MRO FTT/NAS & FLC

FTT/NAS Optical Coatings

MRO-TRE-CAM-1130-0161

The Cambridge FTT Team

rev 1.1

21 December 2012

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Change Record

Revision	Date	Author(s)	Changes
0.1	2012-12-19	JSY	Initial version
1.0	2012-12-20	JSY	Comments from CAH; revised FTT/NAS photon count calculation
1.1	2012-12-21	JSY	Added note about dispersion

Objective

To describe the coatings proposed for the optical components of the first FTT/NA system, and quantify the impact on the system performance of using a temporary coating for the dichroic.

Reference Documents

RD1 Technical Requirements: Fast Tip-Tilt/Narrow-field Acquisition System (INT-403-ENG-0003) – rev 2.2, May 20th 2010

RD2 Derived Requirements (MRO-TRE-0000-0101) – rev 1.0, August 31st 2010

RD3 The optical error budget for the MRO Interferometer – rev 0.2, March 13th 2007 (with accompanying spreadsheet rev 1.3)

Acronyms and Abbreviations

COTS Commercial Off-The-Shelf
FTT Fast Tip-Tilt
FWHM Full Width at Half Maximum
ICoNN Infrared Coherencing Nearest Neighbor fringe tracker
MROI Magdalena Ridge Observatory Interferometer
NAS Narrow-field Acquisition System
PVM Performance Verification Milestone
UT Unit Telescope

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1 Background

As outlined in the February 2012 change order to the FTT/NAS development contract, we have agreed to deliver the *first* FTT/NA system with a preliminary coating on the dichroic mirror. This is in order to minimize the cost and schedule impact of designing and procuring what would otherwise be a challenging custom coating. The change order states that the specification for the temporary coating should be agreed with the MROI Project Office, to which end we have prepared this document.

We expect that the temporary coating would be replaced (by stripping the coating, re-polishing the optic as necesssary, and recoating) with a new design sometime before the MROI near-infrared science instrument is commissioned. The work associated with the final dichroic coating would probably be part of the contract to deliver the second FTT/NAS, with the second FTT/NAS being delivered with the final coatings.

In this document we quantify the impact of using the temporary dichroic coating for initial on-sky commissioning and science operations. For completeness, we also describe the coatings that we plan to deliver for the other optical components (lens and fold mirrors) of the FTT/NAS. These coatings will be identical for the first and all subsequent FTT/NA systems.

2 Proposed coatings

2.1 Dichroic

We propose that the front surface of the dichroic will have a temporary coating designed and applied by a sub-contractor in accordance with the following specifications:

- 80% *minimum* reflectance in the range 500 – 900 nm
- 80% *minimum* transmittance in the range 1.5 – 1.75 μm (*H* band)
- 80% *minimum* transmittance in the range 2.05 – 2.35 μm (*K* band)

Note there is no transmittance requirement for the *J* band (1.25 μm) as we expect to replace this coating before the MROI science beam combining instrument comes online, and the MROI fringe tracker does not use *J*-band light. Omitting this requirement should significantly simplify the coating design. The specification of minimum rather than average values is intended to facilitate evaluation of compliance by the vendor.

The rear surface of the dichroic will be left uncoated initially (an anti-reflection coating will be applied to the rear face at the same time as the dichroic coating is upgraded).

For reference the corresponding specifications for the final dichroic are as follows:

- Reflectance towards the FTT/NAS camera is a derived requirement for the FTT vendor to establish [1]
- The following requirements refer to the overall loss from both surfaces:
  - 97% *average* transmittance in the range 1.17 – 1.33 μm (*J* band)
  - 97% *average* transmittance in the range 1.49 – 1.78 μm (*H* band)
  - 97% *average* transmittance in the range 1.95 – 2.45 μm (*K* band)

[1] We adopt an overall throughput of 85% from 600 – 1000 nm for the dichroic, lens and fold mirrors in RD2.

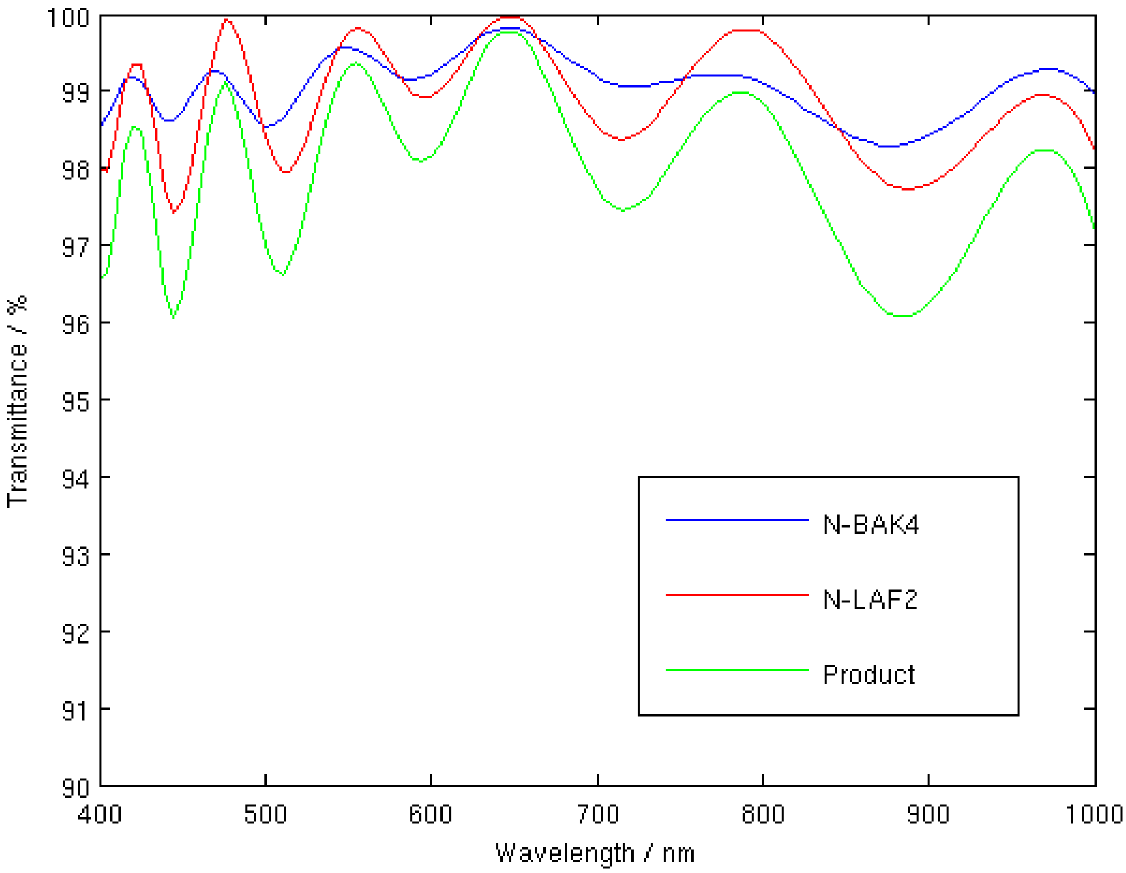

Figure 1: Predicted transmittance of the proposed lens coatings. The transmittance is plotted as a function of wavelength for the two surfaces of the lens (glasses BaK4 and LaF2) separately. The product of the transmittance at the two surfaces is also shown. We expect losses within the lens to be less than 1%.

2.2 Lens

The two outer surfaces of the lens will be delivered with their final coatings, which are expected to be versions of COTS coatings from CVI Melles Griot that have been optimized for the respective glasses. The transmission at the two interfaces as a function of wavelength is shown in Figure 1.

2.3 Fold mirrors

The two fold mirrors will be delivered with COTS protected silver coatings. The vendor has not been selected yet, but we would expect the coating performance to be similar to that shown in Figure 2.

3 System performance

We expect the use of a temporary dichroic coating to have the following impacts on the performance of the first FTT/NA system and MROI as a whole.

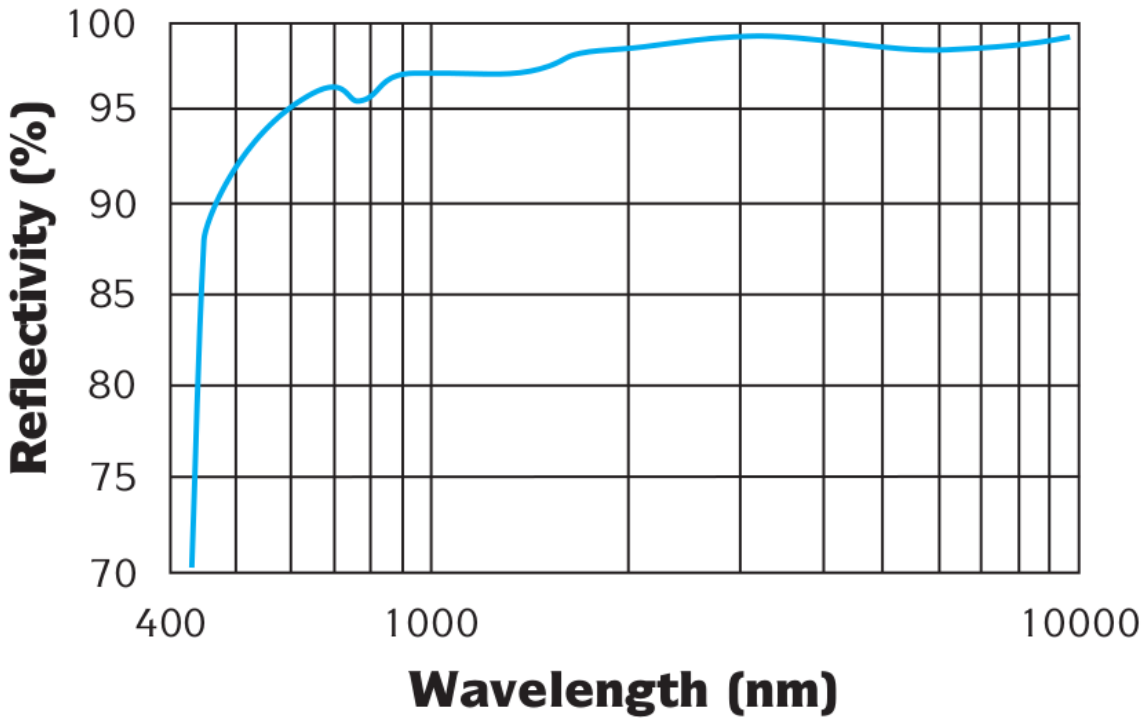

Figure 2: Typical reflectance of a protected silver mirror, taken from the CVI Melles Griot catalogue: `https://www.cvimellesgriot.com/Products/Documents/Catalog/PS_PG.pdf`.

3.1 FTT/NAS limiting sensitivity

A calculation of the photon flux detected by the FTT/NAS camera following that in RD2 but including realistic wavelength-dependent transmittance and reflectance values for the FTT/NAS imaging lens and fold mirrors (with coatings as outlined in Sec. 2) gives 12,458 photons/second from a 16th magnitude star of the colour described in RD1. This assumes a final dichroic coating delivering 98% average reflectance over $600-1000$ nm and zero elsewhere.

With the preliminary dichroic, and assuming that meeting the 80% *minimum* reflectance specification results in 85% *average* reflectance over $500-900$ nm (and zero elsewhere), the detected photon flux increases marginally to 12,559 photons/second (0.8% higher). The photon flux is maintained despite the reduction in dichroic reflectance, because the spectral bandpass has been shifted towards the peak of the detector quantum efficiency.

Shifting the FTT bandpass towards the blue increases the detected photon rate, but there is a potential slight impact on the performance of the FTT system at large zenith distances owing to the increased angular dispersion. For this reason we intend to retain a 600 nm cut-on for the final dichoic. Using a 500 nm cut-on will elongate the image on the FTT camera by $\sim 0.3''$ at 40° zenith distance and $\sim 0.45''$ at 60° zenith distance, both insignificant for the purposes of determining the UT pointing model. These elongations can also be compared with the FWHM of the short-exposure speckle cloud of $0.5-2''$ for the expected range of seeing conditions (RD2).

The detected photon flux determines the "detection noise centroiding error" term in the tilt error budget (RD2 Table 4). With the final dichroic coating we predict this term to be 35.7 mas [2]. With the temporary dichroic the value of this term will be approximately 35.4 mas. Hence the *overall* tip-tilt residual will be 1.4% and 1.3%

[2]The budgeted value for the detection noise centroiding error is 34 mas (RD2).

over budget with the final and temporary dichroic coatings respectively. These larger tilt errors for faint targets give rise to additional visibility losses at *H* band of 0.44% and 0.41% respectively compared with the MROI optical error budget (RD3).

3.2 ICoNN limiting sensitivity

Prior to replacement of the temporary dichroic, there will be a small reduction in the limiting sensitivity of the MROI fringe tracker due to the reduced throughput in the *H* and *K* bands. Using the official error budget spreadsheet (RD3), we predict a 0.2 magnitude impact at both *H* (1.65 μm wavelength) and *K* (2.2 μm) bands, as a result of increasing the losses at the two dichroic surfaces from 2% and 2% to 15% and 3.5%. Here we have assumed that 80% minimum transmittance corresponds to 85% average transmittance. These calculations assume an effective detector readout noise of 2e after averaging of multiple non-destructive reads, and that the temporary coating is applied to *both* of the dichroics associated with the relevant fringe-tracking baseline.

These calculations do not take account of the potential throughput reduction at the edges of the *H* and *K* bands due to the near-IR wavelength ranges specified for the preliminary dichroic coating (see Sec. 2) being some 13% narrower than the bands that ICoNN will use (which are narrower than the MROI science bands, especially at *K*). We expect the resulting flux loss to be less than 5% percent as the cut on and off at the edges of the band will be fairly gradual for a simple coating.

4 Summary

We propose to deliver the dichroic for the first FTT/NA system with a preliminary coating, in order to reduce cost and schedule risk to the MROI project. The temporary dichroic coating will be replaced prior to commissioning of the MROI science instrument. We expect that the contract for the second FTT/NAS will include design of the final dichroic coating and delivery of the dichroic for the 2nd system with the final coating.

The use of a preliminary dichroic coating will have no impact on the ability to use the first FTT/NA system for commissioning of the first Unit Telescope and attainment of PVMs 1–6.

There will be a very slight impact (< 0.2 mag) on the limiting sensitivity of the MROI fringe tracker, and possible slight impact on the performance of the FTT/NAS at large zenith distances, both of which will be recovered when the dichroic coating is replaced.