SPIRE Filters subsystem specification

Issue 1.0

Distribution List :

RAL	K.King			
	B.M.Swinyard			
ATC	C.Cunningham			
QMW	M.J.Griffin			
	P.A.R.Ade			
	C.V.Haynes			
	C.E.Tucker			

Queen **M**ary & **W**estfield College, Astrophysics Laboratory, Mile End Road, London E1 4NS
Tel. +44 (20) 7415 3757 Fax. +44 (20) 8980 0986

Update

Date	Indice	Remarks
03 April 2000		Creation of the document
14 July 2000		Issue 1.0

Host system	Windows NT 4.0
Word Processor	Microsoft Word 2000
File	G:\Projects\First\Spire\Management\Documents\Sub_sys_Spec_docs\Spire Filters subsystem specification.doc

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1. Scope of the document

This document defines the optical filtering scheme for the SPIRE instrument. It is applicable to the CQM, the PFM and the FS. It concentrates solely on the filters, beam splitters and dichroics needed for the photometer and spectrometer. The following topics are covered by this document:

- The general design philosophy
- The scientific requirements for the filtering
- The filtering specifications for the photometer and spectrometer
- The manufacturing procedures and QC/QA for filter production
- Risk analysis and testing procedures

The issue of filter mounting and integration is covered by document AD2, and work breakdown and scheduling is covered by document AD3

2. Documents

2.1. Applicable documents

	Title	Author	Reference	Date
AD1	Instrument Requirements Document	B.M.Swinyard	SPIRE-RAL-PRJ-000034 Issue 0.21	30 Nov. 1999
AD2	Interface Control Document – Structure/Filters	P.Hargrave, B.Winter	SPIRE/ICD/1.1/1.2.1 Issue 1.0	13 June 2000
AD3	SPIRE instrument – Filters subsystem development plan	P.Hargrave	TBC	May 2000

2.2. Glossary

AD	Applicable Document	MGSE	Mechanical Ground Support Equipment
CDR	Critical Design Review	NA	Not Applicable
CoG	Center of Gravity	OGSE	Optical Ground Support Equipment
CQM	Cryogenic Qualification Model	PFM	ProtoFlight Model

3. Subsystem description

3.1. Design philosophy

The first filter in the chain, situated on the 4-K box, should reflect back to the sky as much unwanted high frequency radiation as possible. Filters on lower temperature shields should then reject radiation from higher temperature boxes and shields.
Strategic placement of filters will enable us to:

- Define the spectral passbands.
- Minimise the thermal loading on the ^{3}He fridge, 2-K, and 4-K stages by rejecting short wavelength thermal energy.
- Minimise stray light getting to the detectors.
- Maximise the in-band spectral transmission.

3.2. Filter design – vacuum gap filters – to be completed

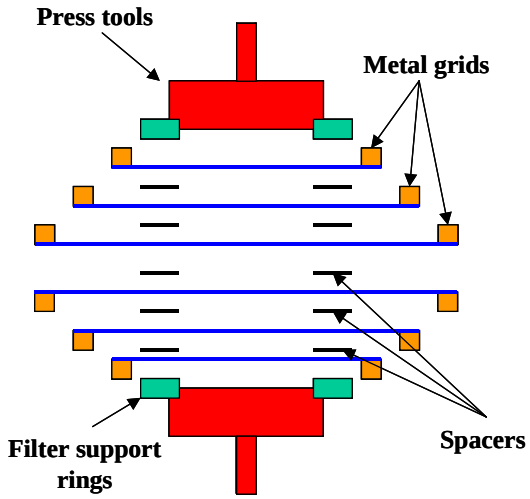

Figure 1 Schematic showing filter construction method

3.3. Filter design – dielectric gap filters – to be completed

3.4. Photometer filtering scheme

Table 1 List of photometer filters and dichroics

Specifications of photometer filters and dichroics						
Component ID	**Temp (K)**	**Location**	**Type**	**Edges (cm^{-1})**	**Minimum clear aperture (mm)**	**Comments**
CFIL1	4	On 4-K box. Exact location TBD	Edge filter	10% 105 50% 100 90% 95	TBD. Depends on location.	
CFIL2	4	TBD	Edge filter	10% 84 50% 80 90% 76	70 x 150	
PFIL3	2	Pupil between POFR2 and POFR3	Edge filter	10% 74 50% 70 90% 66	45 dia. (Pupil is 41 x 44 inc. 20% oversize)	
PDIC1	2	After POFR3	Low Pass Dichroic	10% 40 50% 37 90% 34	90 dia. TBC	Transmits long λ
PDIC2	2	After PDIC1	Low Pass Dichroic	10% 27 50% 25 90% 23	90 dia. TBC	Transmits long λ
PFIL4S	0.3	At SW array	Low pass edge High pass edge	53 38	40 dia. (Field is 19 x 38)	
PFIL4M	0.3	At MW array	Low pass edge High pass edge	36 25.7	40 dia.	
PFIL4L	0.3	At LW array	Low pass edge High pass edge	24 17 (if necessary)	40 dia.	
PFIL5S	0.3	At SW array	Edge filter	10% 70 50% 66 90% 62	40 dia.	
PFIL5M	0.3	At MW array	Edge filter	10% 46 50% 43 90% 40	40 dia.	
PFIL5L	0.3	At LW array	Edge filter	10% 27 50% 26 90% 25	40 dia.	

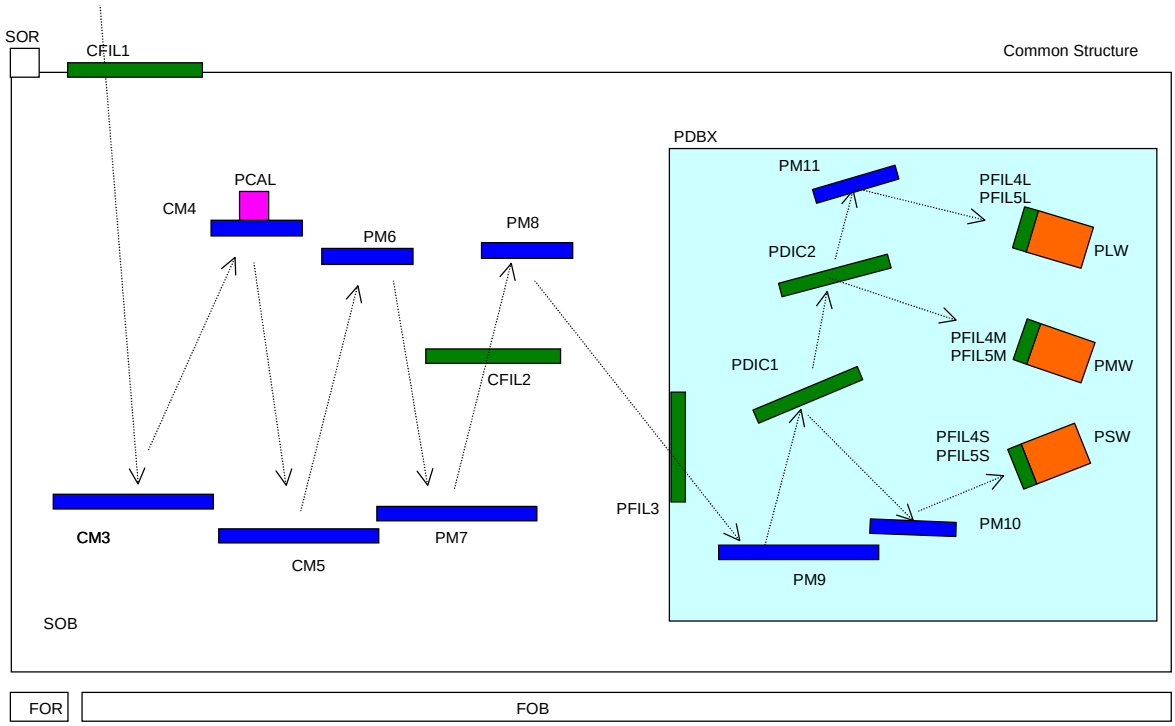

Figure 2 Photometer optics and filter locations

3.5. Spectrometer filtering scheme

Table 2 List of spectrometer filters and beam dividers

Specifications of FTS filters and beam dividers						
Component ID	**Temp (K)**	**Location**	**Type**	**Edges (cm^{-1})**	**Clear aperture (mm)**	**Comments**
CFIL1	4	On entrance to 11-K box	Edge filter	10% 105 50% 100 90% 95	70 x 150 (Beam fooTprint on CIPM is 54 x 132)	Shared with photometer
CFIL2	4	Above M3	Edge filter	10% 84 50% 80 90% 76	70 x 150	Shared with photometer
SBS1	4	After SIRM	Beam divider	15 to 60 >90% 4RT	36 dia.	
SBS2	4	After SDCM-A or -B	Beam divider	15 to 60 >90% 4RT	36 dia	
SFIL3S SFIL3L	2	After SCAM-A or SCAM-B	Edge filter	10% 74 50% 70 90% 66	40 dia.	
SFIL4S	0.3	At SW array	Low pass edge High pass edge	50 33	15	
SFIL4L	0.3	At LW array	Low pass edge High pass edge	33 None ?	15	
SFIL5S	0.3	At SW array	Edge	10% 70 50% 66 90% 62	15	
SFIL5L	0.3	At LW array	Edge	10% 46 50% 43 90% 40	15	

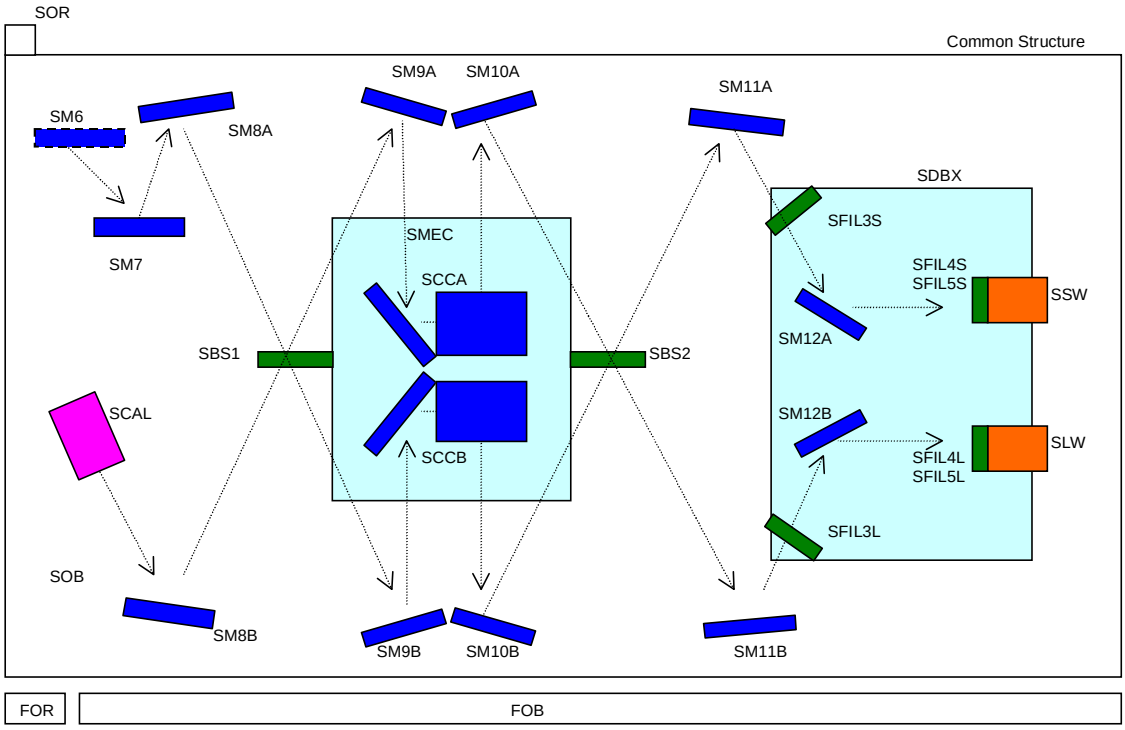

Figure 3 Spectrometer optics and filtering scheme

4. Specification of filter components

4.1. Common filters

4.1.1.CFIL1

Type	Hot Pressed
Dimensions	TBD
Interface	Clamp ring
Mass	TBD
Spectral characteristics	LPE 100cm^{-1}
Comments	Location and dimensions of this filter will be specified once the structure CAD model has been integrated with the optical beams.

4.1.2.CFIL2

Type	Hot pressed
Dimensions	TBD
Interface	Clamp ring
Mass	TBD
Spectral characteristics	LPE 80cm^{-1}
Comments	Location and dimensions of this filter will be specified once the structure CAD model has been integrated with the optical beams.

4.2. Photometer filters

4.2.1.PFIL3

Type	Hot pressed
Dimensions	54mm diameter. 1mm(TBC) thick.
Interface	Clamp ring
Mass	TBD
Spectral characteristics	LPE 70cm^{-1}
Comments	Located at cold stop on 2-K box.

4.2.2.PDIC1

Type	Hot pressed on ring.
Dimensions	Ring dimensions - 95mm o/d, 80mm i/d, 11mm thick
Interface	Ring mounted. Need three-point mount.
Mass	TBD
Spectral characteristics	Low pass dichroic. Transmits below 37cm^{-1}, reflects above 37cm^{-1}.
Comments	This component must be ring mounted to keep it flat. This component is of a non-standard ring size. QMW will re-tool as necessary.

4.2.3.PDIC2

Type	Hot pressed on ring.
Dimensions	Ring dimensions - 85mm o/d, 72mm i/d, 11mm thick
Interface	Ring mounted. Need three-point mount.
Mass	TBD
Spectral characteristics	Low pass dichroic. Transmits below 25cm^{-1}, reflects above 25cm^{-1}.
Comments	This component must be ring mounted to keep it flat. This component is also of a non-standard ring size. However, it may be possible to use a QMW polarizer ring (90mm o/d, 75mm i/d).

4.2.4.PFIL4S

Type	Hot pressed
Dimensions	TBD
Interface	Clamp ring
Mass	TBD
Spectral characteristics	LPE 53cm^{-1}, HPE 38cm^{-1}
Comments	Located at SW array. It may be possible to dispense with the high pass edge, depending on the performance of the feedhorn waveguides.

4.2.5.PFIL4M

Type	Hot pressed
Dimensions	TBD
Interface	Clamp ring
Mass	TBD
Spectral characteristics	LPE 36cm^{-1}, HPE 25.7cm^{-1}
Comments	Located at MW array. It may be possible to dispense with the high pass edge, depending on the performance of the feedhorn waveguides.

4.2.6.PFIL4L

Type	Hot pressed
Dimensions	TBD
Interface	Clamp ring
Mass	TBD
Spectral characteristics	LPE 24cm^{-1}, HPE 17cm^{-1}
Comments	Located at LW array. It may be possible to dispense with the high pass edge, depending on the performance of the feedhorn waveguides.

4.2.7.PFIL5S

Type	Hot pressed
Dimensions	TBD
Interface	Clamp ring
Mass	TBD
Spectral characteristics	LPE 66cm^{-1}
Comments	Located at SW array.

4.2.8.PFIL5M

Type	Hot pressed
Dimensions	TBD
Interface	Clamp ring
Mass	TBD
Spectral characteristics	LPE 43cm^{-1}
Comments	Located at MW array.

4.2.9.PFIL5L

Type	Hot pressed
Dimensions	TBD
Interface	Clamp ring
Mass	TBD
Spectral characteristics	LPE 26cm^{-1}
Comments	Located at LW array.

4.3. Spectrometer filters

4.3.1.SBS1

Type	TBD on ring.
Dimensions	Ring dimensions - 46mm o/d, 38mm i/d, TBDmm thick
Interface	Ring mounted. Need three-point mount.
Mass	TBD
Spectral characteristics	>90% 4RT from 15cm^{-1} to 60cm^{-1}
Comments	Non-standard ring size. QMW will re-tool as necessary.

4.3.2.SBS2

Type	TBD on ring.
Dimensions	Ring dimensions - 46mm o/d, 38mm i/d, TBDmm thick
Interface	Ring mounted. Need three-point mount.
Mass	TBD
Spectral characteristics	>90% 4RT from 15cm^{-1} to 60cm^{-1}
Comments	Non-standard ring size. QMW will re-tool as necessary.

4.3.3.SFIL3A

Type	Hot pressed
Dimensions	43mm diameter (TBC).
Interface	Clamp ring
Mass	TBD
Spectral characteristics	LPE 70cm^{-1}
Comments	Located at entrance to 2-K box. The dimensions of this filter are likely to change. The present structure allows for a 1.5mm lip to clamp this filter. This is not enough.

4.3.4.SFIL3B

Type	Hot pressed
Dimensions	43mm diameter (TBC).
Interface	Clamp ring
Mass	TBD
Spectral characteristics	LPE 70cm^{-1}
Comments	Located at entrance to 2-K box. The dimensions of this filter are likely to change. The present structure allows for a 1.5mm lip to clamp this filter. This is not enough.

4.3.5.SFIL4S

Type	Hot pressed
Dimensions	TBD
Interface	Clamp ring
Mass	TBD
Spectral characteristics	LPE 50cm^{-1}, HPE 33cm^{-1}
Comments	Located at SW array.

4.3.6.SFIL4L

Type	Hot pressed
Dimensions	TBD
Interface	Clamp ring
Mass	TBD
Spectral characteristics	LPE 33cm^{-1}

Comments	Located at LW array.

4.3.7. SFIL5S

Type	Hot pressed
Dimensions	TBD
Interface	Clamp ring
Mass	TBD
Spectral characteristics	LPE 66cm^{-1}
Comments	Located at SW array.

4.3.8. SFIL5L

Type	Hot pressed
Dimensions	TBD
Interface	Clamp ring
Mass	TBD
Spectral characteristics	LPE 43cm^{-1}
Comments	Located at LW array.

5. Requirements

5.1. Performance requirements

Table 3 Scientific and performance requirements specified in [AD1]

Requirement		*Implementation*
IRD-PHOT-R01	Nominal passband 250 mm, 350 mm and 500 mm (TBC) $\lambda/\Delta\lambda = 3$	For each photometer channel, the passband will be defined by the use of low pass filters, band splitting dichroics and band-defining filters
IRD-SPEC-R01	Wavelength range Band A = 200-300mm, 33-50cm^{-1} (TBC) Band B = 300-670mm, 15-33cm^{-1} (TBC)	The spectrometer wavelength bands shall be defined by the use of low pass and high pass edge filters.
IRD-OPTP-05	Overall optical efficiency: Greater than 0.27	A pessimistic estimate of combined filter stack throughput, including all filter losses (scattering, diffraction etc.), is around 0.4
IRD-OPTP-R07	Out of band radiation: Requirement TBD until telescope optical properties defined	Out of band rejection estimates: -10^{-3} for 40 cm^{-1} to 200 cm^{-1} -10^{-6} for 200 cm^{-1} to 1000 cm^{-1} -10^{-9} for 1000 cm^{-1} to 100000 cm^{-1} Achieved by a combination of blockers with edges chosen to block harmonic leaks. Note: detectors, optics and telescope all enhance cut-off; for filters only, the above rejection estimates change to 10^{-3}, 10^{-5} and 10^{-8} respectively.

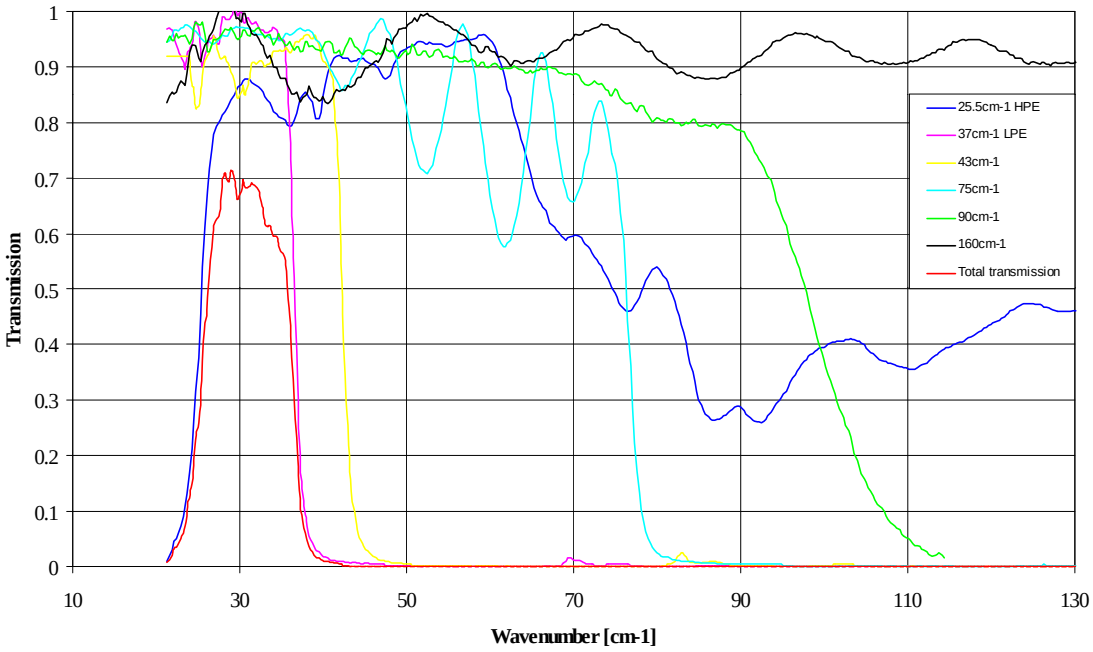

Figure 4 Example showing the definition of a 350 micron photometer channel using real filters developed at QMW. The passband ($\lambda/\Delta\lambda$) in this case is 3.

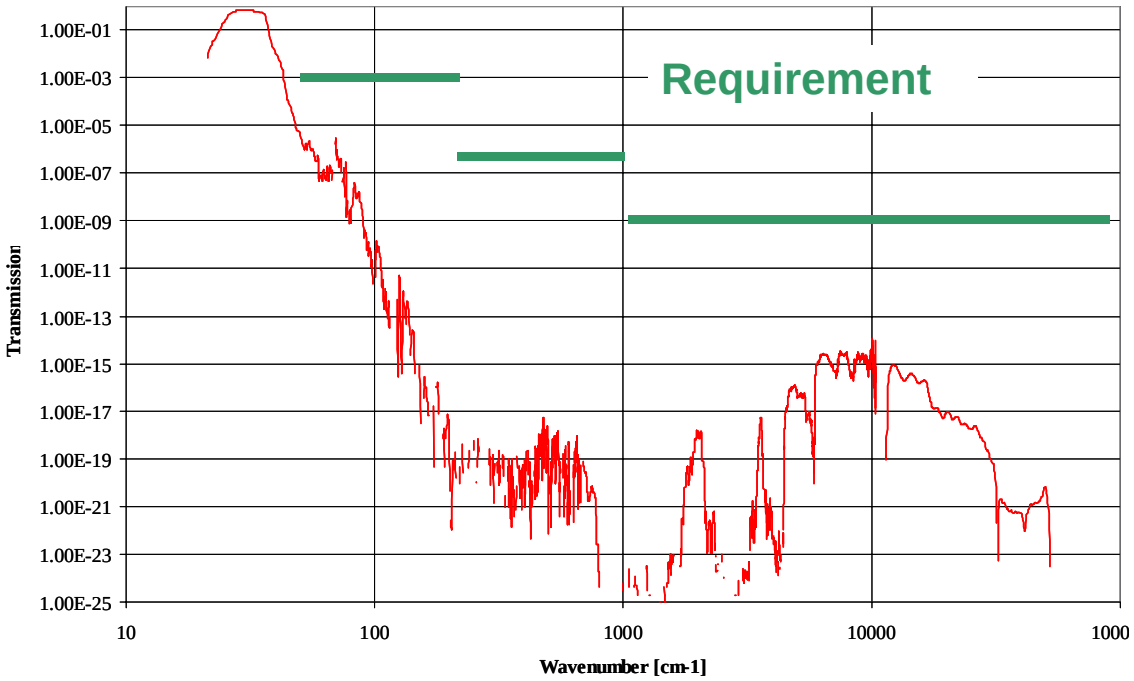

Figure 5 Blocking of out-of-band radiation out to 10^5 cm^{-1} for the filter combination shown in figure 4.

5.2. Technical requirements – to be completed

These requirements are design dependent.

Typical list:
- Axis reference system
- Alignment constraint
- Field view
- Dimensions
- Center of gravity, mass, inertia
- Stiffness

5.3. Operational requirements – to be completed

5.3.1. Operational Safety

Typical list:
- Availability
- Reliability
- Maintenance
- Security

5.3.2. Lifetime

Durations of
- Storage
- Life once integrated
- Life when operational

#	Parameter	Value	IRD	Note
OL1	Ground Storage lifetime	1 year	TBD	A guess
OL2	Integrated lifetime	3 years	TBD	About
OL3	Ground operational lifetime	4 years	TBD	Including all acceptance testing
OL4	On orbit operational lifetime	>4.25 years	TBD	Operating during 1/6 of the mission duration (4.25 years)

5.4. Interface requirements

This will be completed once the structure and optics design is finalised.

List of all the interface constraints between the subsystem and the other subsystems in relation with it.
Typical list:
- Mechanical
- Thermal
- Optics
- Test equipment

This list must be compliant with the interface document if it exists. When an interface document exists, it must be in the list of the Applicable Documents.

5.5. Design and manufacture requirements

5.5.1. Design requirements

This will be completed once the structure and optics design is finalised.

5.5.2. Design rules

General rules (nomalisation, standards) and specific rules applicable for the subsystem design

5.5.3. Manufacture requirements

This will be completed once the structure and optics design is finalised.

Requirements related to the accessibility, the integration/disintegration and ability to test the subsystem.

5.6. Logistics – to be completed

5.6.1. Packaging

Hot pressed filters will be sealed in poly-bags in a clean room environment.
Vacuum gap components will be packaged …..

5.6.2. Transport and handling

The subsystem will be transported to and from RAL, MSSL and QMW.
The containers will have to guarantee that…..

5.6.3. Storage

5.7. Environment – to be completed

5.7.1. Natural environment

This is the description of the natural environment of the subsystem during its life.

5.7.2. Operating environment

This is the description of the environment imposed by the location of the subsystem in SPIRE and in FIRST.
Typical list :

- Mechanical environement : vibration levels, shocks, microvibrations, static loads, acoustic loads, etc...
- Thermal environment : Solar fluxes, inetrface temperature levels, etc...
- EMC environment

5.8. Verification requirements – to be completed

Description of the verification means to be used to demonstrate that the subsystem is compliant with all the specifications listed in this document.

Typical list :

- Mathematical modelling
- Qualification tests
- Acceptance tests
- Life tests