SUBJECT: **Straylight model update**

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KEYWORDS: **Straylight, background, baffles**

COMMENTS: This document updates data on the expected size of straylight backgrounds at critical points and from critical surfaces in the instrument, and summarises developments in the physical model of SPIRE impacting on straylight control in the instrument.

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Contents

1 SCOPE

This note summarises developments made to date to the SPIRE straylight model and results derived from it, using where possible references to work already published as project technical notes. These references are grouped together in section 2.

2 REFERENCE DOCUMENTS

ID	Project Reference	Date issued	Title/Subject
[RD1]	SPIRE/RAL/N0044	25/9/1998	Descriptions of CODEV and APART models of FIRST-SPIRE
[RD2]	SPIRE/RAL/N0101	29/4/1999	FIRST Payload Module/Focal Plane Unit Straylight Model : Final Report
[RD3]	SPIRE/RAL/NOT/000576	23/01/2001	CM4 hole size considerations and Stray-light control
[RD4]	SPIRE/RAL/NOT/000581	25/01/2001	Definition of a combined focal plane aperture for the SPIRE instruments
[RD5]	SPIRE/RAL/NOT/000586	06/02/2001	SPIRE instrument beam sections forwards of the focal plane aperture plate
[RD6]	SPIRE/RAL/NOT/000598	02/03/2001	Proposed shapes for Spectrometer baffle apertures at SBS1 and SBS2

3 INTRODUCTION

The SPIRE instrument CODEV and APART models have been described in [RD1]. That document described an earlier photometer design (PHOT126B) matched to an earlier telescope design. The APART model of SPIRE was subsequently incorporated into a full FIRST payload Module/Focal Plane Unit straylight model detailed in [RD2]. With the evolution of the telescope design and the designs for the SPIRE photometer and spectrometer, the APART model is in the process of being updated. However, some results from the APART analysis of this earlier model are still useful and are reproduced in section 5 below.

The latest instrument optical designs, identified as PH154B (photometer) and SP501E (spectrometer) have already been translated into CODEV form and are now being used to determine geometrical optical beam envelopes in all optical spaces from the detectors to space. These 3-D beam envelope structures are now routinely translated into IGES formatted files that can now be smoothly ported to the CAD platform on which the mechanical structure design is being developed. The optical beams can therefore be smoothly integrated with the structure, enabling conflicts to be easily spotted and resolved.

4 STRAYLIGHT CONCERNS

These divide roughly into two types. The first concerns straylight that directly contributes to the background signal at the detectors. The second concerns radiation that causes thermal loading of critical parts of the instrument assembly. Of continuing concern has been the estimation and control of the background that each detector in each instrument sees as a result of steering the instruments' fields of view using the mirror CM4.[1] It is now proposed that a field stop and thermal filter both be located at the telescope focal surface in the location shown in figure 1. The accurate definition of the aperture in this 'aperture plate' or 'field stop plate' is described in [RD4].

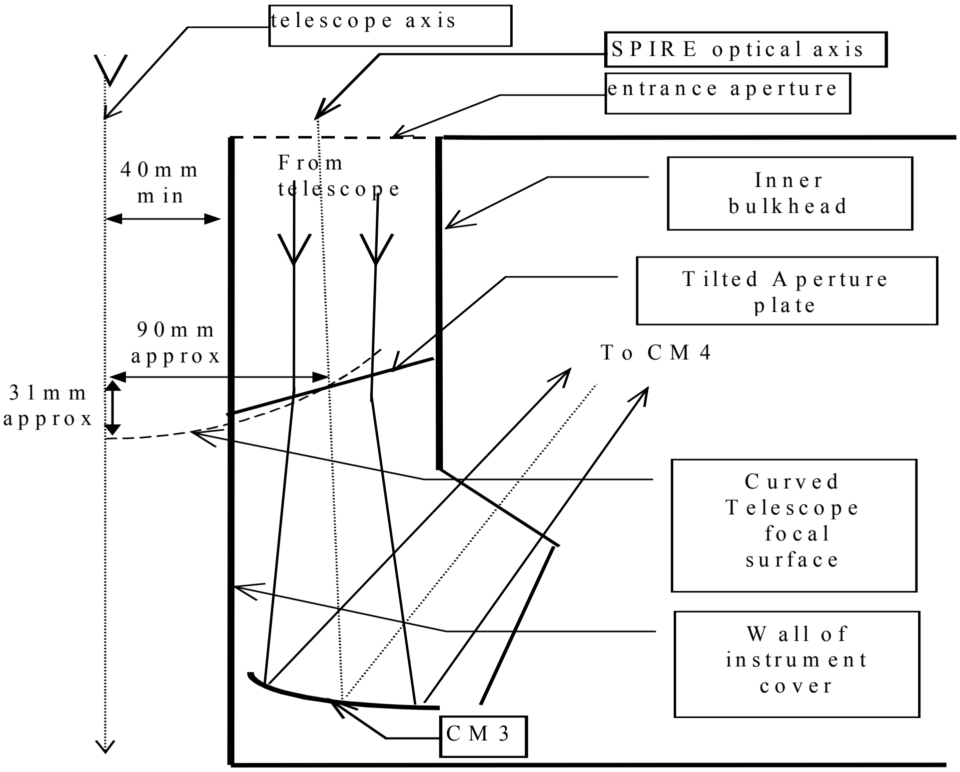

Figure 1 Schematic showing the proposed location for an instrument aperture plate

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[1] The latest system for identifying optical surfaces, proposed by Berend Winter, MSSL, is used here. The memo summarising the system is added as appendix A.

4.1 Thermal Loading at the tilted aperture plate

An estimate has been made, using the existing APART model of the telescope and cryostat, of the expected thermal load from the telescope and cryostat onto a surface co-incident with this aperture plate. The cryostat emission has been modelled as coming from 5 dummy surfaces, each given an effective emissivity to be expected of cavities having highly reflecting coatings in which multiple reflections play a great part. These dummy surfaces are shown in figure 2, which is taken from [RD2]. The surfaces are labelled with their APART identifying numbers.

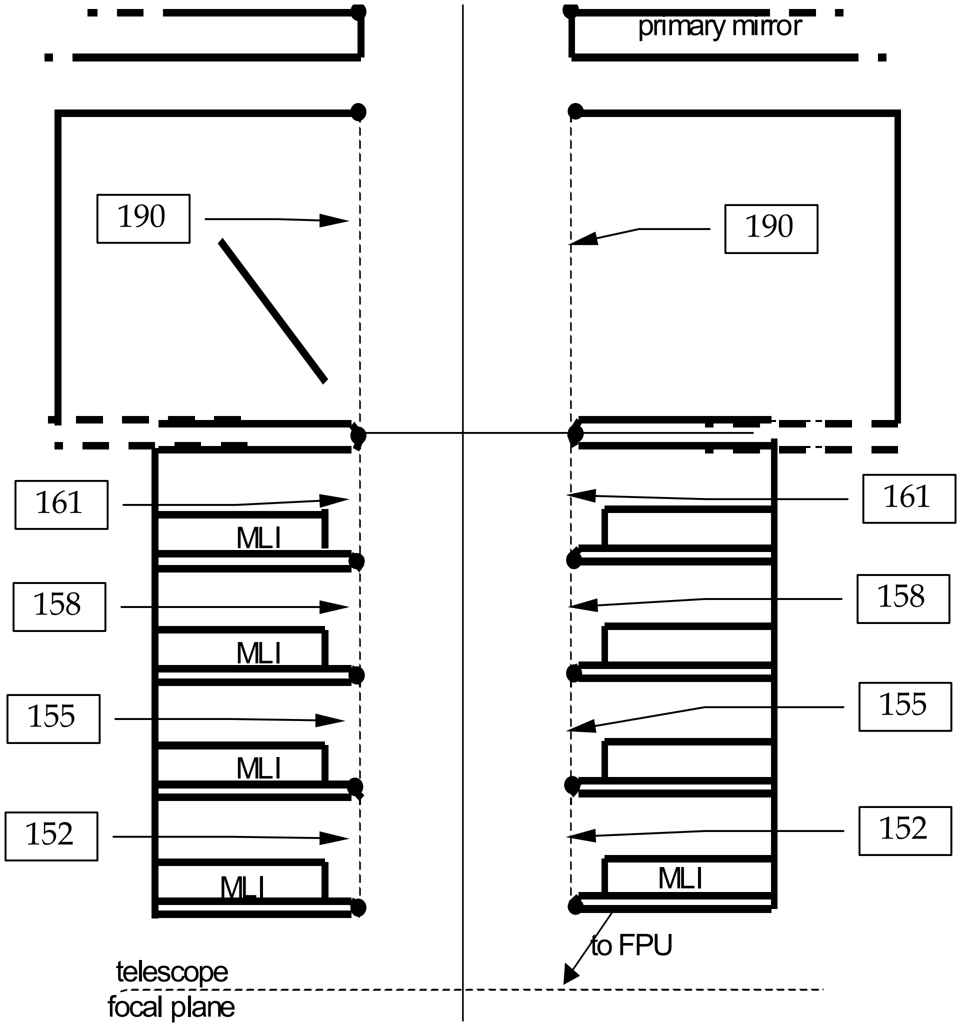


Figure 2 APART model of the cryostat showing the dummy cylindrical radiating surfaces

The rectangular surface located at the telescope focal surface was given dimensions 34 mm by 96 mm. This is quite close to the size required to clear the fields of view. The full-bandwidth thermal power reaching it from the telescope side is estimated to be approximately 2.3*10^-5 watt. This divides into about 66% coming from the cryostat (modelled as 5 emitting cylinders centred on the telescope axis, each cylinder having an effective emissivity of 0.29, 0.26, 0.27, 0.25, 0.15 depending on the cylinder length, and having temperatures 14K, 32K, 49K, 64K and 77 K, both sequences being in order of increasing height above the SPIRE instrument), and 33 % from 14 K internal walls surrounding the space between an aperture in the SPIRE cover and the field stop (see figure 1). As modelled, the radiation from the cryostat reaching the focal surface is restricted by a rectangular aperture in a SPIRE cover, but radiation from the inside surfaces of this cover, initially assumed to be at 14K, also contributes to the load at the rectangular field stop/ thermal filter. However, progress made in the thermal environment of the optical bench will allow the SPIRE structure to be cooled to 4K. This 33% contribution will therefore be reduced proportionally with the temperature reduction from 14K to 4K.

As the APART and thermal models of SPIRE are brought up to date, then the thermal loading at other important surfaces in the instruments will be estimated using APART.

4.2 APART estimates of SPIRE photometer background

The following data were used in order to make reasonably accurate photometer background estimations:

Table 1

Detector	Photometer	Spectrometer
Format	**1.91 x 3.82 cm rectangle**	**0.62 cm radius circle**
Typical total detector area	**7.3 sq.cm.**	**1.2 sq.cm**
Solid angle subtended on sky (Ω)	**2.7 x 10^-6 sr**	**4.49x10^-7**
Mean Footprint on Primary (A)	**173 cm radius=94024 sq.cm**	**173 cm radius=94024 sq.cm**
Throughput to whole detector area (AΩ)	**0.25 sq.cm-sr**	**0.042 sq.cm-sr**
Number of mirrors in optical path at 4K	**6**	
Number of mirrors in optical path at 2K	**2**	
Mirror emissivity ε	**0.01**	

Estimates subsequently made for the total power falling on a detector can be scaled to different detector areas.

It is assumed that we are interested in the total contribution from various sources that reach each detector within the three wavebands 200-300μ, 300-400μ, and 400-650μ. Principal black body radiation sources considered are

Table 2

Source	temperature	Emissivity assumed
Telescope primary and secondary mirrors	**74 K**	**0.01**
4K optics direct to detector	**4 K**	**0.01**
2K optics direct to detector	**2 K**	**0.01**

2K enclosure walls direct to detector	**2 K**	**1.0**

The radiation intensities at each temperature T in each waveband from black bodies having emissivity=1.0 are given below:

Table 3

	Blackbody intensity B(T,λ1,λ2), watt/cm^2/steradian, in waveband λ1->λ2		
T°K	**200-300μ**	**300-400μ**	**400-650μ**
74	**1.17*10^-6**	**3.27*10^-7**	**2.0*10^-7**
4	**9.94*10^-13**	**8.21*10^-12**	**7.58*10^-11**
2	**2.78*10^-18**	**4.81*10^-16**	**1.25*10^-13**

Table 4 summarises the results. The contributions from the primary and secondary mirrors are taken from APART analysis of the earlier SPIRE photometer model covered in [RD2]. Also taken from that document are the estimates (~6.0% of the total) for the contributions due to surfaces in the payload module that lie outside the SPIRE instrument. No allowance has been made for filter transmission losses or mirror reflection losses in the SPIRE optics.

The thermal radiation contributions from the optics in the 4K and 2K boxes are computed using equation 1:

$$E(T,\lambda 1,\lambda 2) = N_M * A * \Omega * \varepsilon_{optic} * B(T,\lambda 1,\lambda 2) \qquad \textbf{(1)}$$

where N_M = the number of optical surfaces. Values for A and Ω are taken from table 1, ε values from table 2 and B(T,λ1,λ2) from table 3.

The contribution from the 2K surround is somewhat over-estimated using

$$E(T,\lambda 1,\lambda 2)_{suround} = \pi * A_{\det ector} * \varepsilon_{surround} * B(T,\lambda 1,\lambda 2)$$

Table 4 summarises the results of the computations.

Table 4

	Signal in watts in-band		
Source	**200-300μ**	**300-400μ**	**400-650μ**
Telescope optics	**2.4*19^-9**	**6.8*10^-10**	**4.3*10^-10**
6% of Telescope signal	**1.44*10^-10**	**4.1*10^-11**	**2.58*10^-11**
2K surround	**6.37*10^-17**	**1.1*10^-14**	**2.87*10^-12**
2K optics	**1.4*10^-20**	**2.4*10^-18**	**6.25*10^-16**
4K optics	**1.49*10^-14**	**1.23*10^-13**	**1.14*10^-12**

Compared to the contributions expected from the optics, the 2K surround direct contribution only becomes significant for the longer waveband. Even then, it is still significantly smaller than the total of the contributions expected from surfaces outside the instrument reaching the detector along the natural optical path through the SPIRE photometer.

5 GEOMETRICAL OPTICAL BEAM ENVELOPES AND FOOTPRINTS

5.1 General

Geometrical optical beam footprints at critical surfaces and beam envelopes in critical spaces have now been recalculated, using the latest optical designs for the two instruments. For each instrument, the centre and 24 points evenly spaced around the perimeter of a detector are used as field points. A rectangular detector (sized to be nominally 8 x 4 arc minutes on the sky) is used for the photometer and a circular detector (sized to be nominally 1.3 arc minutes radius on the sky) is used for the spectrometer. Each instrument's footprint is therefore made up of 25 separate beams. The rays determining the footprints are traced from each detector outwards, passing through each instrument's aperture stop to space, so that the footprints represent regions of surfaces viewable from different points on the edge of a detector.

5.2 Effect of CM4 motions

The view that each detector has of surfaces from CM4 outwards to the telescope is complicated by the necessity to use CM4 to 'chop' the photometer view by up to +-2 arc minutes on the sky at 90 degrees to the fold plane and by up to +-30 arc seconds on the sky in the fold plane (the so-called 'jiggle' mode). Since the spectrometer optical path uses the same optical surfaces as the photometer from CM5 outwards, its detector's view will also be chopped and jiggled. The impact of these movements on the design of the aperture plate is detailed in [RD4]. The view that each instrument has to space through this aperture plate is described in detail in [RD5].

5.3 Straylight control using the hole in CM4

The design of the beam steering mirror (BSM) CM4 includes a 'central' hole inside which the tip of a fibre-optic (transmitting light from a source) is used as a test source to illuminate the detectors. The BSM is at a pupil image plane and so the telescope secondary mirror, M2, is re-imaged there. A study described in [RD3] shows how a hole in CM4 might also be used to control straylight that uses the central region of M2.

5.4 Spectrometer baffle proposals

The beam envelopes inside the spectrometer have been used size apertures required in straylight baffles located near to the beam splitters, as shown in figure 3. The details are given in [RD6]. The design of baffles inside the spectrometer is at an early stage, and it is probable that only one of the two baffles shown will be implemented. Additional baffles surrounding the beam from the calibration source, SCAL (see appendix A), will supplement the remaining baffle. The design of these extra baffles will proceed along the lines set out in [RD6].

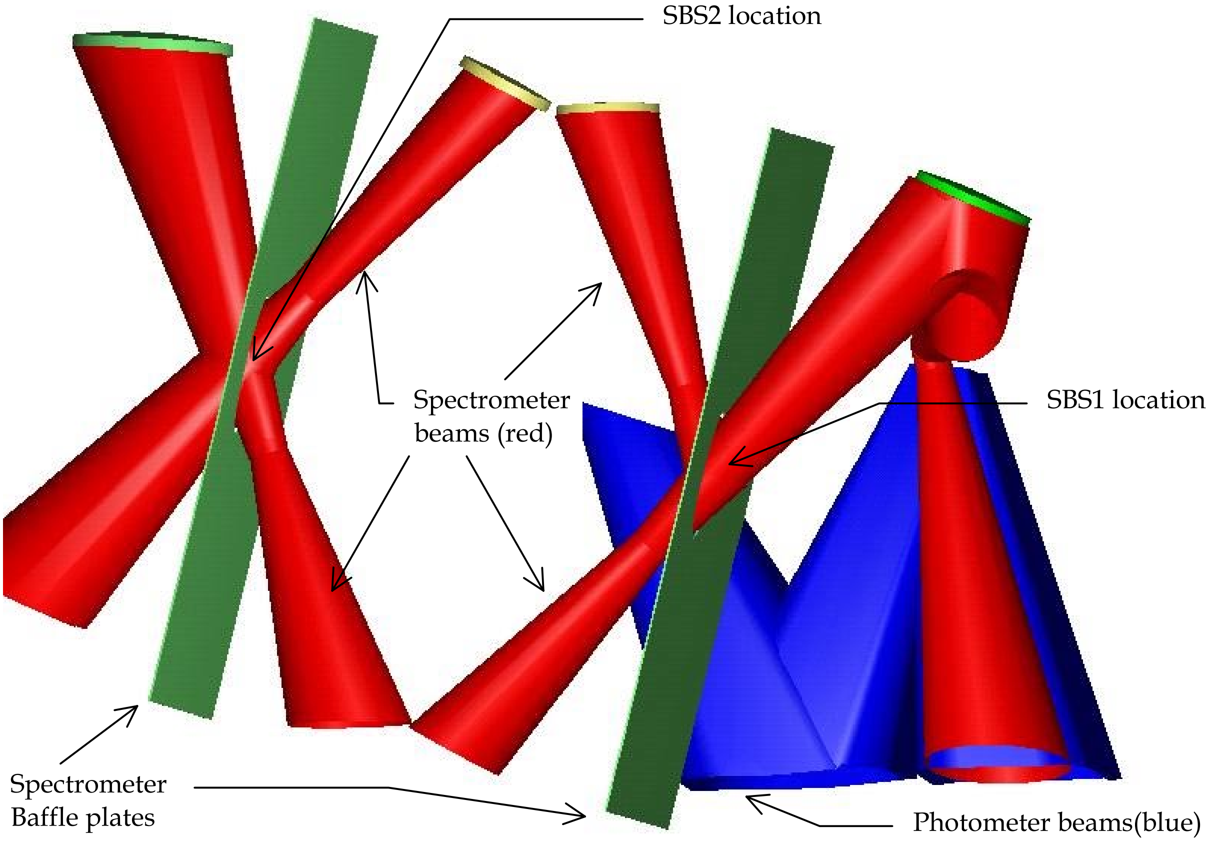
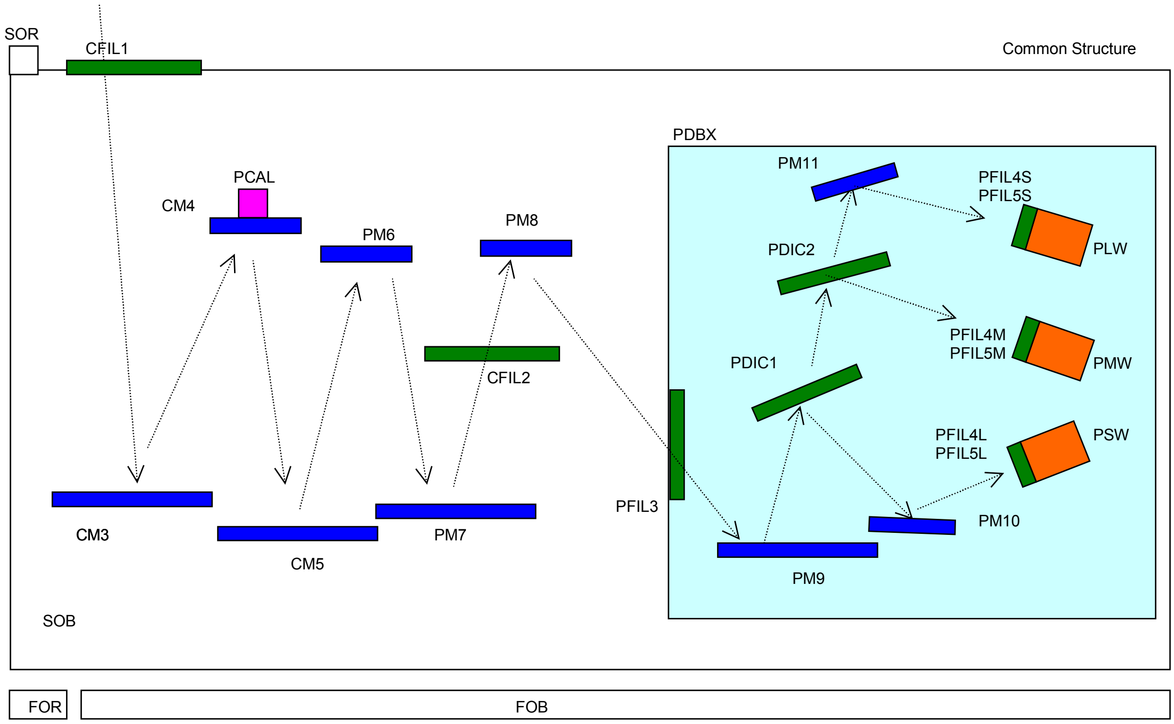


Figure 3 SPIRE Spectrometer beam envelopes showing proposed baffle plates

APPENDIX A : INSTRUMENT TOPOLOGY AND COMPONENT LABELS

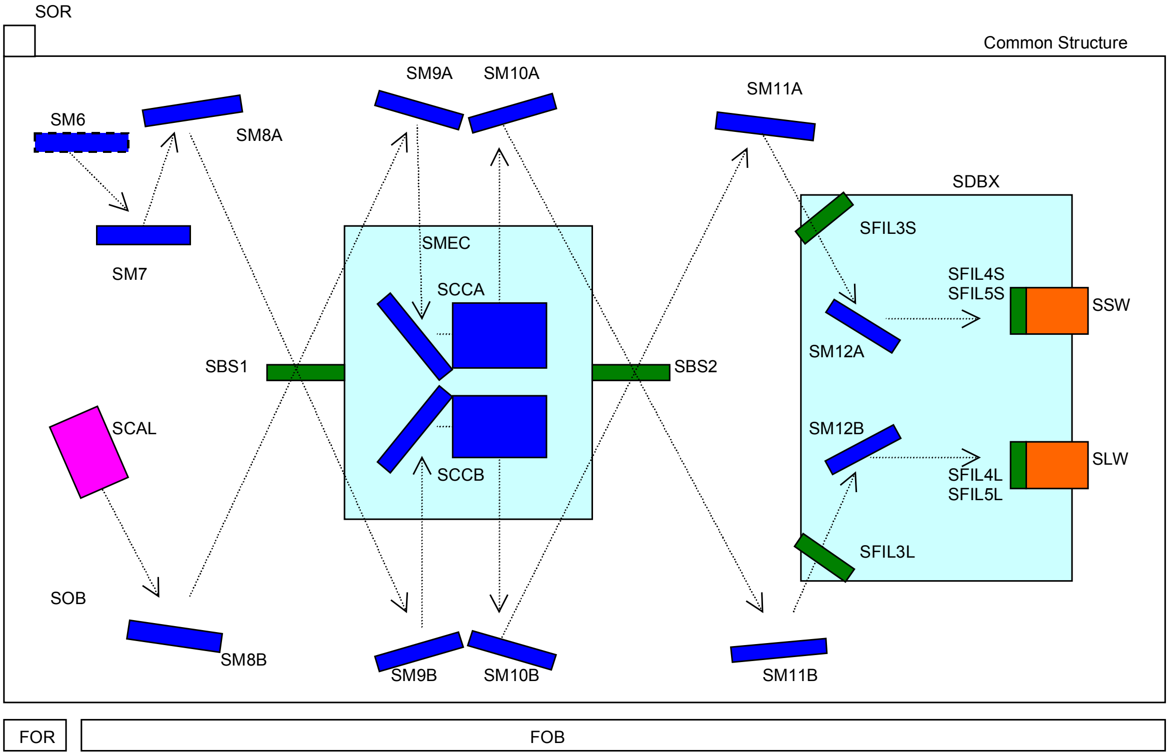
Photometer Topology



Component Labels

CFIL1	Common Filter 1
CFIL2	Common Filter 2
CM3-5	Common Mirror 3-5
FOB	First Optical Bench Panel
FOR	First Optical Reference
PCAL	Photometer CALibrationsource
PDBX	Photometer Detector BoX
PDIC1	Photometer DIChroic 1
PDIC2	Photometer DIChroic 2
PFIL3	Photometer FILter 3 (entrance PDBX)
PFIL4L/5L	Photometer FILter 4 and 5 at nose PLW
PFIL4M/5M	Photometer FILter 4 and 5 at nose PMW
PFIL4S/5S	Photometer FILter 4 and 5 at nose PSW
PLW	Photometer Long Wave detector
PM6-11	Photometer Mirror 6 to 11
PMW	Photometer Medium Wave detector
PSW	Photomter Short Wave detector
SOB	Spire Optical Bench Panel
SOR	Spire Optical Reference

Spectrometer Topology and Component Labels



Component Labels

FOB	First Optical Bench Panel
FOR	Firs Optical Reference
SBS1	Spectromter Beam Splitter 1
SBS2	Spectromter Beam Splitter 2
SCCA	Spectrometer Corner Cube +X
SCCB	Spectrometer Corner Cube –X
SCAL	Spectrometer CALibration source
SDBX	Spectrometer Detector BoX
SFIL3L	Spectrometer FILter 3 (long wave)
SFIL3S	Spectrometer FILter 3 (short wave)
SFIL4L/5L	Spectrometer FILter at nose SLW
SFIL4S/5S	Spectrometer FILter at nose SSW
SM6-7	Spectrometer Mirror6-7
SM8A-12A	Spectrometer Mirror 8-12 +X chain
SM8B-12B	Spectrometer Mirror 8-12 -X chain
SMEC	Spectrometer MEChanism
SOB	Spire Optical Bench Panel
SOR	Spire Optical Rerference