HIRDLS

HIGH RESOLUTION DYNAMICS LIMB SOUNDER

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Subject / Title: Spectral Performance and Spectral Verification Requirements for HIRDLS Optical Elements

Description / Summary / Contents :

This document is the technical specification to define the spectral performance and spectral verification requirements of the optical filters, antireflection coatings, detector elements and mirrors for the EOS High Resolution Dynamics Limb Sounder (HIRDLS) instrument. It forms part of the sequence of documents describing the flow-down of HIRDLS spectral requirements from the Instrument Requirements Document SC-HIR-18 to the various coating specification documents. This sequence is explained in document PM-OXF-153A.

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SECTION 1 – SUMMARY DESCRIPTION

1.1 SCOPE

This document is the technical specification to define the spectral performance and spectral verification requirements of the optical filters, antireflection coatings, detector elements, and mirrors for the EOS High Resolution Dynamics Limb Sounder (HIRDLS) instrument. It forms part of the sequence of documents describing the flow-down of HIRDLS spectral requirements from the Instrument Requirements Document SC-HIR-18 to the various coating specification documents. The sequence is explained in document PM-OXF-153A.

1.2 BACKGROUND

Spectral characteristics of the 21 radiometric channels in the HIRDLS instrument are determined principally by the combination of warm band-defining filters located at the intermediate focal plane of the telescope subsystem and the cooled filters in the detector subsystem. The other elements of the optical system also affect the spectral characteristics of the instrument, notably the germanium absorption in the two lenses, the absorption in the zinc selenide dewar window, the roll-off of the antireflection coatings applied to the lenses and window, and the detector spectral response. A spreadsheet, described elsewhere (TC-RDU-111, Pass Band and Blocking Description Document), determines the overall effect of all these contributions and also includes the effects of the Planck function and limb absorption at the various heights sampled by the instrument. A variation in the use of this spreadsheet can, if so wished, be used to generate the blocking and in-band spectral requirements for the warm filters, allowing for the partial blocking requirement for both warm and cold filters as determined by the need to suppress cross-channel height contamination. Use of this spreadsheet ensures that an adequate additional blocking requirement for the warm filter (and for the cold filter if it is deemed necessary to do so) can be worked out and then specified, thus ensuring that the complete system meets the required ratio of in-band to out-of-band energy ratio, defined as Margin Ratio in SP-HIR-154. The Spectral Measurement and Analysis Spreadsheet (described in TC-RDU-295) shall be used to determine and verify that the Margin Ratio, on a channel by channel basis, meets or is greater than the specified minimum value, both at the final stage of the filter design prior to deposition and by using the results of the spectral measurements of finished filters (and the other components).

The “warm” fully-blocked band-defining bandpass filters (at 301 K) at the intermediate focal plane of the instrument, define the spectral shape of each channel and will provide broad band blocking. The wider “cold” bandpass filters (60–65 K) adjacent to the final image plane directly in front of the detector array will in combination with the warm filters help suppress out-of-field “ghost” images reaching the detectors, reduce the thermal background radiation of the instrument reaching the detectors and reinforce the blocking. By use of the bandpass component of the spreadsheet due allowance can be taken of the effects on filter bandwidth of the rapid variations in transmission present in some spectral regions. The 50% pt. values for some of the warm filter channels in the later tabulations differ from those in SP-HIR-69 for this reason.

The detector subsystem consists of 21 HgCdTe Infrared detectors contained in a vacuum dewar and cooled to 60–65 K by the cooler subsystem. The dewar is sealed by a ZnSe window the material of which provides useful long wavelength blocking. The two germanium lenses elsewhere in the system also provide significant longwave blocking. The antireflection coating performance

and the materials used in the coatings on all these components adds significantly to the short wavelength blocking.

1.3 COLD FILTERS

The set of 21 cold "ghost-suppression" filters will form part of the focal plane detector array for the instrument and are components of the Detector Subsystem (DSS). The filters will operate in f/1.5 converging illumination, (as defined by the angle of incidence ray count distribution in TC-RAL-042) and are positioned 100 μm in front of the detectors. The filters are of various substrate thicknesses (as defined in SP-HIR-255) to compensate for chromatic and field curvature aberrations in the telescope subsystem. The spectral functions of these filters are to reject warm background radiation noise of the instrument, suppress out-of-field "ghost" images in combination with the warm filters, and assist by further attenuating the unwanted out-of-band spectral energy.

1.4 WARM FILTERS

The set of warm band-defining filters will be positioned at the far focus of the (secondary) ellipsoidal mirror of the telescope. These filters will operate in a nominal f/7 cone angle at a temperature of 301 K ± 2.5 K and will be used to define the spectral response of each of the 21 channel passbands and provide the attenuation of unwanted spectral energy. The filters are of fixed substrate thickness as defined in SP-HIR-244. A minimum blocking level has to be assigned to the warm filters to ensure that ghost image suppression requirements are met.

1.5 ANTIREFLECTION COATINGS

The germanium lenses (L1 & L2) and zinc selenide dewar window will be coated with a high performance broadband antireflection coating over the HIRDLS spectral frequency range between 550 cm^{-1} and 1650 cm^{-1} (6–18 μm). The zinc selenide plane window is used as a vacuum seal at the entrance to the detector dewar assembly and provides additional long wavelength spectral blocking. Surface reflections from the dewar window have to be minimised to avoid unacceptable levels of cross-channel signal contamination ("ghost imaging"). The short wavelength roll-off and long wavelength absorption characteristics of these coatings materially assists in meeting the instrument spectral blocking requirements and the spectral performance of the components thus coated forms an input to the spectral passband and blocking budget spreadsheet as described in TC-RDU-111.

1.6 MIRRORS

The Scan Mirror (M0), parabolic Primary Mirror (M1), ellipsoidal Secondary Mirror (M2), and plane Fold Mirror (M4) are all in a common optical system for all channels. The combined spectral response of these mirrors will form an integral part of the optical system and be used to determine the overall spectral response of the instrument.

SECTION 2 – DOCUMENTS

The requirements of this specification follow directly from the HIRDLS Instrument Spectral Requirements (SP-HIR-69B) document.

2.1 DOCUMENT PRECEDENCE

In the event of any inconsistency between this document and any of the applicable documents listed in Appendix A, the order or precedence will be the latest revision of the following documents as defined in the HIRDLS instrument spectral requirements flowdown document PM-OXF-153:

a. SP-HIR-154 Out-of-Band Spectral Blocking Requirements

b. SP-HIR-13 Instrument Technical Specification

c. SP-HIR-69 HIRDLS Instrument Spectral Requirements

d. HIRDLS-unique documents

e. non-HIRDLS-unique documents

2.2 APPLICABLE DOCUMENTS

Applicable documents called up in this specification are described in Appendix A. The latest revision for each document is implied.

2.3 REFERENCE DOCUMENTS

Reference documents called up in this specification are described in Appendix B are for guidance and information. Selected sections of the individual documents described may form part of this specification to the extent specified herein.

2.4 ASSUMPTIONS

2.4.1 The spectral profile of each filter has been designed so that the overall passband profiles specified in SP-HIR-69B will be achieved after integration of the whole telescope optical system, including detectors. The analytical method used to determine how individual filter element profile designs have been derived from these requirements is documented in the Spectral Passband & Blocking Description Document (TC-RDU-111).

2.4.2 On the short and long wavelength edges of the passband, the transmission of any filter will fall monotonically from the 50% relative transmission point to the 0.2% relative transmission point.

2.4.3 The in-band/out-of-band cross-over point is defined at a transmission level of 0.2% of the total instrument response unless otherwise stated

2.4.4 The nominal f/no. for each cold filter at the detector element is f/1.5

2.4.5 The nominal f/no. for each warm filter at the intermediate focal plane is f/7

2.4.6 It has been assumed that all filters will have zero tilt

2.4.7 It is assumed the detector response remains at the peak value at all wavelengths shorter than that of the peak response. *This is in the process of being reviewed.*

2.5 DEFINITIONS

2.5.1 The terms “passband” and “bandwidth” refer to the full spectral width between the 50% (of maximum) relative transmission points. This may also be known as the Full Width Half Maximum (FWHM%).

2.5.2 The terms “beginning of life” (BOL) and “end of life” (EOL) refer to the lifetime of the flight instrument in orbit, and imply that some change in performance or operating range with lifetime is expected; a 5-year lifetime in orbit should be assumed.

2.5.3 In each channel the overall passband will be primarily defined by the warm filter. The cold filter passband will be chosen such that the 50% relative transmission points are pitched approximately at the 2% relative transmission points of the conjugate warm filter.

2.5.4 References to a “plane witness piece” apply to an equivalent-thickness plane coated witness piece as manufactured from the same batch of material and coated during the same deposition runs as the lens(es) to which it corresponds. Every delivered lens will have a corresponding delivered plane witness piece. A witness piece may correspond to more than one lens of the same type. The term “equivalent thickness” means having the same mean optical thickness as that of the lens when averaged over its active area.

SECTION 3 – FILTERS

3.1 ANGLE OF INCIDENCE DISTRIBUTION

In the sections that follow it should be appreciated that the specified requirements are to be complied with when the component is illuminated with the angle of incidence ray count distributions as specified in TC-RAL-042A. SP-RDU-282 contains the equivalent requirements for the filters when illuminated in the measurement cone of f/7.

The requirements that follow do take into account the effects on filter placement of the variations in transmission with wavelength of the optical system/detector response.

3.2 FILTER BLOCKING REQUIREMENTS FOR GHOST IMAGE SUPPRESSION

Note: Cold filter designs are in process of being reviewed; this may change the short wavelength (SW) 10^{-4} pt. and long wavelength (LW) 10^{-2} pts. in the table below. These new values will be used in the imminent ghost image analysis. Also note that in the analysis the cold filter 1% pt. spectral positions (see paragraph 3.5) should be used. The specified extreme short and long wavelength limits define the wavelength range of the ghost image requirement (WF Channel 21 SW 10^{-4} point and WF Channel 1 LW 10^{-2} point).

Channel	Cold Filter × Detector Response		Warm Filter × Optical System Response (Without Detector)	
	µm	Response	µm	Response
1	5.75 – 15.46 18.71 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – 15.85 18.26 – 18.3	$< 10^{-4}$ $< 10^{-2}$
2	5.75 – 15.28 17.20 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – 15.50 16.93 – 18.3	$< 10^{-4}$ $< 10^{-2}$
3	5.75 – TBD 17.55 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – 13.70 17.00 – 18.3	$< 10^{-4}$ $< 10^{-2}$
4	5.75 – TBD 17.06 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – 13.30 16.51 – 18.3	$< 10^{-4}$ $< 10^{-2}$
5	5.75 – 13.27 16.05 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – 13.65 15.65 – 18.3	$< 10^{-4}$ $< 10^{-2}$
6	5.75 – 11.52 12.41 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – 11.60 12.30 – 18.3	$< 10^{-4}$ $< 10^{-2}$
7	5.75 – 11.00 12.39 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – 11.25 12.15 – 18.3	$< 10^{-4}$ $< 10^{-2}$
8	5.75 – TBD 12.45 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – 9.70 12.05 – 18.3	$< 10^{-4}$ $< 10^{-2}$
9	5.75 – 10.35 11.13 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – 10.35 11.05 – 18.3	$< 10^{-4}$ $< 10^{-2}$
10	5.75 – 9.55 10.28 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – 9.60 10.20 – 18.3	$< 10^{-4}$ $< 10^{-2}$
11	5.75 – 9.02 10.15 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – 9.05 10.05 – 18.3	$< 10^{-4}$ $< 10^{-2}$
12	5.75 – 8.45 9.10 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – 8.52 9.02 – 18.3	$< 10^{-4}$ $< 10^{-2}$
13	5.75 – 7.90 8.50 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – 7.80 8.50 – 18.3	$< 10^{-4}$ $< 10^{-2}$
14	5.75 – 7.45 8.40 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – 7.58 8.25 – 18.3	$< 10^{-4}$ $< 10^{-2}$
15	5.75 – 7.31 8.24 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – 7.55 8.05 – 18.3	$< 10^{-4}$ $< 10^{-2}$
16	5.75 – 7.41 7.98 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – 7.46 7.90 – 18.3	$< 10^{-4}$ $< 10^{-2}$
17	5.75 – 6.58 7.95 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – 6.85 7.70 – 18.3	$< 10^{-4}$ $< 10^{-2}$
18	5.75 – 6.27 7.59 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – 6.60 7.33 – 18.3	$< 10^{-4}$ $< 10^{-2}$
19	5.75 – 6.76 7.30 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – 6.94 7.18 – 18.3	$< 10^{-4}$ $< 10^{-2}$
20	5.75 – TBD 7.90 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – TBD 7.35 – 18.3	$< 10^{-4}$ $< 10^{-2}$
21	5.75 – 5.51 6.66 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – 5.75 6.42 – 18.3	$< 10^{-4}$ $< 10^{-2}$
22	5.75 – TBD 7.90 – 18.3	$< 10^{-4}$ $< 10^{-2}$	5.75 – TBD 7.35 – 18.3	$< 10^{-4}$ $< 10^{-2}$

3.3 COLD FILTER BLOCKING REQUIREMENTS

Should any additional (to the ghost image suppression requirements) cold filter blocking requirements be deemed necessary, they will be derived through the Spectral Passband and Blocking Spreadsheet, as described in TC-RDU-111, and used in conjunction with the warm filter blocking requirements to ensure that the design Margin Ratio in the range 3 to 5 for the channel height range is achieved.

3.4 WARM FILTER BLOCKING REQUIREMENTS

The warm filter blocking requirements will be derived through the Spectral Passband and Blocking Spreadsheet calculations, as described in TC-RDU-111, together with the combined spectral throughput of all the other inputs present, including the cold filter blocking requirements (paragraphs 3.2, 3.3) and the design Margin Ratio of 5 to obtain a “warm filter uniform radiance level”. From this, a non-uniform warm filter blocking level requirement is obtained. Warm filter blocking designs are then prepared to meet this requirement broadly (it being not possible to meet exactly the requirement due to the nature of combining multilayer stacks). The spectral performance of the putative design is fed back into the spreadsheet to establish the actual design Margin Ratio; if it falls outside the range 3 to 5 for the channel height range, the process will be repeated with appropriate modifications to the filter design.

For the reason above, a uniform blocking level for warm filters cannot be defined, other than the requirement to meet the ghost image suppression in 4.2.

3.5 COLD FILTER PASSBAND REQUIREMENTS

The short and long wavelength 50% points of the cold filter passband are required to fall between the 1% and 4% absolute transmission positions of the warm filter. The values below are specified in the f/1.5 illumination and correspond to the cold filter 50% pts. being placed on the warm filter 2% pts. The cold filter 50% pts. are allowed to fall between the 0.5% and 4% pts. of the warm filter, thus forming a manufacturing tolerance.

Ch	SW50% (cm^{-1})	Centre (cm^{-1})	LW50% (cm^{-1})	Bandwidth (cm^{-1})	FWHM (%)
1	595.0	572.6	550.1	44.9	7.84
2	621.1	607.4	593.7	27.4	4.51
3	655.8	625.2	594.5	61.3	9.81
4	674.7	642.9	611.0	63.7	9.91
5	689.0	666.9	644.8	44.2	6.63
6	841.6	828.3	814.9	26.7	3.22
7	860.3	843.5	826.7	33.6	3.98
8	925.5	882.5	839.5	86.0	9.75
9	937.4	923.8	910.2	27.2	2.94
10	1016.2	1000.0	983.8	32.4	3.24
11	1057.5	1028.8	1000.0	57.5	5.59
12	1146.4	1129.3	1112.2	34.2	3.03
13	1227.8	1211.0	1194.2	33.6	2.77
14	1271.7	1244.7	1217.7	54.0	4.34
15	1293.3	1269.1	1244.8	48.5	3.82
16	1306.9	1288.6	1270.2	36.7	2.85
17	1387.2	1346.5	1305.8	81.4	6.05
18	1450.4	1411.0	1371.6	78.8	5.58
19	1421.4	1409.1	1396.8	24.6	1.75
20	1590.5	1482.0	1373.5	217.0	14.64
21	1654.7	1608.0	1561.2	93.5	5.81
22	1590.5	1482.0	1373.5	217.0	14.64

3.6 WARM FILTER PASSBAND REQUIREMENTS

The values below are specified in f/7 illumination

Ch	SW50% (cm^{-1})	Tol ($\pm cm^{-1}$)	Centre (cm^{-1})	LW50% (cm^{-1})	Tol ($\pm cm^{-1}$)	Width (cm^{-1})	FWHM (%)	$T_{(Min)}$ (%)
1	585.3	1.0	572.4	559.4	2.0	25.9	4.53	68.0
2	614.9	1.0	607.5	600.1	2.0	14.8	2.44	60.0
3	640.1	2.0	625.3	610.4	3.0	29.7	4.75	79.0
4	659.3	3.0	642.9	626.5	3.0	32.8	5.10	81.0
5	679.6	3.0	666.9	654.2	3.0	25.4	3.81	79.0
6	835.2	2.4	828.3	821.4	2.3	13.8	1.67	76.0
7	851.8	2.4	843.4	835.0	2.4	16.8	1.99	78.0
8	903.5	2.5	882.3	861.0	2.5	42.5	4.82	90.0
9	931.5	2.6	923.8	916.0	2.6	15.5	1.68	83.0
10	1009.0	2.8	1000.0	991.0	2.8	18.0	1.80	84.0
11	1046.5	2.9	1028.8	1011.0	2.9	35.5	3.45	91.0
12	1138.5	3.2	1129.3	1120.0	3.2	18.5	1.64	85.0
13	1220.0	3.4	1211.0	1202.0	3.4	18.0	1.49	84.0
14	1259.8	1.0	1244.6	1229.5	2.0	30.3	2.43	88.0
15	1281.8	1.0	1269.0	1256.3	1.0	25.5	2.01	84.0
16	1298.8	1.0	1288.5	1278.3	1.0	20.5	1.59	79.0
17	1367.5	3.8	1346.5	1325.5	3.8	42.0	3.12	88.0
18	1435.0	4.0	1411.0	1387.0	4.0	48.0	3.40	85.0
19	1415.8	1.0	1409.0	1402.3	1.0	13.5	0.96	58.0
20	1542.0	4.3	1482.0	1422.0	4.1	120.0	8.10	90.0
21	1630.5	4.6	1608.0	1585.5	4.5	45.0	2.80	80.0
22	1542.0	4.3	1482.0	1422.0	4.1	120.0	8.10	90.0

SECTION 4 – ANTIREFLECTION COATINGS

High performance broadband antireflection coatings over the HIRDLS spectral frequency range between 550 cm^{-1} and 1650 cm^{-1} (6 and 18 μm) are required on germanium lenses L1 and L2 and the zinc selenide dewar window. In the case of the dewar window, there is a special need to minimise reflection in order to minimise "ghost imaging", which could lead to cross-channel spectral contamination.

4.1 IN-BAND REFLECTIVITY

4.1.1 The germanium lenses (L1 & L2) and zinc selenide dewar window shall be coated with a high performance broadband antireflection coating over the HIRDLS spectral frequency range between 550 cm^{-1} and 1650 cm^{-1} (6–18 μm) with a reflectivity of < 2.7% per surface at BOL.

4.1.2 Reflectivity performance for each surface shall be verified through spectral measurement of a single-side-coated 2.0 mm thick witness piece, with the rear face reflection unambiguously removed (by use of a wedged substrate or an appropriately ground rear surface).

4.2 IN-BAND TRANSMISSION

4.2.1 The transmission of the coating shall be as high as possible over the HIRDLS spectral bands 550–1650 cm^{-1} (6–18 μm). The minimum in-band transmission is required to be 92%, with a minimum average transmission over the band of 94%. These figures are for both the germanium and zinc selenide cases, with both surfaces coated.

4.2.2 Transmission performance for each component shall be verified by spectral measurement of a witness piece, coated on both sides. It is appreciated that in the case of germanium, the substrate absorption will impose difficulties on the determination of transmission beyond 11.5 μm. Modelling the effects of germanium absorption on the transmission of the coated test piece, so as to produce a best estimate of the transmission (and absorption, when used in conjunction with reflection measurement 4.1 above) of the coating out to the 18 μm region, will be required.

4.3 OUT-OF-BAND BLOCKING

4.3.1 For spectral frequencies above 1650 cm^{-1}, transmission shall fall to 1% or less at 2500 cm^{-1} and remain continuously below 1% until 4000 cm^{-1}. At all frequencies above 4000 cm^{-1}, transmission will be continuously less than 0.01%.

4.3.2 For frequencies above 4000 cm^{-1}, reflectivity shall not exceed 50%, and the energy which is not reflected will be absorbed.

SECTION 5 – MIRRORS

The spectral reflectivity of the Scan Mirror (M0), parabolic Primary Mirror (M1), ellipsoidal Secondary Mirror (M2), plane Fold Mirror (M4) and Space View Mirror (M5) shall meet or exceed the following minimum reflectance values specified for each channel:

Channel	Minimum Reflectance (%)
1–2	98.8
3–5	98.7
6–9	98.6
10–22	98.5

SECTION 6 – SPECTRAL MEASUREMENT AND ANALYSIS

The spectral measurement and analysis programme shall be conducted through the Spectral Measurement & Analysis Spreadsheets as described in TC-RDU-295 (Spectral Measurement and Analysis Spreadsheet Description Document) to determine the margin ratio, instrument throughput profiles, total radiance profiles, and thermal background, and to verify that the specified requirements are met, using the data from the following spectral measurements.

6.1 F/NO. CORRECTION

It is a requirement that the spectral measurements specified below must be adjusted where and when appropriate for the differences in illumination between that used in the measurement and that experienced in the use in the HIRDLS instrument, before spectral data is used in the Spectral Measurement and Analysis Spreadsheet. At a minimum, this adjustment shall take the form of a shift of measured filter passband profile to shortwave, the value of the shift being determined by comparison with computation. In the case of the edge position of the antireflection coatings, a shift of edge position shall be determined in the same way. TC-RDU-288 describes the angle-of-incidence effects on these coatings. The detailed adjustments shall be carried out by comparing the measured performance with computed performance, applying any corrections as necessary to ensure convergence, and then computing the corrected design in the appropriate illumination.

SP-RDU-282 contains the equivalent requirements for the spectral performance and the conditions of measurements for filters when illuminated in a known measurement cone. This document sets out what measurements are necessary for inputs into the verification process, adjusted as above where and if necessary.

6.2 SPECTRAL MEASUREMENT AND ANALYSIS OF COLD FILTERS

Spectral data shall be prepared for analysis (by applying, where appropriate, the necessary f/no. corrections as described in 6.1 and 6.2.3 below) from spectral measurements which shall be performed as follows on each coated mother piece before cutting into individual filters. The measurements shall be made under conditions of known illumination at a temperature of 63 K ± 3 K.

6.2.1 The in-band transmission vs. wavenumber shall be measured with a spectrophotometer resolution of 2.0 cm^{-1} between the 0.2% relative transmission points, with an amplitude accuracy of ± 1.5% of the peak transmission, or ± 15% of the transmission at the frequency of measurement (whichever is more accurate), and a spectral frequency accuracy of ± 0.2 cm^{-1}.

6.2.2 The out-of-band transmission vs. wavenumber shall be measured with a spectrophotometer resolution of 2.0 cm^{-1} from 6500 cm^{-1} to 250 cm^{-1} (omitting the passband), with an amplitude accuracy of 50% of the transmission at the frequency of measurement and an absolute amplitude sensitivity of 1E–4 or better.

6.2.3 In addition to the above measurements, the spectral transmission between the 0.2% relative response points shall be computed for both the known measurement illumination case and for the case where the incident ray count distribution is as tabulated for each cold filter in TC-RAL-42, using the operating temperature model of 63 K ± 3 K.

6.2.4 Spectral measurements on individual cut cold filters will be attempted at room temperature to verify the coating functionality, if this is not practicable a comprehensive visual examination of the cut filter will be performed to verify the coating integrity.

6.2.5 The corrected spectral measurements resulting from 6.2.3 above for all mother pieces over the wavelength range, resolution and operating temperature requirements described above shall be transferred to the Spectral Measurement & Analysis Spreadsheet TC-RDU-295 as interpolated data over the range 4000 $cm^{-1}$to 220 cm^{-1} at 2 cm^{-1} intervals.

6.3 SPECTRAL MEASUREMENT AND ANALYSIS OF WARM FILTERS

Spectral measurements shall be performed as follows on each coated mother piece before cutting into individual filters. The measurements shall be performed in known incident illumination at a temperature of 301 K ± 2.5 K; Spectral data shall be prepared for analysis (by applying where appropriate the necessary f/no. corrections as described above in 6) from Spectral measurements which shall be performed as follows on each coated mother piece before cutting into individual filters.

6.3.1 The in-band transmission vs. wavenumber shall be measured with a spectrophotometer resolution of 2.0 cm^{-1} between the 0.2% relative transmission points with an amplitude accuracy of ±1.5% of the peak transmission or ±15% of the transmission at the frequency of measurement (whichever is more accurate) and a spectral frequency accuracy of ±0.2 cm^{-1}

6.3.2 The out-of-band transmission vs. wavenumber shall be measured with a spectrophotometer resolution of 2.0 cm^{-1} from 6500 cm^{-1} to 250 cm^{-1} (omitting the passband) with an amplitude accuracy of 50% of the transmission at the frequency of measurement and an absolute amplitude sensitivity of 1E-4 or better

6.3.3 In addition to the above measurements, the spectral transmission between the 0.2% relative response points shall be computed for both the near-parallel (measurement) illumination case and for the case where the incident ray count distribution is as tabulated for each warm filter in TC-RAL-42 using the operating temperature model of 301 K ± 5 K.

6.3.4 Spectral measurements on individual cut warm filters will be attempted at 301 K ±2.5 K to verify coatings functionality. If this is not practicable a comprehensive visual examination of the cut filter will be performed to verify the coating integrity.

6.3.5 The corrected spectral measurements resulting from 6.3.3 above for all mother pieces over the wavelength range, resolution and operating temperature requirements described above shall be transferred to the Spectral Measurement & Analysis Spreadsheet TC-RDU-295 as interpolated data over the range 4000 cm^{-1} to 220 cm^{-1} at 2 cm^{-1} intervals.

6.4 SPECTRAL MEASUREMENT AND ANALYSIS OF LENSES

6.4.1 The following measurements shall be made on all deliverable components:

a) the relative transmission of each uncoated lens
b) the relative transmission of each coated lens
c) the transmission of each coated plane witness piece
d) the reflectance of each coated surface of each plane witness piece
e) the centre thickness and temperature (to be recorded for each lens measured)

6.4.2 All spectral measurements of antireflected plane witness pieces shall be performed with a spectrophotometer resolution of 2.0 cm^{-1}, over the spectral range 6500 cm^{-1} to 250 cm^{-1}, under known incident illumination at a temperature of 301 K ± 5 K. This spectral range encompasses the actual HIRDLS bands and the out-of-band regions where data is required for verification of blocking performance. Wavenumber accuracy shall be ± 1 cm^{-1} or better between 250 cm^{-1} and 1750 cm^{-1}, and ± 0.1% or better between 2000 cm^{-1} and 6500 cm^{-1}.

6.4.3 In the spectral regions where the transmission is above 90%, transmission measurements shall be accurate to ± 1.0% of the transmission. In the spectral regions where the reflectance is below 10%, reflectance measurements shall be accurate to ± 1.0% of the reflectance. In all other regions within the specified spectral range, transmission measurements shall be accurate to ± 1.5%, and reflectance measurements to ± 2.0%.

6.4.4 Measurements in the out-of-band blocking region shall have a sensitivity which is adequate to allow the specified performance to be verified (i.e., 0.01% transmission > 4000 cm^{-1}). Alternatively, disclosure of the design and/or the results of analysis shall be provided to show that the predicted transmission of the coating beyond 4000 cm^{-1} is 0.002% or less.

6.4.5 Spectral measurements of individual lenses shall be performed under the above measurement conditions to verify the coating integrity, but shall not be used in the spectral measurement analysis. The purpose of the transmission measurement of the lenses is to demonstrate that the coating has been placed correctly in the specified spectral position.

6.4.6 Spectral measurements on antireflected plane witness pieces of 3.5 mm thickness, from the same deposition batch, shall be performed over the wavelength range, resolution requirements and operating temperatures as described above, from which interpolated data over the range 4000 cm^{-1} to 220 cm^{-1} at 2 cm^{-1} intervals shall be used to verify and calibrate the computed spectral performance of the coating design under the measurement conditions.

6.4.7 The spectral measurements of the deposited design shall be compared with computations of the spectral performance of the as deposited coating designs, and the design/spectral performance adjusted for convergence with that measured. Computations of the corrected design are then to be carried out using the tabulations of angle-of-incidence ray count distribution data for each warm filter as described in TC-RAL-42, and the results of the computations shall be used, after transfer to the Spectral Measurement and Design Spreadsheet (TC-RDU-295), in the determination (together with the other inputs) of instrument spectral performance.

6.5 SPECTRAL MEASUREMENT AND ANALYSIS OF WINDOWS

6.5.1 The following measurements shall be made on all deliverable components:

a) the transmission of each uncoated window
b) the transmission of each coated window
c) the transmission of each coated witness piece
d) the reflectance of each coated surface of each window

6.5.2 All spectral measurements of windows shall be performed with a spectrophotometer resolution of 2.0 cm^{-1}, over the spectral range 6500 cm^{-1} to 250 cm^{-1}, under incident illumination that is normal and parallel to within 5 degrees. This spectral range encompasses the actual HIRDLS bands and the out-of-band regions where data is required for verification of blocking performance. Wavenumber accuracy shall be ± 1 cm^{-1} or better between 250 cm^{-1} and 1750 cm^{-1}, and ± 0.1% or better between 2000 cm^{-1} and 6500 cm^{-1}.

6.5.3 Reflectivity performance for each surface shall be verified through spectral measurement of a single-side coated 2.0 mm thick witness piece, with the rear face reflection unambiguously removed (by use of a wedged substrate or an appropriately ground rear surface).

6.5.4 In the spectral regions where the transmission is above 90%, transmission measurements shall be accurate to ± 1.0% of the transmission. In the spectral regions where the reflectance is below 10%, reflectance measurements shall be accurate to ± 1.0% of the reflectance. In all other regions within the specified spectral range, transmission measurements shall be accurate to ± 1.5%, and reflectance measurements to ± 2.0%.

6.5.5 Measurements in the out-of-band blocking region shall have a sensitivity which is adequate to allow the specified performance to be verified (i.e., 0.01% transmission beyond 4000 cm^{-1}). Alternatively, disclosure of the design and/or the results of analysis shall be provided to show that the predicted transmission of the coating beyond 4000 cm^{-1} is 0.002% or less.

6.5.6 Spectral measurements on each antireflected window shall be performed over the wavelength range, resolution requirements, and operating temperatures as described above, from which interpolated data over the range 4000 cm^{-1} to 220 cm^{-1} at 2 cm^{-1} intervals shall be used for transfer to the Spectral Measurement & Analysis Spreadsheet (TC-RDU-295), as in 6.4.6 and 6.4.7 above.

6.5.7 The spectral measurements of the deposited design shall be compared with computations of the spectral performance of the as deposited coating designs, and the design/spectral performance adjusted for convergence with that measured. Computations of the corrected design are then to be carried out using the tabulations of angle of incidence ray count distribution data for each warm filter as described in TC-RAL-42, and the results of the computations shall be used, after transfer to the Spectral Measurement and Design Spreadsheet (TC-RDU-295), in the determination (together with the other inputs) of instrument spectral performance.

6.6 SPECTRAL MEASUREMENT AND ANALYSIS OF MIRRORS

6.6.1 Spectral reflectivity measurements on plane witness pieces shall be performed over the wavelength range, resolution requirements, and operating temperatures as described above, from which interpolated data over the range 4000 cm^{-1} to 220 cm^{-1} at 2 cm^{-1} intervals shall be transferred to the Spectral Measurement & Analysis Spreadsheet (TC-RDU-295).

6.7 SPECTRAL CRITERIA FOR COMPONENT ACCEPTANCE

6.7.1 Individually delivered filters, lenses, windows, and mirrors shall be deemed spectrally acceptable only if the measurements and analyses specified in sections 6.2 to 6.6 have been performed, and demonstrate that the corresponding requirements have been satisfied.

6.7.2 From the analysis performed through the Spectral Measurement & Analysis Spreadsheet (TC-RDU-295), the resulting overall instrument passband profiles for each channel, shall be compared with the requirements of the passband profiles specified in SP-HIR-69. In each channel the predicted passband profile shall be within the specified limits.

SECTION 7 – DETECTORS

The 21 anti-reflection-coated photo-conductive HgCdTe IR detector elements, and associated cold filters, are contained in a hermetic vacuum dewar and cooled to between 60 K and 65 K by the Cooler Subsystem.

7.1 LONG WAVELENGTH DETECTOR RESPONSE

In order for the overall optical system to meet the instrument out-of-band spectral requirements, without excessive demands being made of the warm and cold filters to provide long-wave blocking, the relative spectral responsivity of the detector elements must conform to the limits given in Table 7.1. These have been defined in terms of the wavelengths at which, on the long-wave side of the peak response, the responsivity of the detector shall have fallen respectively to 10%, 1%, and 0.2% of the peak responsivity – expressed in energy units (i.e., "per watt", not "per photon").

Table 7.1 Detector Cut-Off Limits

Channel	Detector Group		Centre (μm)	L/W50% (μm)	L/W10%* (μm)	L/W1% (μm)	L/W0.2% (μm)
1	H_2O	1	17.4	22.2	24.5	28.8	32.9
2	CO_2	2	16.5	20.8	22.8	26.4	29.8
3	CO_2	2	16.0	20.8	22.8	26.4	29.8
4	CO_2	2	15.6	20.8	22.8	26.4	29.8
5	CO_2	3	15.0	19.0	20.7	23.6	26.3
6	Aerosol	4	12.1	15.8	16.9	18.8	20.4
7	CFC-11	4	11.8	15.8	16.9	18.8	20.4
8	HNO_3	4	11.3	15.8	16.9	18.8	20.4
9	CFC-12	4	10.8	15.8	16.9	18.8	20.4
10	O_3	5	10.1	12.0	16.7	18.5	20.1
11	O_3	5	9.57	12.0	16.7	18.5	20.1
12	O_3	5	8.85	12.0	16.7	18.5	20.1
13	Aerosol	6	8.26	12.0	12.6	13.6	14.4
14	N_2O_5	6	8.04	12.0	12.6	13.6	14.4
15	N_2O	6	7.88	12.0	12.6	13.6	14.4
16	$ClONO_2$	6	7.76	12.0	12.6	13.6	14.4
17	CH_4	6	7.43	12.0	12.6	13.6	14.4
18	H_2O	7	7.09	8.8	9.2	9.7	10.1
19	Aerosol	7	7.10	8.8	9.2	9.7	10.1
20	H_2O	7	6.75	8.8	9.2	9.7	10.1
21	NO_2	7	6.22	8.8	9.2	9.7	10.1
22	Align.	7	15.0	19.0	20.7	23.6	26.3

From Frank Adams RESPONSE.XLS

SECTION 8 – APPENDICES

APPENDIX A – APPLICABLE DOCUMENTS

Document Reference	Title	Available From
SP-HIR-013	Instrument Technical Specification (ITS)	Note 2
SP-HIR-154	Out-of-Band Spectral Blocking Requirements	Note 2
SP-HIR-069	HIRDLS Instrument Spectral Requirements	Note 2
TC-HIR-149	HIRDLS Acronyms, Abbreviations, Dictionary of Terms and Optical System Terminology	Note 2
TC-OXF-048	Electronic Documentation of Measured HIRDLS Filter Passbands	Note 2
TC-RAL-042	Angle of Incidence Distributions for SP-HIR-32 Optical Design	Note 3

APPENDIX B – REFERENCE DOCUMENTS

Document Reference	Title	Available From
SP-HIR-032	Optical System Specification Document	Note 3
PM-OXF-153	HIRDLS Instrument Spectral Requirements Flowdown	Note 2
TC-RAL-037	Optical System Throughput	Note 3
TC-RAL-047	Ghost Analysis Results	Note 3
TC-RDU-111	Spectral Passband & Blocking Budget Description Document	Note 1
TC-RDU-288	Effects of Angle of Incidence Ray Count Distribution on HIRDLS Antireflection Coatings	Note 1
TC-RDU-295	Spectral Measurement and Analysis Spreadsheet Description Document	Note 1
SP-OXF-167	Technical Specification for HIRDLS Antireflection Coatings	Note 2

NOTES (Sources)

1. The University of Reading, Infrared Multilayer Laboratory, Department of Cybernetics, Whiteknights, Reading, Berkshire, RG6 2AY, England, UK
2. The University of Oxford, Department of Atmospheric, Oceanic and Planetary Physics, Clarendon Laboratory, Parks Road, Oxford, OX1 3PU, England, UK.
3. Rutherford Appleton Laboratory, Space Science Department, Chilton, Didcot, Oxon, OX11 0QX, England, UK.

APPENDIX C – SPECTRAL ILLUSTRATIONS

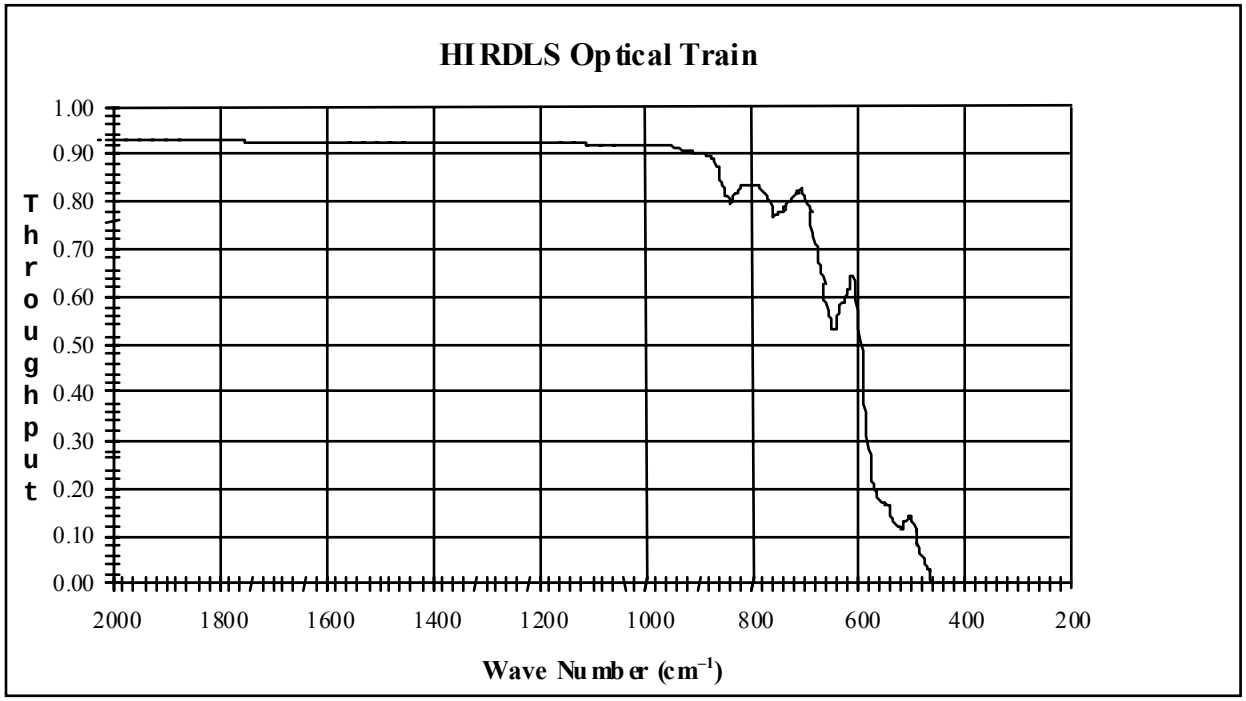

Figure 8.1 Optical System Throughput (5–30 μm)

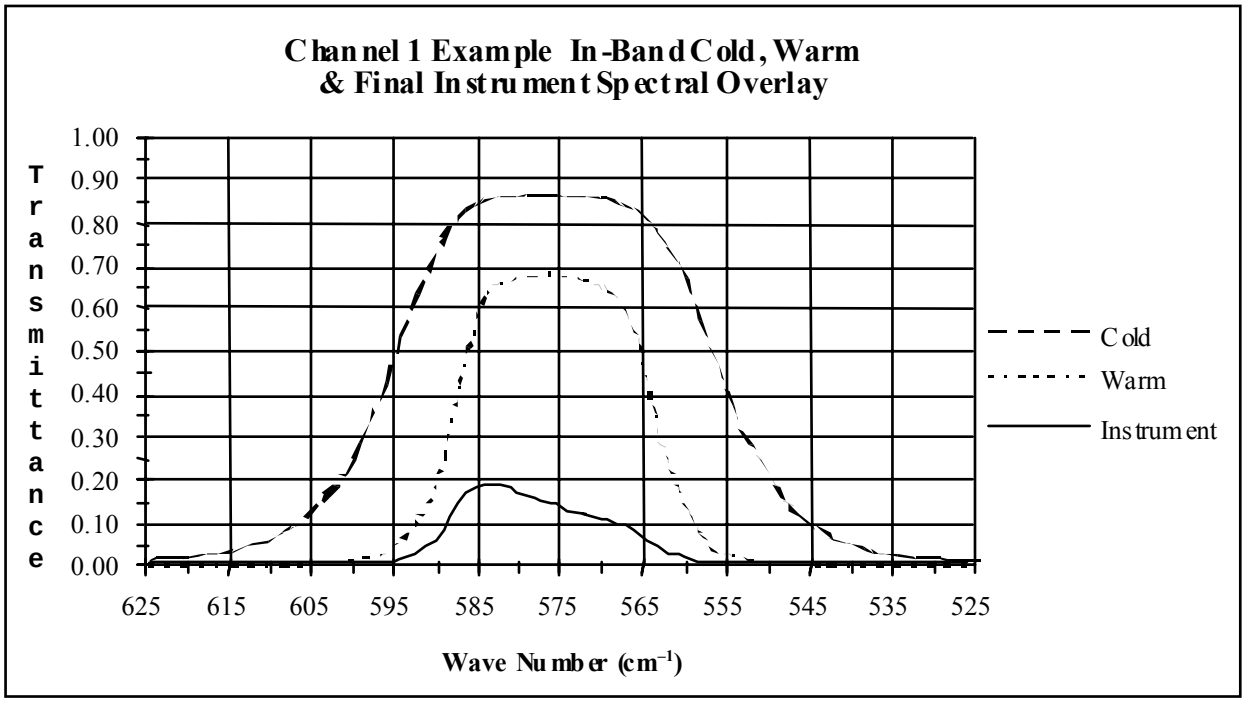

Figure 8.2 Channel 1 Example – Overlay of Cold, Warm, & Final Instrument Spectral Response