SPIRE Mirrors Specification

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Update

Date	Indice	Remarks
5 June 2000	1	Creation of the document
12 Oct 2000	2	Updated mirror dimensions. Spec P5 added.
28 Nov 2000	3	Corrected illustration of CM3 (p. 9)
18 Dec 2000	4	Remodified CM3 dimension. Spec P6 added (RoC)
21 Feb 2001	5	Fig. p5 replaced by CM3. Sec. 3.3: no. of sets. Added notes in table 1. Corrected baseline version numbers
12 June 2001	6	Clarification of dimensions and decenters in Table 1.
12 July 2001	7	Mirror masses update
20 July 2001	8	Coordinate axes changed to SPIRE standard. Table 2 added showing spigot and dowl co-ordinates. Shape of SM7 corrected. Clarification of toric surface generation.
17 Sept. 2001	9	Corrected PM11 and SM11 decenter and SM6 toricity and ellipticity. PM8 diameter increased. As-built dimensions added. Improved nomenclature.

Table of contents

1. Scope of the document

This specification defines the requirements applied to the performances, the design and the qualification of the SPIRE mirrors. It is applicable to the PFM and the FS.

SPIRE (Spectral and Photometric Imaging REceiver) is one of the three instruments which will equip the Far Infrared Space Telescope (FIRST), an ESA mission planned to be launched in 2007. It will provide astronomical images in the 200-670 µm band.

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	Structure/Optics Interface		SPIRE 1.1/1.2	
AD3	SMEC / Optics Interface		SPIRE 1.2/1.5.2	

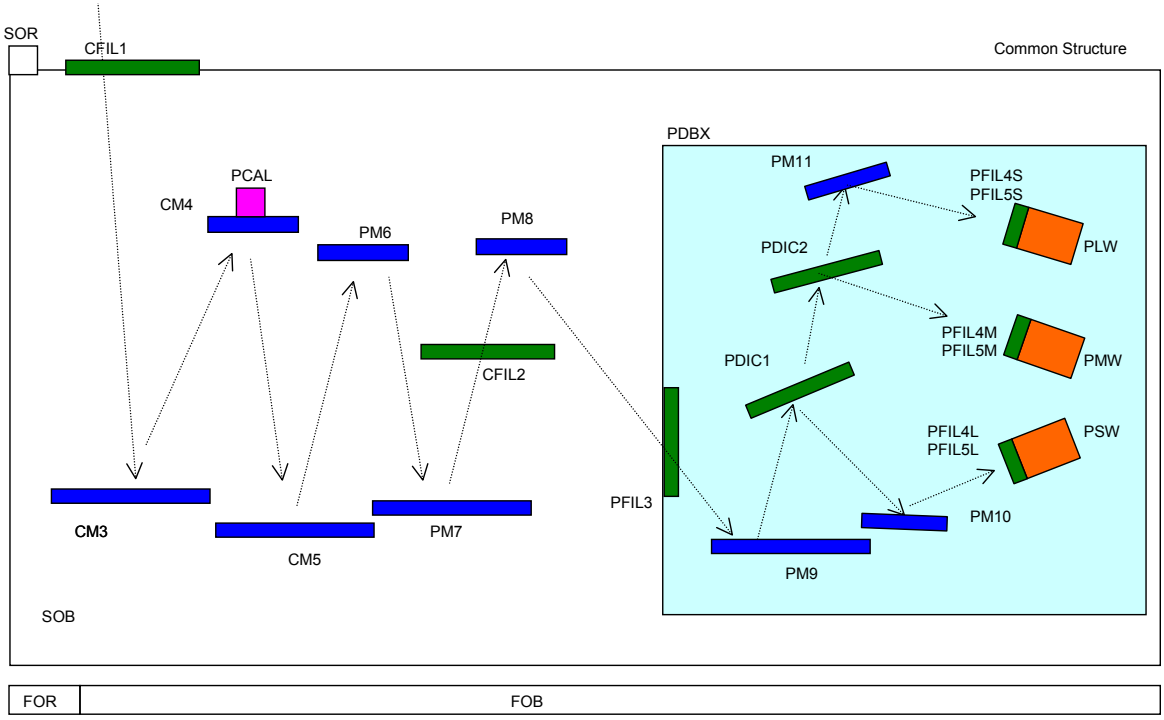
2.2. Glossary

AD	Applicable Document		
BSM	Beam Steering Mirror	LAM	Laboratoire d'Astrophysique de Marseille
BSMm	BSM cryogenic mechanism		
CEA	Commissariat à l'Energie Atomique	MGSE	Mechanical Ground Support Equipment
CDR	Critical Design Review	MM	Mechanical Model
CNES	Centre National des Etudes Spatiales	MSSL	Mullard Space Science Laboratory
CoG	Center of Gravity	NA	Not Applicable
CQM	Cryogenic Qualification Model	OGSE	Optical Ground Support Equipment
DDR	Detailed Design Review	PDR	Preliminary Design Review
		PFM	Prototype Flight Model
DM	Development Model	RAL	Rutherford Appleton Laboratory
		RD	Reference Document
		SMEC	Spectrometer mirror MEChanism
		SMECm	SMEC cryogenic mechanism
		SMECp	SMEC cold preamplifier
		SPIRE	Spectral and Photometric Imaging REceiver
FIRST	Far InfraRed Submillimeter Telescope	TBC	To Be Confirmed
FPU	Focal Plane Unit	TBD	To Be Defined
FS	Flight Spare model	TBU	To Be Updated
FTS	Fourier Transform Spectrometer	TBW	To Be Written
GSFC	Goddard Space and Flight Center	WE	Warm Electronics

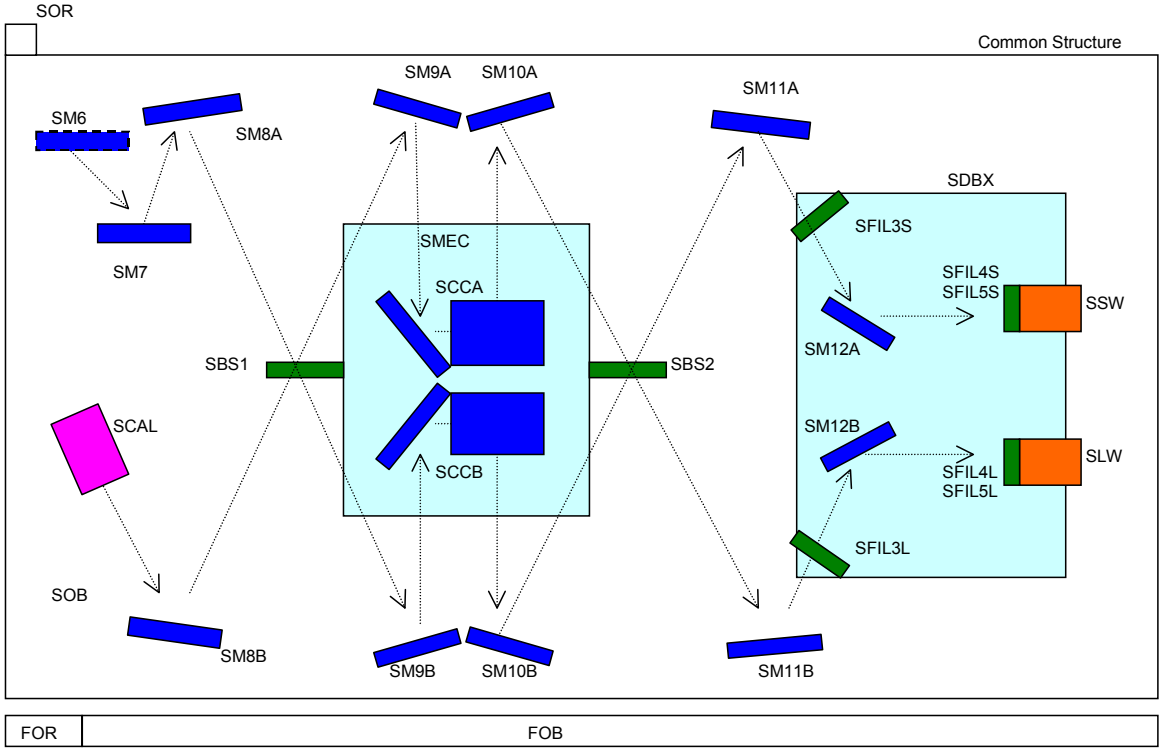
3. The mirrors

3.1. Instrument description

Figure 1 shows a schematic overview of the SPIRE instrument. It consists of two channels, Photometer (upper) and Spectrometer (lower), located one on either side of a central panel. Mirrors CM3, CM4 and CM5 are common. Mirrors PM6 and SM6 are field mirrors picking off a part of the beam for each channel.



Photometer channel.



Spectrometer channel.

Figure 1. Schematic layout and nomenclature for the SPIRE instrument.

3.2. Mirrors description

The basic design of the mirrors is the same as the one used for ISO-LWS.
The mirrors are made in Aluminium 6061.
They all have a standard interface with the structure, i.e. an M8 screw and a pin.
Each mirror is machined in a single block of aluminium (diamond cutting). The screw part of the attachment exerts pressure only on the shoulder part of the mirror, avoiding deformation of the optical surface.
The mount of each mirror is located on the optical bench by means of a pin.
This pin ensures that in case of dismounting of the mirror it will be mounted again in the same position.
During integration of the mirrors in the SPIRE structure, the mirrors are mounted on brackets which are provided by MSSL.
The figure below gives a drawing of the CM3 mirror, which is the more complex.

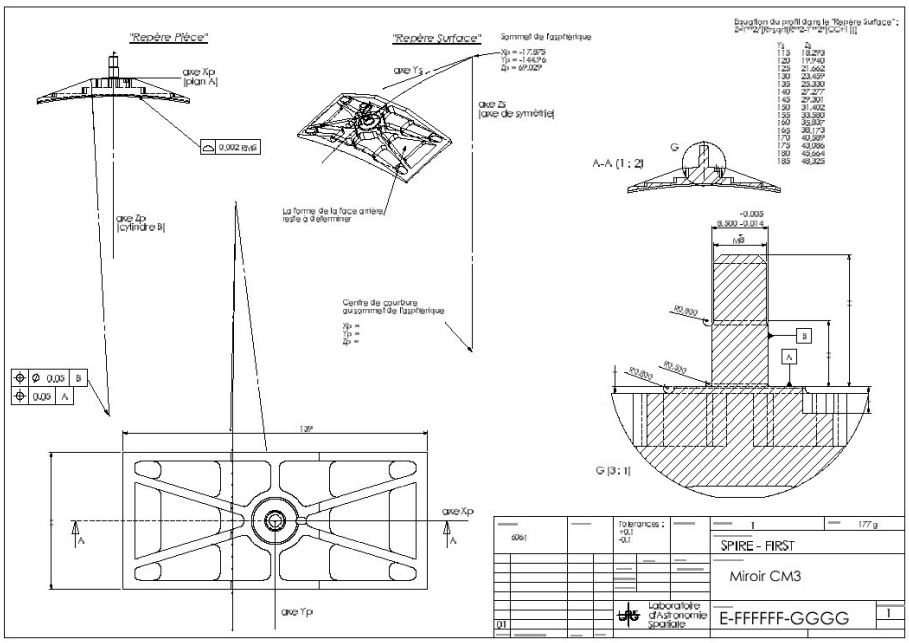


Figure 2.

The interface between the corner cube mirrors and the SMEC mechanism is TBD.

3.3. Mission profile

Here are the successive phases of the subsystem life from the end of manufacturing to the end of life.
These are for information only. Discrepancies with actual AIV and operation plan are allowed.
Durations are TBC.

Operation	Where	Duration	Note
Bakeout	LAM	1 week	
Control	LAM	4 weeks	
Warm Vibrations	LAM	1 week	On the CM5 mirror only
Thermal cycles	LAM	4 weeks	
Control	LAM	4 weeks	
Transport	From LAM to RAL	2 days	
Integration in the SPIRE Structure	RAL	TBD	
Bakeout	RAL	1 week	
Warm vibrations	RAL	1 week	

Transport	From RAL to ?	TBD	
Cold vibrations	?	3+ weeks	
Transport	From ? to RAL	TBD	
Thermal cycles	RAL	TBD	
Calibrations	RAL	TBD	
Transport	From RAL to ESA	TBD	
Satellite tests	ESA	TBD	
Storage	ESA	2 years (TBC)	
Launch	Kourou	TBD	
Beginning of operation	Orbit	TBD	
Operations	Orbit	4.25 years	
End of operations	Orbit	TBD	

3.4. Product tree

Each mirror is made of three parts : the mirror, a dowell pin and a nut.
The corner cubes are not yet defined.

Two complete sets of mirrors are required.

4. Requirements

4.1. Functional requirements

4.1.1. Performance requirements

The overall instrument performance requirements are listed in [AD1] and have been translated into the following requirements for the mirrors.

#	Parameter	Value	IRD	Note
P1	Infrared relflectivity	>0.99		
P2	Infrared emissivity	<0.01		
P3	Visible reflectivity	>0.8 (TBC)		For vis. alignment purpose
P4	Surface roughness	< 10nm RMS		For vis. alignment purpose
P5	Surface shape	< 1 µm RMS (TBC)		Corresponds to 2 µm on the reflected wave, i.e., λ/100 at 200µm
P6	Radius of curvature	$\Delta R/R < 10^{-3}$		For non-flat surfaces
P7				
P8				
P9				
P10				

4.1.2. Technical requirements

#	Parameter	Value	IRD	Note
Tm1	Axis definition	TBD		
Tm2	Alignment tolerances	0.5arcmin, 0.05mm		
Tm3	Dimensions			See table 1 below
Tm4	Center of gravity	TBD		
Tm5	Mass	2.5 kg including 20% margin		See table 1 below
Tm6	Inertia	TBD		

4.1.3. Mirror parameters

All the data given in Tables 1 and 2 are generated from the optical design model. Current baseline designs are BOLPHT155 (photometer) and BOLSP501G (spectrometer). **The dimensions given are valid at operating conditions (4K).** A scaling factor of 1.00415 (TBC) allows calculating room temperature values. No factor must be applied to the conic constant, CC, which is dimensionless.

The mirrors are defined with respect to a co-ordinate system local to each mirror whose x-axis is perpendicular to the optical surface at the summit of the surface (not necessarily coinciding with the centre of the mirror).

Table 1 gives required surface shape and minimum mirror aperture dimensions. When different, as build dimensions are given in **bold** face. Notes:

Positive radius of curvature signifies **concave** mirror. For **toric** mirrors, Rz is the radius in the x-z plane and Ry is the radius about which the x-z curve is rotated to generate the toric surface.

Dimensions of the mirrors are given for the **projection** of the mirror aperture onto the local y-z plane. The differences with respect to actual mirror dimensions are particularly important for CM3. The following dimensions are given:

Rectangular mirrors (rect):	ay and az are sides along y and z axes, respectively
Elliptical mirrors (ellipt):	ay and az are diameters along y and z axes, respectively
Circular mirrors (circle):	dia is diameter

Decentering data are also projected onto the local y-z plane. One identifies four points in this plane, see Figure 3a:

The **surface summit**, origin of the local co-ordinate system (0,0)
The projection of the **spigot intersection point** between mirror surface and spigot axis (ys,zs)
The **centre** of the projected mirror aperture (yc,yz)

Mirror thickness at the spigot is 15 mm (TBC) at room temp (TBC) for CM3, CM5, PM7, PM9. All the other mirrors have centre thickness 7 mm (TBC) at room temp (TBC).

Calculated masses are TBC and exclude margin.

CM4 and CC faces are not part of the main mirror manufacturing contract.

Table 2 gives co-ordinates of spigot and dowl positions in the local coordinate system for each mirror as illustrated in Figure 3 b. Table 2 is copied from the SurfDef sheet of the SPIREconfig31 document.

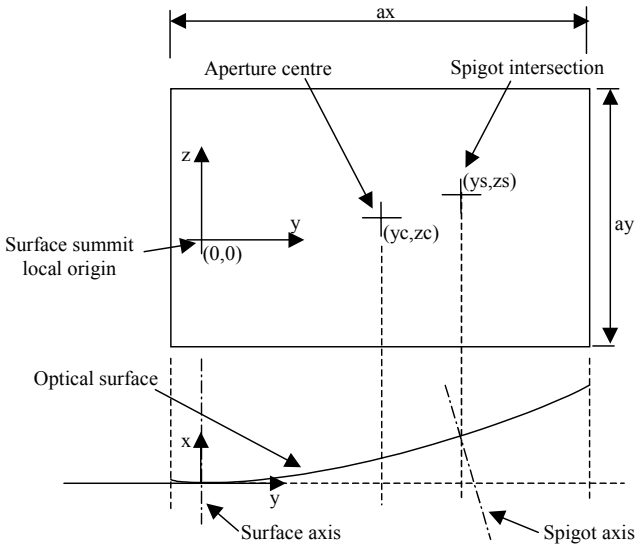


Figure 3 a. Illustration of aperture dimensions and decentering usid in Table 1.

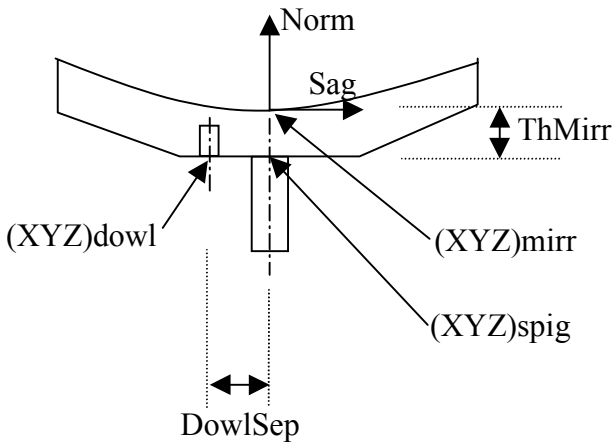


Figure 3 b. Illustration of terms used in Table 2.

Table 1 : Mirror parameters

Subass'y	Mirror	Type	R or Rz (mm)	CC or Ry (mm)	Shape and size ay x az or dia	Spigot intersection ys, zs	Aperture centre yc, zc	Nb. of parts per model	Mass (kg) Excl. margins
Fore optics	CM3	Off-axis asphere	365.963	-0.5095	Rect 139x62	-19.5, 145 See fig. 4.	-19.5, 145	1	0.250
	CM4 (BSM)	*Flat*			*Ellipt. 30x32* ***(Ø 32.5)***			*1*	*0.021*
	CM5	Toric	294.638	278.418	Rect 161x85	19.5, -1.5	19.5, -1.5	1	0.362
Photometer	PM6 (Pick-off)	Toric	-307.49	-359.42	Rect 46x27			1	0.023
	PM7	Sphere	330.70		Rect 118x101		0, -1.0	1	0.254
	PM8	Sphere	-286.651		Circle Ø 64			1	0.040
	PM9	Sphere	350.851		Circle Ø 112			1	0.201
	PM10 (Fold mirror)	Flat			Rect 78x40		2.5, 0	1	0.051
	PM11 (Fold mirror)	Flat			Rect 56x53		0, 2.75	1	0.048
Spectrometer	SM6 (Pick-off)	Toric	269.92	523.79	Ellipt 24x18 **(Ø 26)**		0, 1.0 **(0,0)**	1	0.013
	SM7 (Fold mirror)	Flat			Rect 57x40		4.0, 0	1	0.038
	SM8A, B (Relay in)	Toric	230.34	202.00	Circle Ø 60			2	0.108
	SM9A, B (Collimator)	Sphere	259.50		See fig. 5. Ø50			2	0.068
	CC face1	*Flat*			*See fig. 6 40x60*			*2*	*0.044*
	CC face2	*Flat*			*See fig. 6 28x68*			*2*	*0.070*
	CC face3	*Flat*			*See fig. 6 28x68*			*2*	*0.070*
	SM10A, B (Camera)	Sphere	260.00		See fig. 5 Ø60			2	0.092
	SM11A, B (Relay out)	Toric	196.99	169.84	Circle Ø 74 **(Ø 76)**		0, -1 **(0,0)**	2	0.160
	SM12A, B (Fold mirrors)	Flat			Ellipt 42x32		-1, 0	2	0.050
Total								**27**	**1.963**

Table 2: Spigot and dowl co-ordinates

Mirror thickness
Thick -14.9380073
Thin -6.97107006

Dowl separation
DowlSep 11.95040582

SystemPart	CompName	System	ThMirr	DowlDir	Flag	Xmirr	Ymirr	Zmirr	Xnorm	Ynorm	Znorm	Xspig	Yspig	Zspig	Xsag	Ysag	Zsag	Xdowl	Ydowl	Zdowl	Check	CompName
	Dummy	Phot			Ignore																	Dummy
Telescope	M1	Phot			Ignore																	M1
	M2	Phot			Ignore																	M2
Common optics	CFP	Phot			Hole																	CFP
	CM3	Phot	Thick	1	M3Cent	29.842009	-19.500476	145.000210	0.923152	0.051240	-0.381006	16.051964	-20.265898	150.691682	-0.052142	0.998608	0.007963	15.428851	-8.332128	150.786845	90	CM3
	CM4	Phot			Ignore																	CM4
	CM5	Phot	Thick	1	M5Cent	0.687534	19.499867	-1.499950	0.997531	-0.070038	0.005091	-14.213596	20.546097	-1.575997	0.069930	0.997372	0.018928	-13.377900	32.465101	-1.349798	90	CM5
Photometer optics	PM6	Phot		1	Vertex	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	-6.971070	0.000000	0.000000	0.000000	1.000000	0.000000	-6.971070	11.950406	0.000000	90	PM6
	PM7	Phot	Thick	1	Vertex	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	-14.938007	0.000000	0.000000	0.000000	1.000000	0.000000	-14.938007	11.950406	0.000000	90	PM7
	PM8	Phot		1	Vertex	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	-6.971070	0.000000	0.000000	0.000000	1.000000	0.000000	-6.971070	11.950406	0.000000	90	PM8
	PCS	Phot			Hole																	PCS
	PM9	Phot	Thick	1	Vertex	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	-14.938007	0.000000	0.000000	0.000000	1.000000	0.000000	-14.938007	11.950406	0.000000	90	PM9
Short wave	PDIC1	Phot			Ignore																	PDIC1
	PM10	Phot		-1	Vertex	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	-6.971070	0.000000	0.000000	0.000000	1.000000	0.000000	-6.971070	-11.950406	0.000000	90	PM10
	PSW	Phot			Det																	PSW
	PDIC1	Phot			Ignore																	PDIC1
Medium wave	PDIC2	Phot			Ignore																	PDIC2
	PMW	Phot			Det																	PMW
	PDIC2	Phot			Ignore																	PDIC2
Long wave	PM11	Phot		1	Vertex	0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	-6.971070	0.000000	0.000000	0.000000	1.000000	0.000000	-6.971070	11.950406	0.000000	90	PM11
	PLW	Phot			Det																	PLW
	CM5	SpecUp		1	Ignore																	CM5
Spectrometer optics	SM6	SpecUp		1		0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	-6.971070	0.000000	0.000000	0.000000	1.000000	0.000000	-6.971070	11.950406	0.000000	90	SM6
	SCS	SpecUp			Hole																	SCS
	SM7	SpecUp		-1		0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	-6.971070	0.000000	0.000000	0.000000	1.000000	0.000000	-6.971070	-11.950406	0.000000	90	SM7
	SM8A	SpecUp		-1		0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	-6.971070	0.000000	0.000000	0.000000	1.000000	0.000000	-6.971070	-11.950406	0.000000	90	SM8A
Upper arm	SBS1	SpecUp			Hole																	SBS1
	SM9A	SpecUp		-1		0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	-6.971070	0.000000	0.000000	0.000000	1.000000	0.000000	-6.971070	-11.950406	0.000000	90	SM9A
	SCCA1	SpecUp			Ignore																	SCCA1
	SCCA2	SpecUp			Ignore																	SCCA2
	SCCA3	SpecUp			Ignore																	SCCA3
	SM10A	SpecUp		-1		0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	-6.971070	0.000000	0.000000	0.000000	1.000000	0.000000	-6.971070	-11.950406	0.000000	90	SM10A
	SBS2	SpecUp			Hole																	SBS2
	SM11A	SpecUp		-1		0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	-6.971070	0.000000	0.000000	0.000000	1.000000	0.000000	-6.971070	-11.950406	0.000000	90	SM11A
	SM12A	SpecUp		-1		0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	-6.971070	0.000000	0.000000	0.000000	1.000000	0.000000	-6.971070	-11.950406	0.000000	90	SM12A
	SSW	SpecUp			Det																	SSW
	SM8A	SpecLo			Ignore																	SM8A
Lower arm	SBS1	SpecLo			Hole																	SBS1
	SM9B	SpecLo		-1		0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	-6.971070	0.000000	0.000000	0.000000	1.000000	0.000000	-6.971070	-11.950406	0.000000	90	SM9B
	SCCB1	SpecLo			Ignore																	SCCB1
	SCCB2	SpecLo			Ignore																	SCCB2
	SCCB3	SpecLo			Ignore																	SCCB3
	SM10B	SpecLo		-1		0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	-6.971070	0.000000	0.000000	0.000000	1.000000	0.000000	-6.971070	-11.950406	0.000000	90	SM10B
	SBS2	SpecLo			Hole																	SBS2
	SM11B	SpecLo		-1		0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	-6.971070	0.000000	0.000000	0.000000	1.000000	0.000000	-6.971070	-11.950406	0.000000	90	SM11B
	SM12B	SpecLo		-1		0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	-6.971070	0.000000	0.000000	0.000000	1.000000	0.000000	-6.971070	-11.950406	0.000000	90	SM12B
	SLW	SpecLo			Det																	SLW
Ref Arm	SM8B			-1		0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	-6.971070	0.000000	0.000000	0.000000	1.000000	0.000000	-6.971070	-11.950406	0.000000	90	SM8B
Axe						x	y	z	x	y	z	x	y	z	x	y	z	x	y	z		
Local						Norm	Sag	Tang	Norm	Sag	Tang	Norm	Sag	Tang	Norm	Sag	Tang	Norm	Sag	Tang		

Axis directions:

X	-Zsyno	Tow. tel	*Directions*
Y	Xsyno	Tow. Spectro	Tow. tel
Z	Ysyno	Tow. PAX	Tow. Spectro
			Tow. PAX

SPIRE	*SYNO*	*LOCAL*
X	-Zsyno	Norm
Y	Xsyno	Sag
Z	Ysyno	Tang

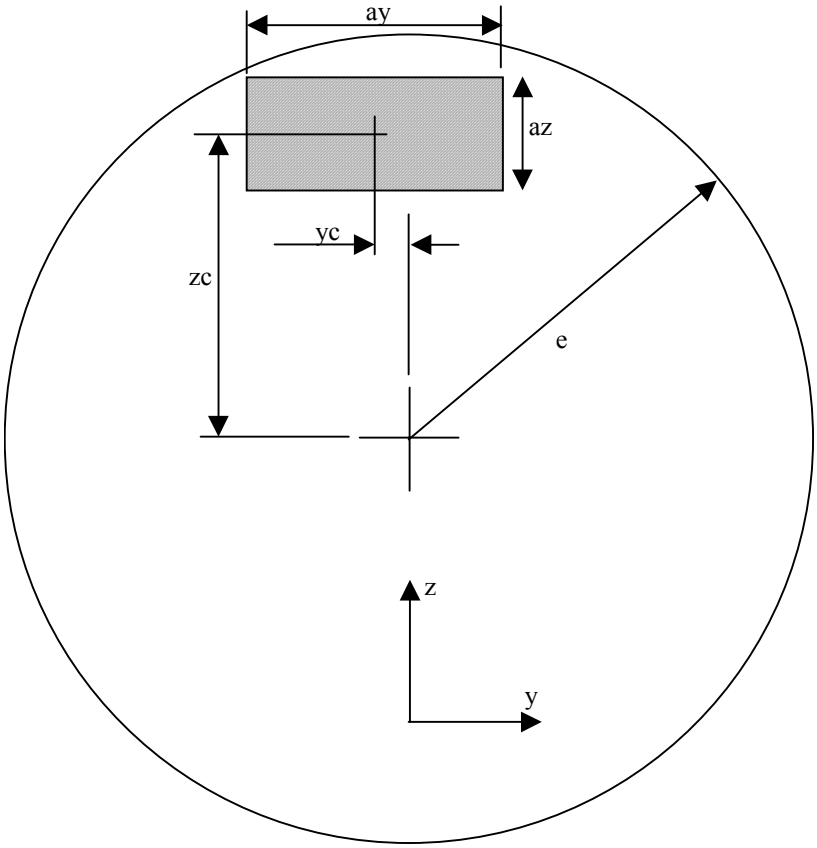


Figure 4. Mirror CM3, off-axis part of asphere. Values of ay, az, yc and zc are given in Table 1. The symmetric substrate radius is calculated by: $e = \sqrt{\left(ay/2 + |yc|\right)^2 + \left(az/2 + |zc|\right)^2}$. Its current value is 202 mm.

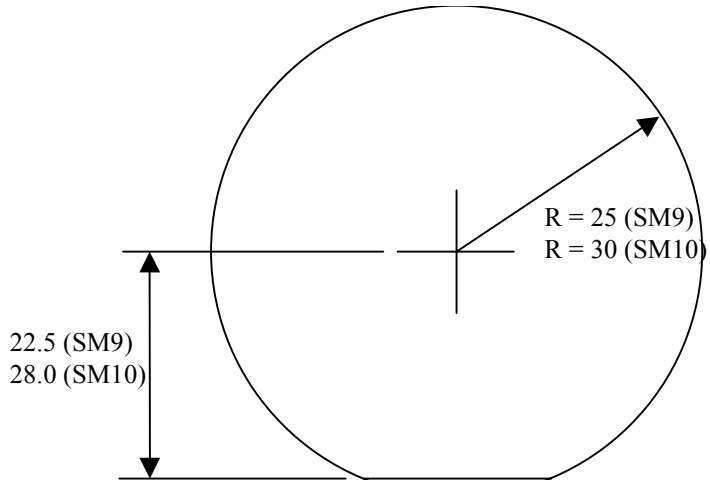


Figure 5. Mirrors SM9 and SM10. "Chopped-off" circular apertures.

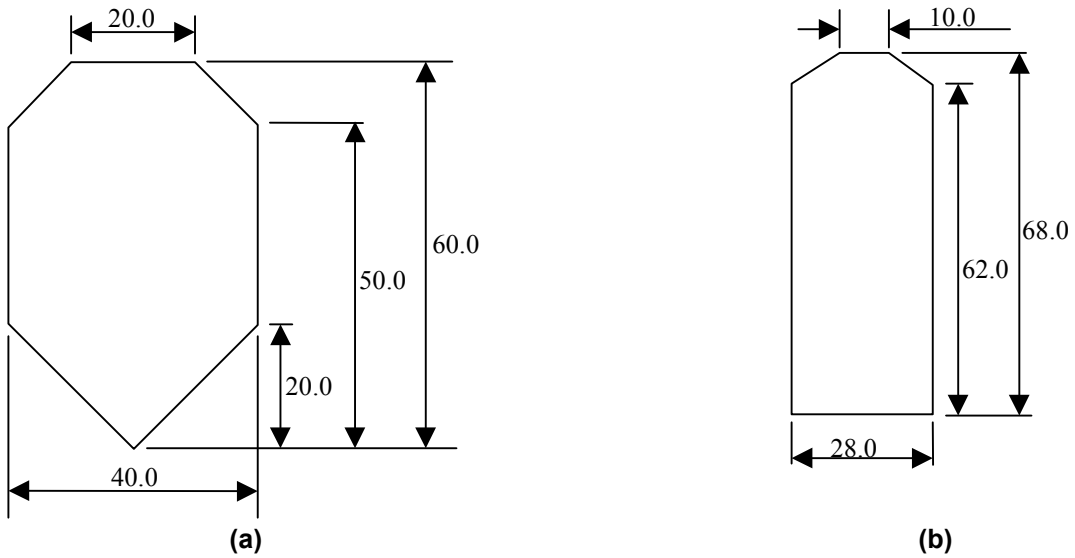


Figure 6. Corner cube faces. (a): face 1, (b): faces 2 and 3.

4.2. Operational requirements

4.2.1. Reliability

4.2.2. Lifetime

#	Parameter	Value	IRD	Note
OL1	Ground Storage lifetime	2 years		A guess
OL2	Ground Integrated lifetime	4 years		About
OL3	Ground operational lifetime	1.5 years		6 months for subsystem acceptance 6 months for SPIRE acceptance 6 months for FIRST acceptance Under 1g conditions
OL4	On orbit operational lifetime	4.25 years		

4.2.3. Operating modes

Non applicable

4.2.4. Telemetry

Non Applicable

4.2.5. Telecommands

Non Applicable

4.3. Interface requirements

The interfaces are defined in the relevant applicable documents.

Part	Interface	With	Document
SMECm	Mechanical	SPIRE Structure	SPIRE 1.1/1.5.2
	Thermal	SPIRE Structure	SPIRE 1.1.1/1.5.2
	Optics	SPIRE Optics	SPIRE 1.2 / 1.5.2
SMECp	Mechanical	SPIRE Structure	SPIRE 1.1/1.5.2
	Thermal	SPIRE Structure	SPIRE 1.1.1/1.5.2
SMECe	Mechanical	DRCU	SPIRE 1.5.2 / 2.2
	Thermal	DRCU	SPIRE 1.5.2 / 2.2
	Electronic	DRCU	SPIRE 1.5.2 / 2.2
	Electronic	MCU	TBW
MCU	Mechanical	DRCU	SPIRE 1.5.2 / 2.2
	Thermal	DRCU	SPIRE 1.5.2 / 2.2
	Electronics	DRCU	SPIRE 1.5.2 / 2.2

4.4. Design and manufacture requirements

4.4.1. Design requirements

TBD

4.4.2. Design rules

TBD

4.4.3. Manufacture requirements

These are requirements on accessibility, dismountability, testability and manufacturing processes.

- TBD fluids to be forbidden during manufacture to avoid pollution.
- TO BE COMPLETED

4.5. Logistic requirements

The subsystem wil be transported to and from RAL.
The containers will have to guarantee that:

- no shocks are greater than those defined for the launch.
- no pollution sneaks to the mirrors
- TO BE COMPLETED

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4.6. Environment requirements

These requirements describe the environement in which the mirrors will live.

4.6.1. Natural environement

This is the description of the natural environment around the mirrors.

#	Parameter	Value	Note
EN1	Vacuum	Less than 10-4 Pa	During tests, launch and in operation
EN2	Operating temperature	during system qualif and on orbit = 4K during subsystem qualification = 300K and 20K	
EN3	Storage and handling temperature Humidity Cleanliness	-20 to +30 °C Less than 45% Class TBD	Overall, on ground In clean room In clean room
EN4	Radiations	Less than 3.5 kRAD	On orbit

4.6.2. Operating environment

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

#	Parameter	Value	IRD	Note
ON1	Vibrations	TBD		At 4K
ON2	Shocks	TBD		At 4K
ON3	Microvibrations	TBD		NA
ON4	Acoustic	NA		Launched under vacuum

4.7. Verification requirements

TO BE COMPLETED