



Specifications for 40m RC folding mirror (PR3/SR3)

AUTHOR(S)	DATE	Document Change Notice, Release or Approval
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1. Description

Specification for 2” diameter optic that will replace existing PR3/SR3 at the CIT 40m. Designed to be concave to account for the fact that PR2/SR2 at the CIT 40m are convex with RoC ~600m, such that the PRC/SRC will be stable (TMS in the 1.4-1.8 MHz range for PRC and SRC), tolerances specified such that mode matching between recycling cavity and arm cavity will be > 98.5% (assuming the RoC of the installed PR2/SR2 to be approximately -700m).

HR side coating specified for (i) minimum T for 1064nm (p-pol), (ii) maximum T for 532nm (s and p-pol). AR side coating specified for minimum R for 1064nm (p-pol) and 532nm (s and p-pol). The quoted MC errors are computed assuming Gaussian errors with spread of (i)1% on individual layer thickness, (ii) 1% on refractive indices of SiO₂ and Ta₂O₅, and (iii) 5% on angle of incidence.

2. Radius of Curvature

ROC = 1000 meters +/- 150 meters

Sagitta = $0.323^{+0.057}_{-0.042}$ microns [7% @633 nm precision needed]

3. Physical dimensions

Diameter: 2.0 inches

Thickness: 10 mm

Horizontal Wedge: 2 degrees

4. Surface finish

Super polished on both faces with < 1 Angstrom RMS roughness

Clear aperture 80%

Quality 10-5

5. Coating

HR side (Angle of Incidence = 41.1°)

T<50 ppm @ 1064 nm, p-Pol (MC analysis says T<100ppm with probability >0.9)

T>99% @ 532 nm, both s-Pol and p-Pol (MC analysis says T>97% with probability >0.7)

AR side (Angle of Incidence = 24.8°, after considering 2° wedge)

R< 0.2% @ 532 nm, both s and p-Pol (MC analysis says R<0.4% with probability >0.95)

R< 5% @ 1064nm, p-Pol (MC analysis says R<6% with probability >0.95)



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6. Marking

Serial number to be etched on barrel

Indicate HR side with arrow on barrel

Mark the direction of wedge on barrel with mark at thinnest location

7. Details on coating calculation

The coating design was arrived at by solving a constrained optimization problem such that we get a layer structure that meets the R and T requirements at 1064nm and 532nm for the polarizations of interest. Further terms were added to the optimization cost function such that sensitivity to deviations in assumed values of parameters listed below was minimized

- Refractive indices of SiO_2 and Ta_2O_5 at 1064nm and 532nm at the 1% level
- Refractive index of substrate at 1064nm and 532nm at the 1% level
- Deviation in SiO_2 and Ta_2O_5 layers *optical* thickness from design value at the 1% level. All SiO_2 layers were perturbed by the same amount at the same time, and similarly for all Ta_2O_5 layers, as we expect the error in these variables to be systematic and constant for layers of the same material (but layer thickness of SiO_2 layers and Ta_2O_5 layers were allowed independent errors).
- Angle of incidence at the 1% level

Once the optimized layer structure was found, we used a Monte-Carlo analysis to investigate sensitivity to possible systematic errors. Specifically, we assumed each of the six errors listed above as an independent random variable. These random variables were sampled from Gaussian distributions with zero mean and variance of 1%. The resulting perturbations were imposed on the optimized layer structure, and the resulting distribution of R and T were examined. The design requirements in Section 5 are made after considering the results of this MC study.

The optimized coating layer **optical thicknesses** are listed in the accompanying spreadsheet, for the HR and AR coatings. The assumed dispersion relations were:

$$n_{SiO_2}^2(\lambda) - 1 = \frac{0.6961663 \lambda^2}{\lambda^2 - 0.0684043^2} + \frac{0.4079426 \lambda^2}{\lambda^2 - 0.1162414^2} + \frac{0.8974794 \lambda^2}{\lambda^2 - 9.896161^2}$$

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and

$$n_{Ta_2O_5}^2(\lambda, \omega) = \left(2.06 + \frac{0.025}{\lambda^2}\right)^2 - \frac{6490^2}{\omega^2 + 6.5e5 \times i\omega} + \sum_{j=1}^6 \frac{\omega_{p,j}^2}{\omega_j^2 - \omega^2 - i\gamma_j\omega}$$

where $\omega = \frac{2\pi}{\lambda}$ is the wavenumber in cm^{-1} , and $\omega_{p,j}$, ω_j , and γ_j are given by the arrays [1040, 573, 634, 408, 277, 373], [266, 500, 609, 672, 868, 3020] and [188, 112, 88, 43, 113, 652].

Using these formulae, the assumed refractive indices used to specify **optical** thicknesses for the layer structure in the accompanying spreadsheet are:

$$n_{SiO_2}(1064 \text{ nm}) = 1.4496$$

$$n_{SiO_2}(532 \text{ nm}) = 1.4607$$

$$n_{Ta_2O_5}(1064 \text{ nm}) = 2.0760$$

$$n_{Ta_2O_5}(532 \text{ nm}) = 2.1469$$