mounted in a fixture as near as possible to the correctors *in-situ*. They may be removed every-other year or so and re-measured to verify the long-term stability of the corrector coatings. The final method is to directly measure the transmission of the corrector elements themselves at discreet wavelengths using lasers and a radiometer. NOAO has some facilities which may be employed to do this.

Conclusion:

There are probably a handful of companies in the US who have the equipment (primarily, a large enough planetary arrangement) to do these coatings. These companies could be easily identified by making a cursory short list of companies in an index such as the *Photonics Buyer's Guide*. I estimate that the cost would in the region $1-2k.

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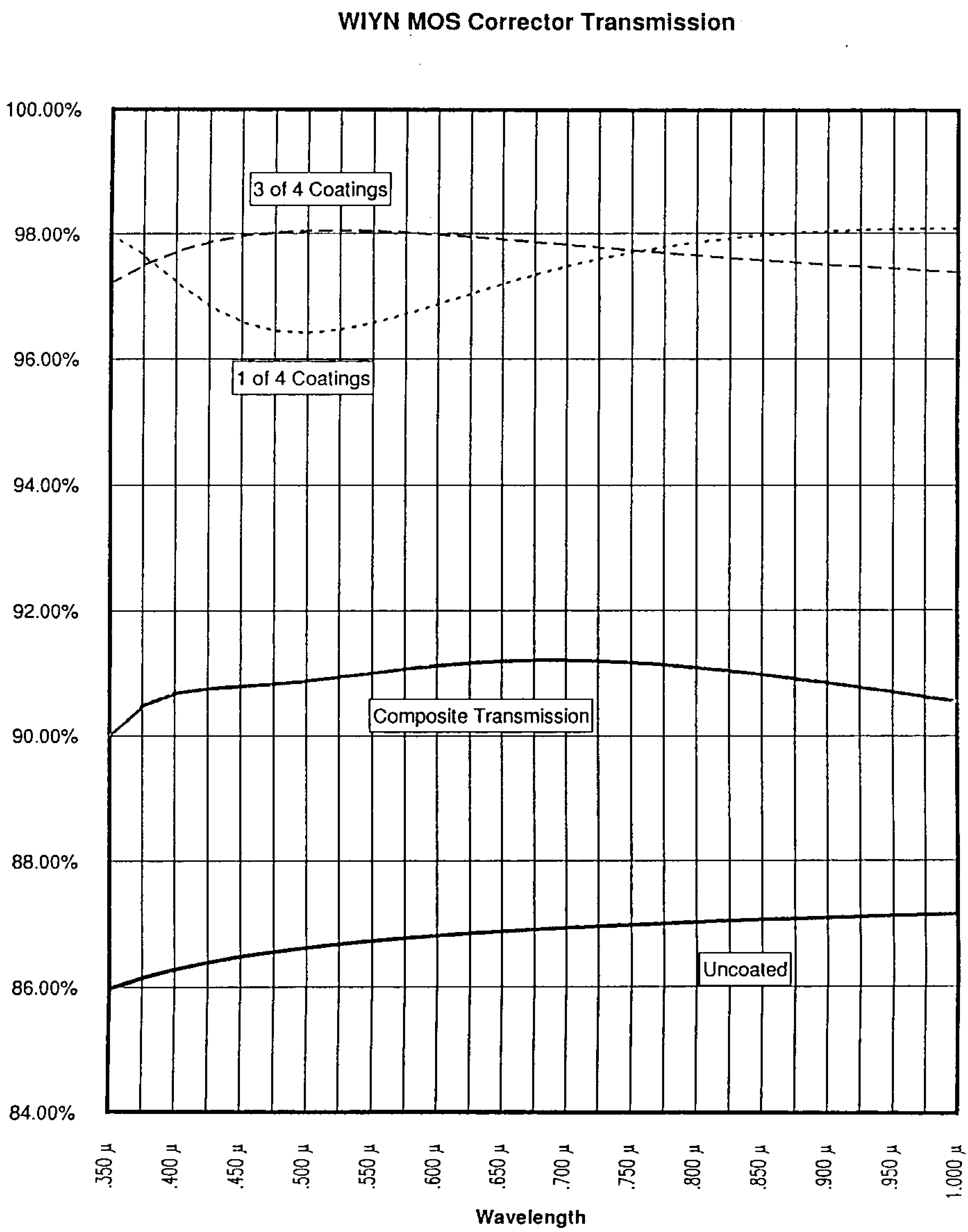
WIYN MOS Corrector Transmission
100.00%
98.00%
96.00%
94.00%
92.00%
90.00%
88.00%
86.00%
84.00%
3 of 4 Coatings
1 of 4 Coatings
Composite Transmission
Uncoated
.350 µ
.400 µ
.450 µ
.500 µ
.550 µ
.600 µ
.650 µ
.700 µ
.750 µ
.800 µ
.850 µ
.900 µ
.950 µ
1.000 µ
Wavelength