Specifications for the procurement of the dichroics

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DOCUMENT HISTORY

Issue	Date	Sections Affected	Change Description
Draft 1	May 14th 2016		First draft for iteration with company
Draft 2	Jun 13th 2016		Simplified specs
Draft 3	Jun 17th 2016	Sect. 4.3, 5.2, 5.5, 5.6	Details on surface figure after coating
Draft 4	Jul 14th 2016	Table 3	Finalized for optical-FDR after last inputs from company
Version 1.0	Dec 14th 2016	All	Included RIXs and comments from ESO, removed non-essential descriptions/discussions.
Version 1.1	Apr 07th 2017	Sect. 5.4	Removed optional measurements
Version 1.2	5th May 2017	All.	Minor updates to the text. Fixed formatting issue with Table 7. Renumbered tables.
Version 1.3	30th May 2017	All	Removed RD1 and RD2. Defined goal specifications in separate tables.
Version 1.4	1st June 2017	Table 3 and Table 5	Updated SFE tolerance
Version 1.5	5th June 2017	Table 3 to Table 6	Updated cut-off wavelength of S2
Version 1.6	22nd June 2017	All	Updated to clarify some of the wording
Version 1.7	28th June 2017	Table 4 and Table 6	Listed goal specifications in order of importance
Version 2.0	30th June 2017	All	Specification released for manufacture
Version 3.0	24th July 2017	Table 3 and Table 5	Minor updates to clarify wording and addition of scratch-dig specification.

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LIST OF ACRONYMS AND ABBREVIATIONS

Ø	Symbol representing diameter
A	Fraction of light absorbed by a given optical surface
CCD	Charge Coupled Device
ESO	European Southern Observatory
FDR	Final Design Review
ICD	Interface Control Document
IR	Infrared
N/A	None Applicable
PA	Product Assurance
PDR	Preliminary Design Review
ppm	Parts per million
P-V	Peak to Valley
QA	Quality Assurance
QAP	Quality Assurance Plan
QC	Quality Control
R	Fraction of light reflected by a given optical surface
Rave	Average reflectivity
Rmin	Minimum reflectivity
RMS	Root Mean Square
S1	Surface 1
S2	Surface 2
T	Fraction of light transmitted through a given optical surface
Tave	Average transmission
Tmin	Minimum transmission
TBC	To be confirmed
TBD	To be decided
Tot	Total transmission of the dichroic
WL	Wavelength

1 INTRODUCTION

1.1 Purpose and scope of Document

MOONS (acronym for Multi-Objects Optical and Near-infrared Spectrograph) is a new concept for an astronomical spectrograph for the European Southern Observatory's Very Large Telescope (VLT). It has been selected by the European Southern Observatory (ESO) in response to a call for proposals for the study of new instruments. The project was officially approved by ESO. The preliminary design phase and an early final design review for long-lead optical elements were successfully completed. This document describes and specifies the parameters of the dichroics. It also describes the acceptance tests that the manufacturer must fulfill prior to delivering the dichroics.

1.2 Intended Audience

This specification document defines the parameters and the acceptance tests necessary for the procurement of the dichroics. It is the reference document for the commercial contract that will be signed with the manufacturing company. The main audience consists of the manufacturing company and the persons of the MOONS consortium in charge of the specific task.

2 APPLICABLE AND REFERENCE DOCUMENTS

2.1 Applicable Documents

The following documents at their indicated revision form part of this document to the extent specified herein.

Table 1 Applicable Documents

Ref No	Document/Drawing Number	Document Title	Issue Number
N/A			

2.2 Reference Documents

The following documents provide useful reference information associated with this document. These documents are to be used for information only. Changes to the date and/or revision number do not make this document out of date.

Table 2 Reference Documents

Ref No	Document/Drawing Number	Document Title	Issue Number
RD1	Heraeus data-sheet	Quartz Glass for Optics: Data and Properties	July 2015

3 DESCRIPTION OF THE DICHROICS

This section gives a brief description of the instrument and of the dichroics.

3.1 Overall description of the MOONS spectrograph

The MOONS project foresees the construction of two identical, cryogenic spectrographs fed by optical fibres. Therefore, we need two items for all the sub-systems and components listed below. The layout of one spectrograph is shown in Figure 1. The optics can be conveniently divided into the following sub-systems

- **Fibres, collimator, dispersers, cameras;** not pertinent to this document.
- **Dichroic-I, Dichroic-H;** the subject of this document. They are used to split the light in three bands separated in wavelengths. Their first (entrance) faces must reflect the shorter wavelength “blue” and transmit the longer wavelength “red” light with the highest possible efficiency. To avoid the use of extra-filters, their second (exit) face must reflect the thermal infrared radiation (wavelengths range 2100-2700 nm).

All the optical elements will be mounted on an optical bench inside a vacuum tank, cooled to cryogenic temperatures (about 120K).

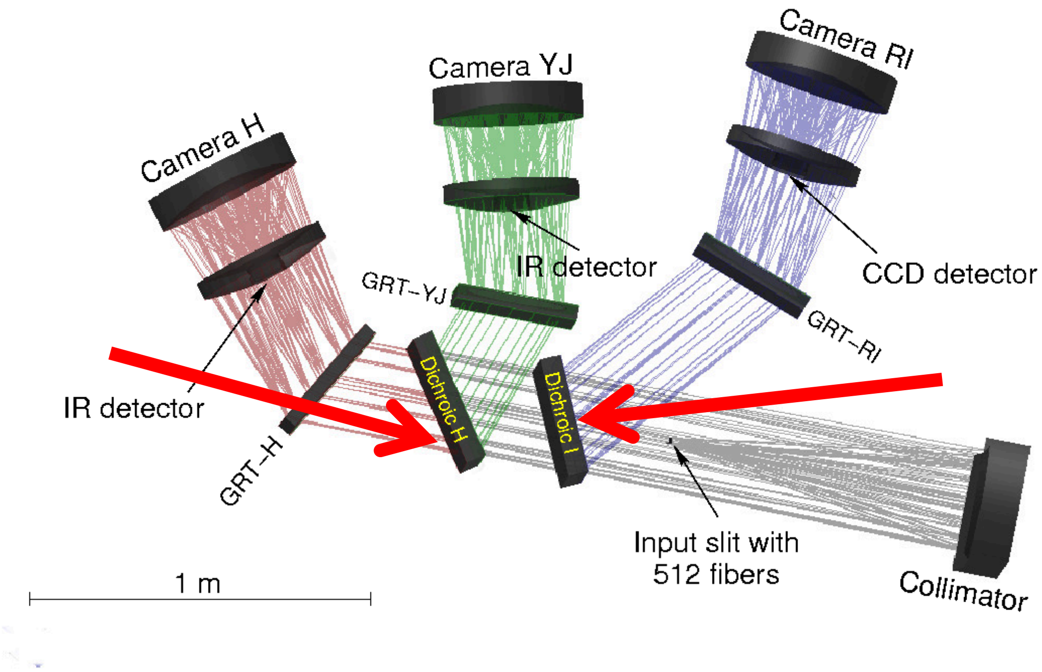


Figure 1 Layout of the MOONS spectrograph. The dichroics are indicated by the arrows.

3.2 Choice of dichroic parameters

Each spectrograph includes two dichroics (see Figure 1). Their cut-on/off wavelengths are tuned to match absorption bands produced by water vapour in the Earth’s atmosphere and to take full advantage of the higher performances offered by the CCD detectors below 940 nm. The atmospheric telluric transmission spectrum, in the selected regions, is plotted in Figure 2 together with the required transmission (red bars) and reflection (blue bars) for the dichroics.

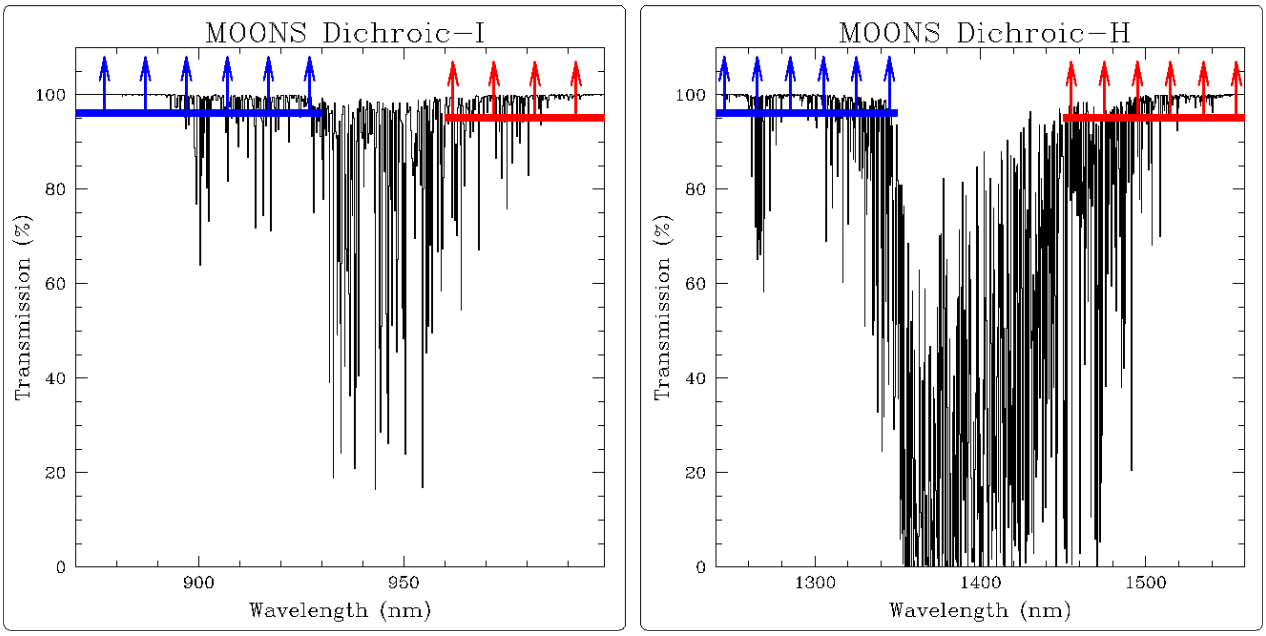


Figure 2 Telluric transmission and requirements for reflection/transmission (blue/red bars)

The dichroics are designed to minimize the amount of thermal radiation reaching the infrared detectors in the YJ and H arms. This requires adding a cut-off (short-pass) dichroic coating on the second face of each dichroic. They must guarantee high reflection (or absorption) over 2100-2700 nm wavelength range. Radiation at longer wavelengths is absorbed by the cold part of the optical fibres.

The dichroics work in a collimated/parallel beam. The spectra in the RI and YJ arms are generated by the light reflected by the first faces of dichroic-I and dichroic-H. The radiation reflected by the second faces generates ghost-images that are at focus on the detector. To ensure that these ghost images do not contaminate the spectra we require that the two surfaces of the substrate are parallel to within <3 arc-sec. We also require that the relative intensity of the ghost images is much lower (<0.01%) than the main images; and this constraint is added as a goal for the coating.

4 GLASS BLANKS

4.1 Glass blanks for the substrates

The dichroic substrates are made of Infrasil 302. The parameters of the blanks are summarized in the drawings displayed in Figure 3 and Figure 4. The parameters of the glass (bubbles, striae, homogeneity, residual stress etc.) are according to the catalog of Heraeus (see reference document RD1 and Appendix 1).

The customer will supply free of charge two blanks of each type to the successful bidder.

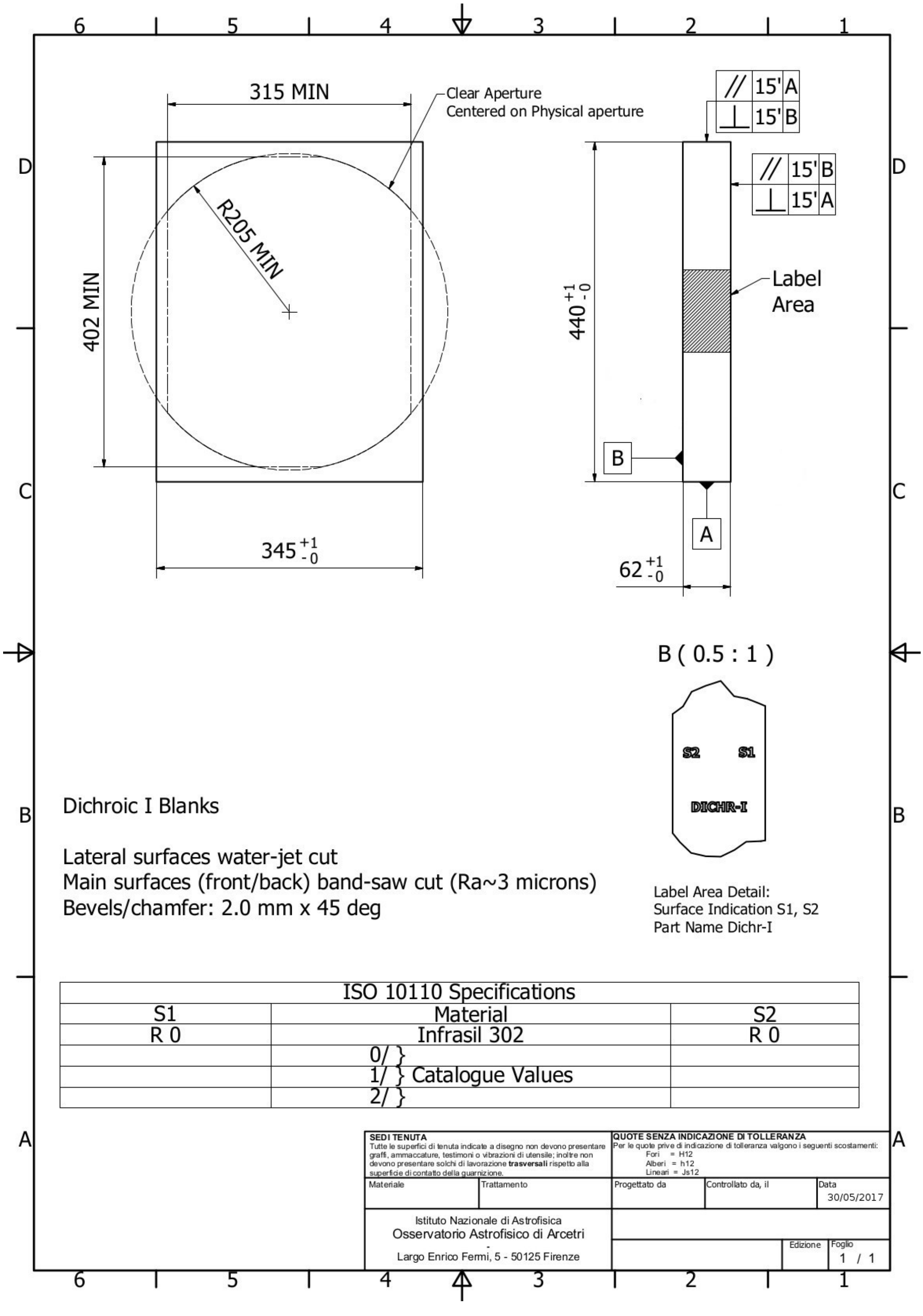


Figure 3 Drawing of the blanks for the dichroic-I.

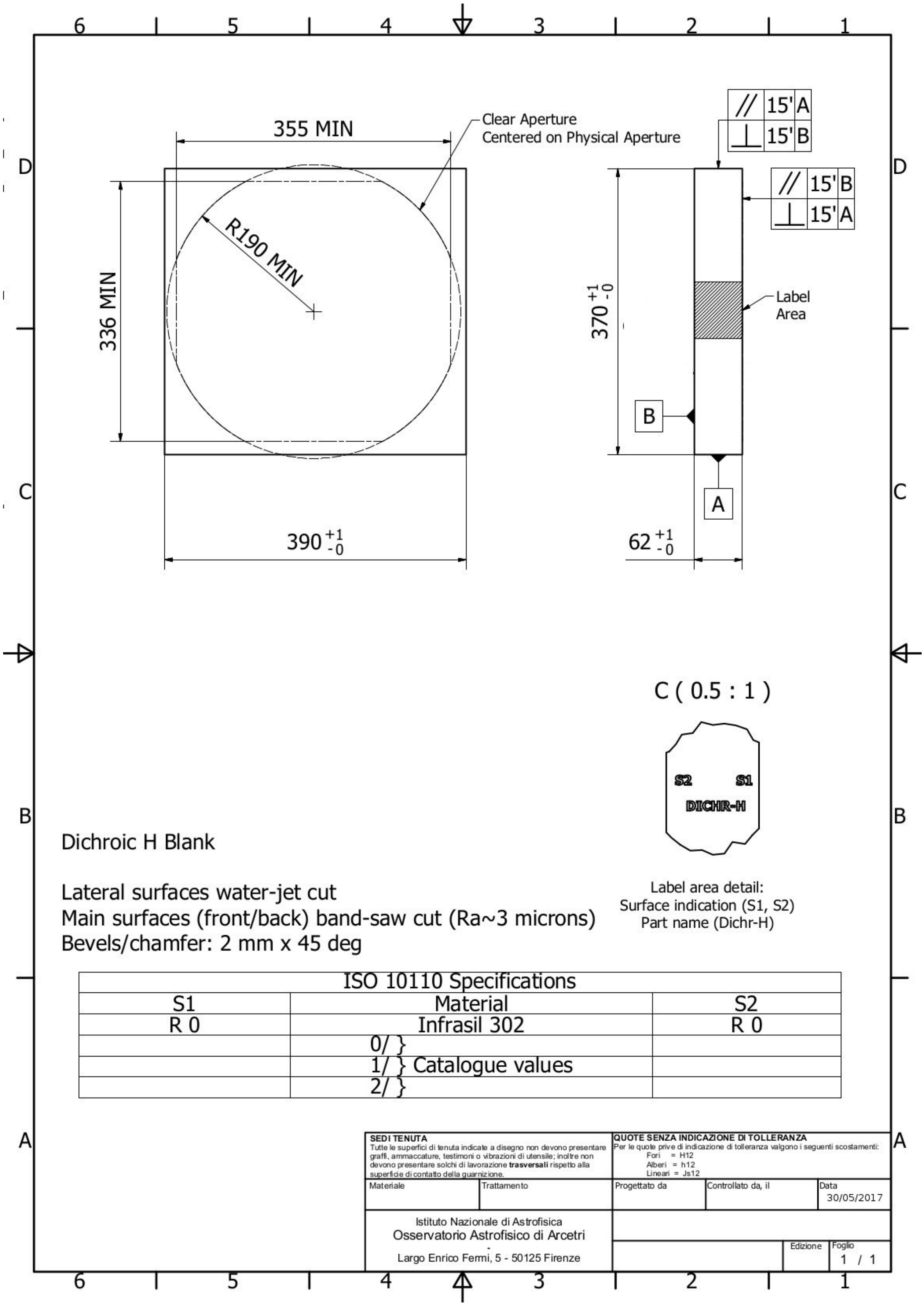


Figure 4 Drawing of the blanks for the dichroic-H

5 MANUFACTURING SPECIFICATIONS

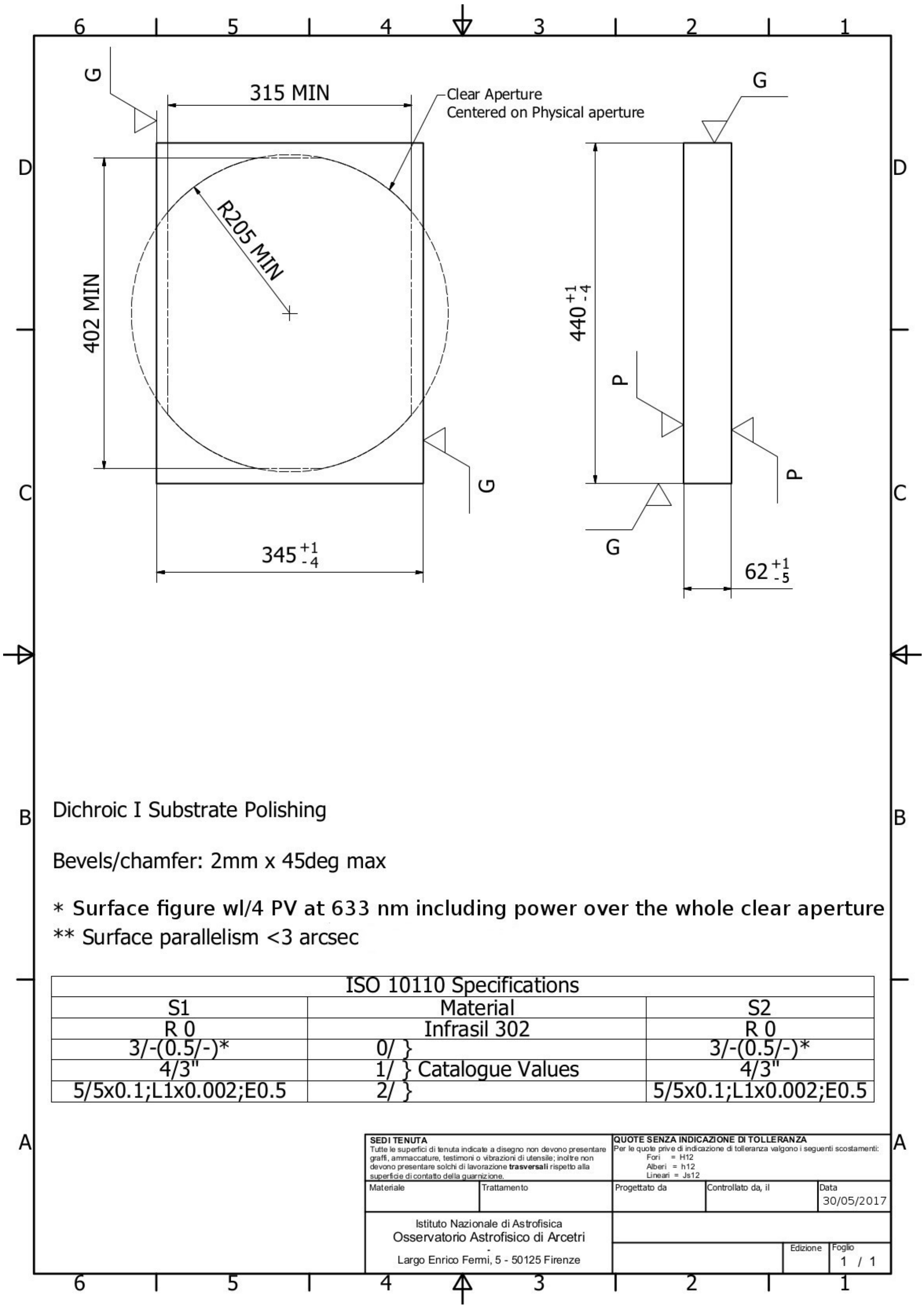
This section summarizes all the parameters of the dichroics. We need two dichroics per type (order quantity is 2-off dichroic-I and 2-off dichroic-H).

5.1 Requirements for the polishing of substrates

The requirements for the polishing of the substrates are summarized in the drawings shown in Figure 5 and Figure 6 for the dichroic-I and dichroic-H respectively.

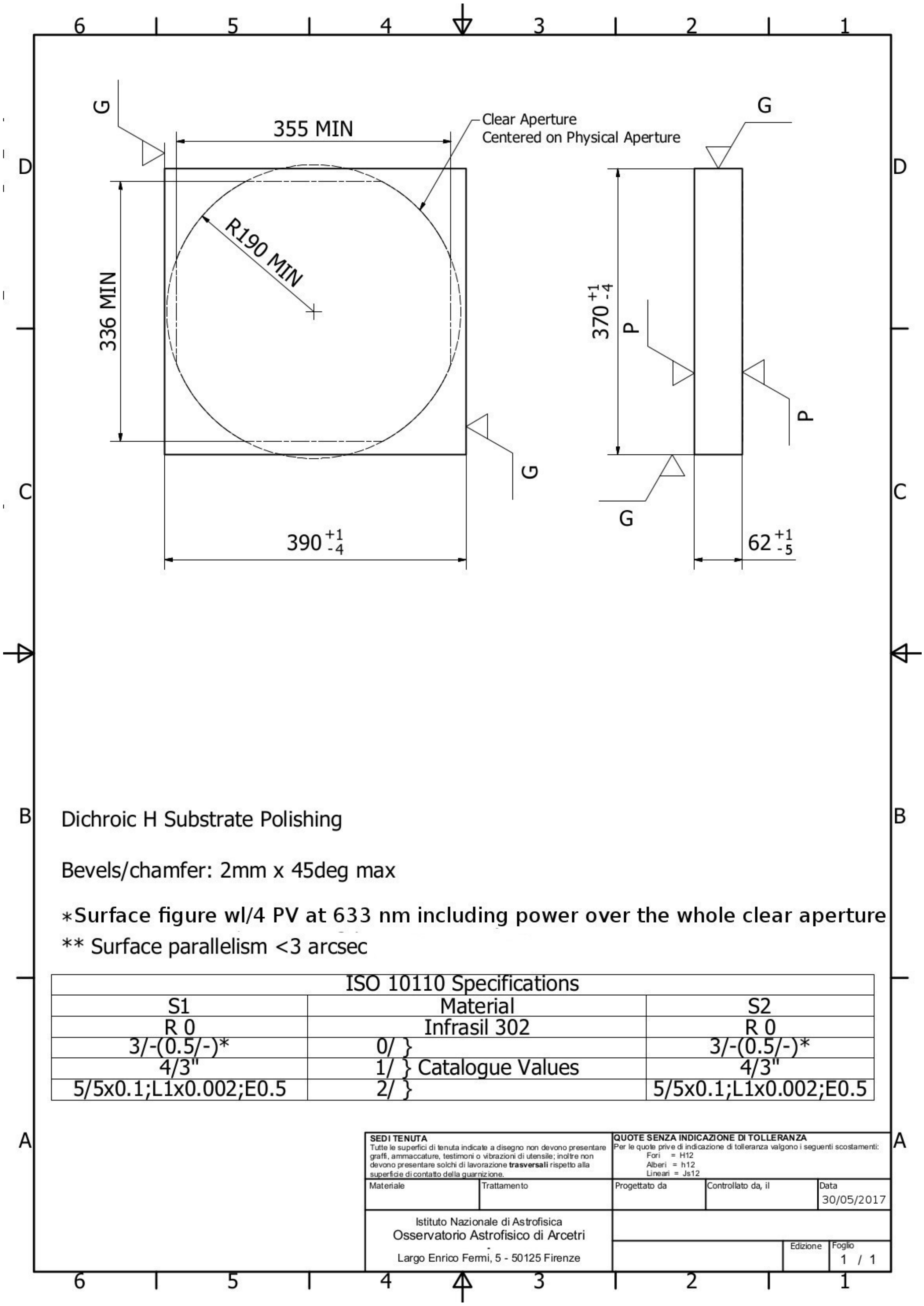
The parallelism (specification <3 arc-sec) is the most critical parameter, while the surface figure (λ/4 P-V at 633nm) and surface finish (SD 40/20) are quite standard.

The manufacturing tolerances on outer dimensions (+1mm and -4mm) and thickness (+1mm and -5mm) of the substrate are sized to allow material to be removed in view of multiple re-polishing of the same substrates imposed by coating failures.



ISO 10110 Specifications		
S1	Material	S2
R 0	Infrasil 302	R 0
3/-(0.5/-)*	0/ }	3/-(0.5/-)*
4/3"	1/ } Catalogue Values	4/3"
5/5x0.1;L1x0.002;E0.5	2/ }	5/5x0.1;L1x0.002;E0.5

Figure 5 Drawing of the polished substrates for the dichroic-I



ISO 10110 Specifications		
S1	Material	S2
R 0	Infrasil 302	R 0
3/-(0.5/-)*	0/ }	3/-(0.5/-)*
4/3"	1/ } Catalogue Values	4/3"
5/5x0.1;L1x0.002;E0.5	2/ }	5/5x0.1;L1x0.002;E0.5

Figure 6 Drawing of the polished substrates for the dichroic-H

5.2 Requirements for the dichroic-I coating

The mandatory specifications for the dichroic-I coating are summarized Table 3.

All values of reflection (R), transmission (T) and absorption (A) are for non-polarized light. The relationship between the above quantities is T=(1-R)*(1-A).

Table 3 Specifications for the coating of dichroic-I

Ref	Parameter	Specification	Comment
1.	Operating conditions	Temperature =120 ± 10 K Pressure <10^{-5} mbar	Cryogenic environment.
2.	Storage/handling conditions	Temperature < 80 Celsius Relativity humidity <95%, non-condensing.	
3.	Durability	Coating to withstand thermal cycling from room temperature to 77K in no less than 12 hours, and normal procedures for cleaning (e.g. CO_2 snow and wet cleaning methods). If any special procedures are required it shall be indicated by supplier.	
4.	Minimum area to be coated	Clear aperture as defined in Figure 5	
5.	Incidence angles	25 ± 0.5 degrees	Angles measured relative to the surface normal.
6.	Coating on S1 (entrance surface)	Rave>97% over 640-930 nm Rmin>93% over 640-930 nm Tave>97% over 960-1350 nm Tmin>93% over 960-1350 nm Tave>97% over 1470-1800 nm Tmin>93% over 1470-1800 nm These values are at the operational temperature of 120 K	Rave: average reflection Rmin: minimum reflection Tave: average transmission Tmin: minimum transmission
7.	Coating on S2 (exit surface)	Rave>90% over 2000-2700 nm Rmin>80% over 2000-2700 nm Tave>97% over 940-1350 nm Tmin>93% over 940-1350 nm Tave>97% over 1470-1800 nm Tmin>93% over 1470-1800 nm These values are at the operational temperature of 120 K	
8.	Uniformity of coating	T and R values over above wavelength ranges shall vary by less than 1% Cross-over wavelength of S1 <5 nm	Relative variation measured on sub-areas over the clear aperture.
9.	Surface figure of both surfaces after coating	The manufacturer shall attempt to minimize the high order aberrations (astigmatism, coma, spherical etc.) caused by the coating process such that the aberrations are compatible with substrate before coating (see Sections. 6.5, 6.6). The maximum permissible surface form error is 400 nm RMS for astigmatism.	Measured in reflection on any Ø=270 mm sub-aperture of the clear aperture defined in Figure 5.

10.	Surface quality after coating	Scratch-Dig 60-40	Measured over any 100mm sub-aperture of the clear aperture defined in Figure 5.
11.	Radioactivity	The coating must not include radioactive compounds (e.g. ThF_4).	

The goal specifications for the dichroic-I coating are listed in Table 4. Although these goals are not mandatory they are a desirable requirement for the customer. The goal specifications have been ranked in order of importance, with Table 4 ref 1, surface figure, being the most important goal, and Table 4 ref 4, constraints for ghosts, being the least important.

Table 4 Specifications of goals for the coating of dichroic-I

Ref	Parameter	Specification	Comment
1.	Surface figure of both surfaces after coating	Power < 300 nm RMS Astigmatism < 100 nm RMS	Measured in reflection on any Ø=270 mm sub-aperture of the clear aperture defined in Figure 5.
2.	Coating on S1 (entrance surface)	Rave>99% over 640-930 nm Rmin>98% over 640-930 nm Tave>99% over 960-1350 nm Tmin>98% over 960-1350 nm Tave>99% over 1470-1800 nm Tmin>98% over 1470-1800 nm These values are at the operational temperature of 120 K	Rave: average reflection Rmin: minimum reflection Tave: average transmission Tmin: minimum transmission
3.	Coating on S2 (exit surface)	Rave>99% over 2000-2700 nm Rmin>98% over 2000-2700 nm Tave>99% over 940-1350 nm Tmin>98% over 940-1350 nm Tave>99% over 1470-1800 nm Tmin>98% over 1470-1800 nm These values are at the operational temperature of 120 K	
4.	Extra constraints for ghosts	Goal is: (1-A1)*(1-R1)*R2*(1-R1)*(1-A1) < 0.01% over 640-950 nm	A1: absorption of S1 R1: reflection of S1 R2: reflection of S2

5.3 Requirements for the dichroic-H coating

The mandatory specifications for the dichroic-H coating are summarized Table 5.

All values of reflection (R), transmission (T) and absorption (A) are for non-polarized light. The relationship between the above quantities is T=(1-R)*(1-A).

Table 5 Specifications for the coating of dichroic-H

Ref	Parameter	Specification	Comment
1.	Operating conditions	Temperature =120 ± 10 K Pressure <10^{-5} mbar	Cryogenic environment.
2.	Storage/handling conditions	Temperature < 80 Celsius Relativity humidity <95%, non-condensing.	
3.	Durability	Coating to withstand thermal cycling from room temperature to 77K in no less than 12 hours, and normal procedures for cleaning (e.g. CO_2 snow and wet cleaning methods). If any special procedures are required it shall be indicated by supplier.	
4.	Minimum area to be coated	Clear aperture as defined in Figure 6	
5.	Incidence angles	35 ± 0.5 degrees	Angles measured relative to the surface normal.
6.	Coating on S1 (entrance surface)	Rave>97% over 940-1350 nm Rmin>93% over 940-1350 nm Tave>97% over 1470-1800 nm Tmin>93% over 1470-1800 nm These values are at the operational temperature of 120 K	Rave: average reflection Rmin: minimum reflection Tave: average transmission Tmin: minimum transmission
7.	Coating on S2 (exit surface)	Rave>90% over 2000-2700 nm Rmin>80% over 2000-2700 nm Tave>97% over 1470-1800 nm Tmin>93% over 1470-1800 nm These values are at the operational temperature of 120 K	
8.	Uniformity of coating	T and R values over above wavelength ranges shall vary by less than 1% Cross-over wavelength of S1 <10 nm	Relative variation of measurements on sub-areas over the whole clear aperture.
9.	Surface figure of both surfaces after coating	The manufacturer shall attempt to minimize the high order aberrations (astigmatism, coma, spherical etc.) caused by the coating process such that the aberrations compatible with substrate before coating (see Sections. 6.5, 6.6). The maximum permissible surface form error is 400 nm RMS for astigmatism.	Measured in reflection on any Ø=270 mm sub-aperture of the clear aperture defined in Figure 6.
10.	Surface quality after coating	Scratch-Dig 60-40	Measured over any 100mm sub-aperture of the clear aperture defined in Figure 6.

11.	Special requirements	The coating must not include radioactive compounds (e.g. ThF_4).	

The goal specifications for the dichroic-H coating are listed in Table 6. Although these goals are not mandatory they are a desirable requirement for the customer. The goal specifications have been ranked in order of importance, with Table 6 ref 1, surface figure, being the most important goal, and Table 6 ref 4, constraints for ghosts, being the least important.

Table 6 Specifications of goals for the coating of dichroic-H

Ref	Parameter	Specification	Comment
1.	Surface figure of both surfaces after coating	Power < 300 nm RMS Astigmatism < 100 nm RMS	Measured in reflection on any Ø=270 mm sub-aperture of the clear aperture defined in Figure 6.
2.	Coating on S1 (entrance surface)	Rave>99% over 940-1350 nm Rmin>98% over 940-1350 nm Tave>99% over 1470-1800 nm Tmin>98% over 1470-1800 nm These values are at the operational temperature of 120 K	Rave: average reflection Rmin: minimum reflection Tave: average transmission Tmin: minimum transmission
3.	Coating on S2 (exit surface)	Rave>99% over 2000-2700 nm Rmin>98% over 2000-2700 nm Tave>99% over 1470-1800 nm Tmin>98% over 1470-1800 nm These values are at the operational temperature of 120 K	
4.	Extra constraints for ghosts	Goal is: (1-A1)*(1-R1)*R2*(1-R1)*(1-A1) < 0.01% over 940-1350 nm	A1: absorption of S1 R1: reflection of S1 R2: reflection of S2

6 PROCUREMENT, FABRICATION AND ACCEPTANCE

This section describes the main steps of procurement, fabrication and the procedures for acceptance.

6.1 Glass blanks

The glass blanks will be procured by the MOONS consortium and shipped to the company in charge of polishing and coating. Only two blanks per type will be procured, i.e. no spares are foreseen. The acceptance of the blanks by the MOONS consortium will be based on the results given in the report of the glass blank manufacturing company, and this report will be made available to the coating and polishing company. The report will include measurements of homogeneity and residual stress (birefringence) of the blank or of the ingot from which the blank was cut. These parameters will be within the specification defined in glass manufacturers datasheet, reference document RD1.

6.2 Polishing of the substrates

The polishing of the substrates will be in charge of the same company that manufactures the coating. This process may be sub-contracted to another company with proven experience. Since there are no spare blanks, the company must foresee in the contract the possibility of repeated polishing to recover failures during the coating. The acceptance of the polished substrates will be based on the results given in the report of the company in charge of the polishing process. This report shall include interferometric measurements of the two surfaces as specified in Section 5.1, Figure 5 and Figure 6. The same procedures for acceptance of the polished substrates shall be repeated for each re-polishing after any coating-failure.

6.3 Prediction and preliminary coating of samples

The company in charge of the coating must first produce theoretical curves with the expected parameters (R, T, A) over the 350-2700 nm wavelength range. The models shall also include predictions of the effect of temperature (from room temperature to cryogenic conditions) and incidence angle. The acceptance of the theoretical curves will be based on the specifications given in Table 3 and Table 5.

The coating recipe shall be verified by producing at least two coated prototype samples, for each type of dichroic, on standard fused-silica substrates. The supplier is responsible for providing the polished substrates for the prototype samples, which can be of a standard size such as a 1 or 2 inches diameter. The primary acceptance tests will be based on measurements of - at least - R1 (reflection from the first surface) and Tot (total transmission of the dichroic) at the nominal incidence angles given in Table 3 and Table 5. The measurements of total transmission shall be corrected for the intrinsic absorption (OH-bands) of the fused-silica substrate using the curves/data available for this material.

The second part of the acceptance tests will be based on the results of measurements at cryogenic temperatures (next section).

6.4 Cryogenic cycling and measurements of samples

The company shall measure the behavior of the coating sample(s) at cryogenic conditions. The sample(s) shall be submitted to thermal cycles as specified under “durability” in Table 3 and Table 5. The coating shall withstand these cycles without any measurable deterioration, such as change in appearance of the coating, change in optical performance, peeling, or failure of an adhesion test.

6.5 Mechanical stress of the coating

The mechanical stress induced by the coating on the dichroic substrates, shown in Figure 5 and Figure 6, shall be modelled at room temperature and cryogenic temperature. The company shall also carry out measurements of deformation on a smaller prototype sample, such as the prototype described in section 6.3, with a Diameter/Thickness ratio that mimics the mechanical stresses on the final dichroic. The prediction and tests shall demonstrate that the deformation induced by the coating has a minimal effect on higher-order aberrations (astigmatism, coma, spherical etc.) although the deformation may affect the power.

6.6 Measurement and acceptance of the dichroics

The transmission and reflection of the final dichroics at the nominal incidence angle shall be measured at ambient temperature on witness samples coated in the same batch as the dichroics. The measured values – scaled to cryogenic temperatures - shall comply with the requirements in Table 3 and Table 5.

The uniformity of the coating shall be measured on at least 16 sub-apertures uniformly distributed over the clear aperture of each dichroic. These measurements may be performed at incidence angle different from the nominal values. The relative variation of the measured values shall be within the limits defined in Table 3 and Table 5.

The surface figure of both surfaces of each dichroic shall be measured in reflection using an interferometer with aperture of at least 270 mm diameter. Smaller apertures may be used; provided that the interferometric results are properly stitched.

6.7 Summary of contract deliverables

The deliverables will be as follows:

1. Polished substrates and interferometric test reports.
2. Theoretical predictions of coating performance.
3. Results of measured transmission and reflectance of coating prototype samples.
4. Results of cryogenic thermal cycling on the coating prototype samples.
5. Results of the theoretical prediction of the mechanical deformation of the substrate and how this affects surface form error.
6. Results of the measured mechanical deformation of the prototype samples.
7. Measured transmission and reflectance data of the final coated substrates.
8. Results of interferometric measurements of the coated surfaces of the dichroics.
9. Dichroic-I, 2-off and dichroic-H, 2-off.
10. Witness samples for dichroic-I and dichroic-H.
11. Packaging and shipping of dichroic-I, 2-off, dichroic-H, 2-off, and witness samples to the UK Astronomy Technology Centre in Edinburgh, UK.

7 APPENDIX 1: PROPERTIES OF INFRASIL 302

The properties of Infrasil 302 are summarized in second line from the bottom of Table 7.

Table 7 Main properties of Heraeus fused silica glass, extracted from RD1.

= 3D material, optically isotropic.
In quartz glass, the homogeneity is typically specified in one direction only. Heraeus manufactures quartz glass grades, which are controlled and specified in all 3 directions regarding striae, homogeneity and stress induced birefringence, for the most demanding applications. These materials are identified by the 3D symbol.

[1] For raw formed ingots the bubble specification is valid for the area defined by the minimum diameter tolerance. For machined parts it is defined as 100 % of the material.
[2] Bubbles or inclusions ≤ 0.08 mm diameter are not counted. For Suprasil® 311/312 and Suprasil® 3001/3002 a specification for bubbles and inclusions of ≤ 10µm is possible on request.
[3] For non-spherical bubbles the diameter is averaged.
[4] The Δn value is the maximum permissible lateral variation in refractive index (measured by interferometer at 632.8 nm after subtraction of tilt and offset) over 90% of the diameter or edge length of a fine ground piece, or 80% of a raw formed ingot. The maximum test diameter is 430 mm. Larger pieces are measured using overlapping interferograms.
[5] Does not apply to drawn rods.
[6] Lower values available on request.
[7] The residual strain values refer to the measured phase difference per cm light path. The residual strain value is specified over 90% of the diameter or edge length of a fine ground piece, or 80% of a raw formed ingot.
[8] On request.

Grade	Bubbles and Inclusions [1] [2] The bubble grade is given for every 100 cm³. Quartzglass from Heraeus is free of inclusions.			Homogeneity [5] Δn-value [4]		Residual Strain [7]	Fluorescence	OH-Content
	DIN 58927	DIN ISO 10110 [3]	Total cross-sections (in mm²) of all bubbles (TBCS value)	Striae class as [4] per DIN ISO 10110 (per 30 mm thickness)	PV value [6] (Peak-to-Valley)	nm/cm [6]	Excitation by Hg-Lamp@ λ= 254 nm and UG 5-filter; Lamp-power: 8W; Detection: adapted eye	ppm (µg/g)
Suprasil® 311 (3D)	0	1/1*0.08	≤ 0.015	2 / -;5	≤ 3·10-6	≤ 5	free	ca. 250
Suprasil® 312	0	1/1*0.08	≤ 0.015	2 / -;5	≤ 4·10-6	≤ 5	free	ca. 250
Suprasil® 3001 (3D)	0	1/1*0.08	≤ 0.015	2 / -;5	≤ 4·10-6	≤ 6	slight blue	≤ 1
Suprasil® 3002	0	1/1*0.08	≤ 0.015	2 / -;5	≤ 10·10-6	≤ 6	slight blue	≤ 1
Suprasil® 300	0	1/1*0.08	≤ 0.015	acc. MIL	n. sp.	≤ 5	slight blue	≤ 1
Suprasil® 3301 (3D)	0	1/1*0.08	≤ 0.015	2 / -;5	≤ 2·10-6	≤ 2	free	≤ 20
Suprasil® 3302	0	1/1*0.08	≤ 0.015	2 / -;5	≤ 3·10-6	≤ 3	free	≤ 20
Suprasil® 1 (3D)	0	1/1*0.08	≤ 0.015	2 / -;5	≤ 5·10-6	≤ 5	free	≤ 1300
Suprasil® 2 Grade A	0	1/1*0.08	≤ 0.015	2 / -;5	≤ 5·10-6	≤ 5	free	≤ 1300
Suprasil® 2 Grade B	0	1/1*0.08	≤ 0.015	2 / -;5	≤ 10·10-6	≤ 5	free	≤ 1300
Suprasil® CG	0	1/1*0.08	≤ 0.015	acc. MIL	≤ 30·10-6	≤ 20	free	≤ 1300
Suprasil® 1 ArF / KrF (3D)	0	1/1*0.08	≤ 0.015	2 / -;5	≤ 5·10-6	≤ 5	free	≤ 1300
Suprasil® 2 ArF / KrF	0	1/1*0.08	≤ 0.015	2 / -;5	≤ 5·10-6	≤ 5	free	≤ 1300
Spectrosil® 2000	0	1/1*0.08	≤ 0.015	2 / -;5	≤ 10·10-6 [8]	≤ 5	free	≤ 1300
Infrasil® 301 (3D)	0	1/1*0.16	≤ 0.03	2 / -;5	≤ 5·10-6	≤ 5	blue-violet	≤ 8 [6]
Infrasil® 302	0..1	1/1*0.35	≤ 0.1	2 / -;5	≤ 6·10-6	≤ 5	blue-violet	≤ 8 [6]
HOQ® 310	2...3	1/1*0.63 ≤ 6 kg 1/2*1.0 > 6 kg	0.5	n. sp.	n. sp.	≤ 10	blue-violet	ca. 30

Synthetic Fused Silica (dark blue) Natural Quartz (light blue) n. sp. = not specified (3D) = 3D material, optically isotropic

Refractive index
at 20°C and 1 bar
The given values are interpolated from measured values. More accurate data available upon request.

In contrast to other optical glasses, quartz glass shows very little difference in refractive index from melt to melt.
*without Suprasil® 3001, 3002, 300

Wavelenght nm		Suprasil-family	Suprasil® 3301/3302	Infrasil / HOQ
	190	1,5657	-	-
ArF	193,4	1,5601	-	-
	200	1,5505	-	-
	202,54	-	-	1,5473
	220	1,5285	-	1,5287
	232,94	-	-	1,5183
	240	1,5133	-	1,5136
KrF	248,4	1,5083	-	-
	260	1,5024	-	1,5026
4 x Nd:YAG	266	1,4997	-	1,4999
	274,87	1,4961	-	1,4963
	280	1,4942	-	1,4944
	300	1,4878	-	1,4880
XeCl	308	1,4856	-	1,4858
	320	1,4827	-	1,4829
HeCd	325	1,4816	-	1,4818
N2	337	1,4792	-	1,4794
	340	1,4787	-	1,4788
	360	1,4753	-	1,4754
(ni)	365,48	1,4745	1,4748	1,4746
	380	1,4725	1,4728	1,4726
	400	1,4701	1,4704	1,4703
(nh)	404,65	1,4696	1,4699	1,4698
(ng)	435,83	1,4667	1,4670	1,4668
HeCd	441,6	1,4662	1,4665	1,4663
Kr	447,1	1,4658	1,4661	1,4659
(nF)	486,13	1,4631	1,4634	1,4632
Ar	488	1,4630	1,4633	1,4631
Ar	514,5	1,4616	1,4619	1,4617
2 x Nd:YAG	532	1,4607	1,4610	1,4608
(ne)	546,07	1,4601	1,4604	1,4602
(nd)	587,56	1,4585	1,4588	1,4586
HeNe	632,8	1,4570	1,4573	1,4571
(nc)	656,27	1,4564	1,4567	1,4565
Ruby	694,3	1,4554	1,4557	1,4555
Kr	752,5	1,4542	1,4545	1,4543
	800	1,4533	1,4536	1,4534
	850	1,4525	1,4528	1,4526
	900	1,4518	1,4520	1,4519
GaAs	905	1,4517	1,4520	1,4518
	1000	1,4504	1,4507	1,4505
Nd:YAG	1064	1,4496	1,4499	1,4497
HeNe	1153	1,4486	1,4489	1,4487
	1200	1,4481	1,4483	1,4482
Nd:YAG	1319	1,4467	1,4470	1,4468
	1400	1,4458	1,4461	1,4459
	1600	1,4434	1,4437	1,4435
	1800	1,4409	-	1,4410
	2000	1,4381	-	1,4382
	2200	1,4350	-	1,4352
	2400	1,4316	-	1,4318
	2600	1,4279	-	1,4280
	2800	1,4238	-	1,4239
	3000	1,4193	-	1,4194
	3200	1,4143	-	1,4144
	3400	1,4088	-	1,4090