SPIRE spectrometer field lens description

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Update

Date	Indice	Remarks
30 Jan 2002	D	Creation of the document
19 March 2002	1	HDPE replaces LDPE. Distance to focus modified. Spot diagrams added
19 June 2002	2	Lenses turned round, bulge towards detectors

Reference documents

#	Title	Author(s)	Reference	Date
1	Herschel - SPIRE: Optical Error Budgets	K. Dohlen	LOOM.KD.SPIRE.2000.002-5	20 March 2002

Host system	Windows 95
Word Processor	Microsoft Word 97
File	C:\Utilisateurs\Kjetil\SPIRE\OptoMech\SpecOpt\SpectroLenses03.doc

1. Scope of the document

Description of field lenses added in front of the spectrometer detectors in order to render the detected beam telecentric. Baseline design is BOLSP509H.

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. Introduction

The nominal, zero OPD position of the exit pupil in the spectrometer is situated 112.57 mm in front of the geometrical focal plane. For a circular FOV of radius 1.3', corresponding to about 6.5mm on the detector, the chief ray angle of incidence is 3.3°. The detectors, however, have their line of sight parallel with the axis and a Gaussian edge taper reaching $1/e^2$ at the edges of a F/5 beam, corresponding to a solid angle whose angular radius is 5.7°. Observations at the field edge therefore suffers a great loss of throughput.

To ameliorate this situation it is decided to introduce field lenses in front of the detectors. These project the nominal zero OPD pupil to infinity, making the detected beam telecentric, hence better adapted to the horns. This is done without changing the global position of the detectors, nor of any other opto-mechanical component. The lenses are mounted at tip of the detector head together with filters.

Lenses will be made out of HDPE, a high-density form of polyethylene. For the SPIRE spectral range (~200microns->700microns), refractive index can be considered as constant over the spectral range. At T~293K: n(HDPE) ~ 1.54, at T~6K: n(HDPE) ~ 1.575. The latter is assumed in the 4K optical model. Abs. coef (imaginary part of the optical constant), can also be considered constant over the spectral range. It's value at 300K is K(HDPE) < 0.001 and may be expected to be closer to 0.0005 at 4K.

3. Lens description

Two identical, plano-convex lenses are used. They were originally oriented with the flat face towards the detectors as this was though necessary from an integration point of view. However, a 2mm thick spacer separates the filter/lens assembly from the detector nose, it is possible to mount the lens with the bulge towards the detector. This has several advantages:

- The distance of the powered surface from the focal plane is minimized, hence minimizing defocus and change in image scale.
- Reducing ghost images and risk of standing waves.

The lens material is HDPE, whose refractive index is assumed constant across the band, with n = 1.575 at 6K. The figure 1 [cf M. Ferlet, mail 10/12/2001] shows chromatic index variations for a similar material, LDPE. The variations from the asumed value have no significance.

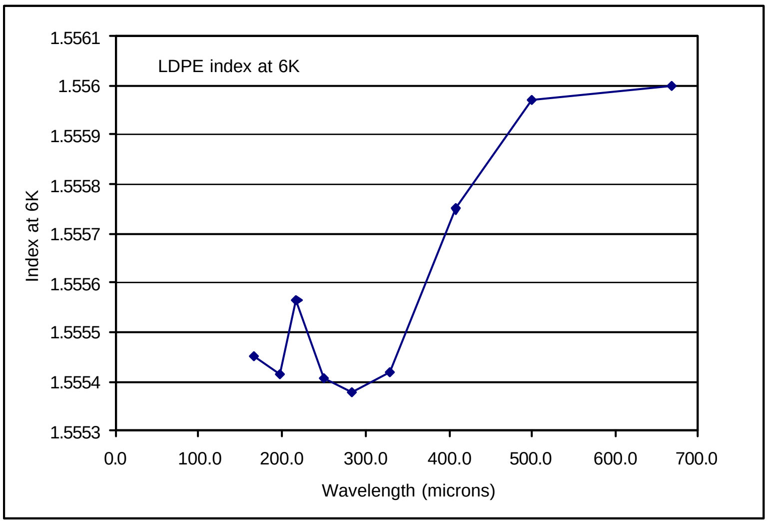


Figure 1. Index of refraction of LDPE at 6K. Although HDPE does not have exactly the same index, the chromatic variation is assumed to be similar.

Lens design parameters are:

Radius of curvature	50±1 mm
Edge thickness	1±0.5 mm
Material	HDPE, n(6K) = 1.575
Diameter	16±1 mm

All dimensions and tolerances can be reviewed if necessary. Point is that things are not at all sensitive.

Lens diameter assures 20% oversizing with respect to the individual beams, not to the entire beam bundle. If much increased diameter is required, may need to increase thickness.

4. Mechanical implementation

The lens is CNC machined into HDPE material and takes the form of a bulge on a 1mm thick plate. The plate is mounted together with the filter between two spacer rings, see Figure below. Dimensions are shown in Figure 2 and table 1.

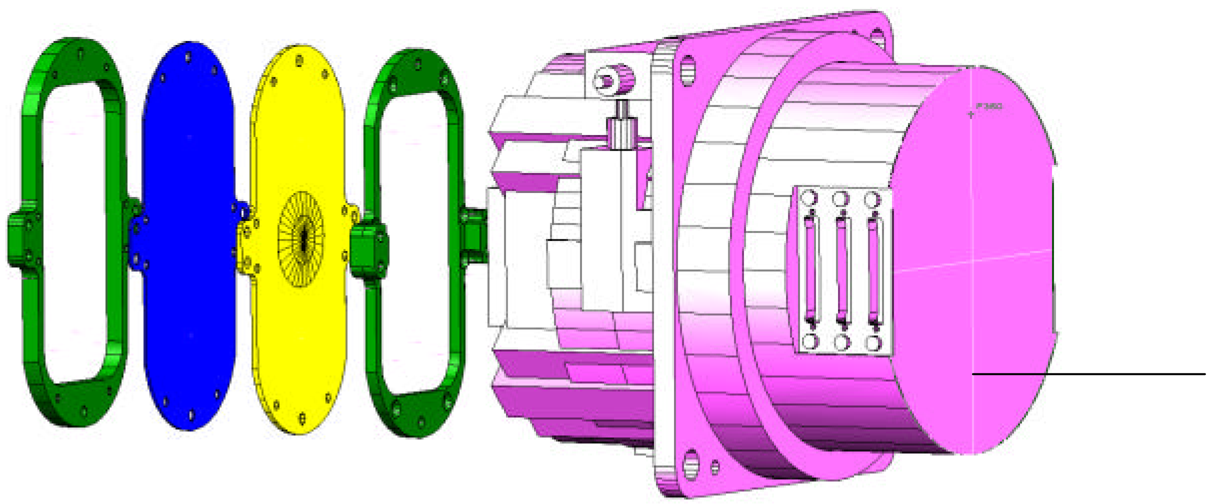


Figure 2. Exploded view of filter & lens assembly

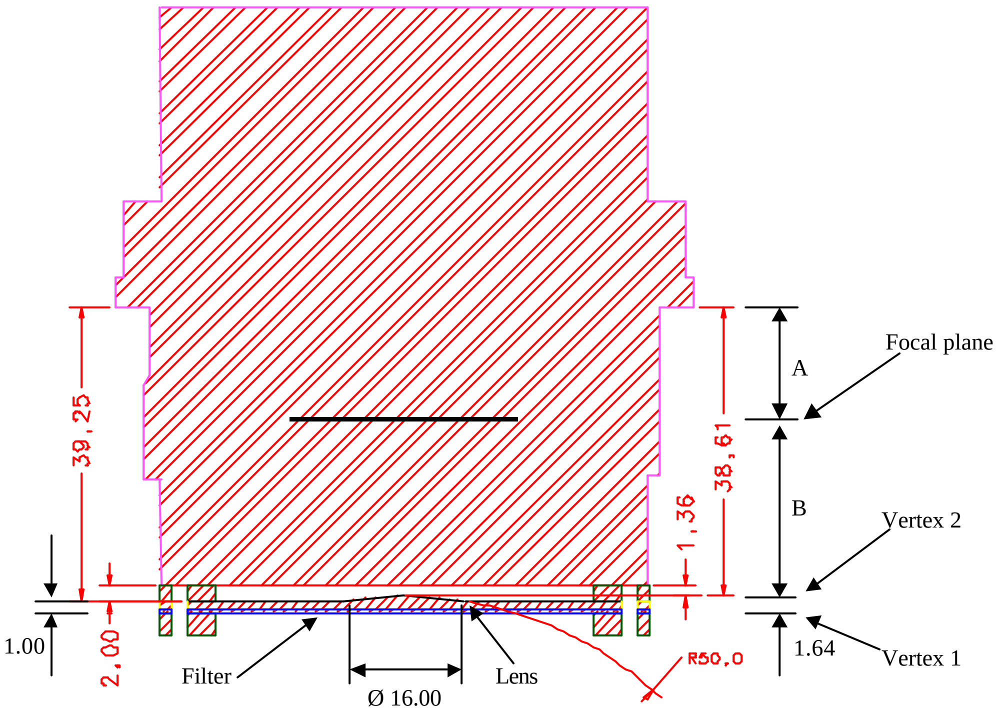


Figure 2 – Dimensions of filter – lens – detector assembly

Table 1. Position of lens vertex and focal plane wrt detector mounting flange

	SLW	SSW
A (cf JPL ICD 9 Nov 2001)	36.9	26.7
B = 38.61 - A	1.71	11.91

5. Optical quality

Since the lenses are located a non-zero distance from the focal plane, the image is shifted away from the original focal position, introducing defocus, as seen in Figure 3. For the short-wavelength lens (SFLA), where the distance to the focal plane is the greatest, the defocus increases the design wavefront error at the worst point in the FOV from 8.3 µm rms without lens to 9.5 µm rms with lens. This reduces the global budget Strehl ratio at that point from 0.89 without lens to 0.88 with lens (IRD = 0.9) [RD-1]. In the original configuration where the active lens surface was further away from the detector, the defocus was considerably larger, reducing the Strehl ratio to 0.85.

The lenses also change the image scale, as can be seen in Figure 3. The figure shows 8 point source images, all at a distance of 1.3’ from the optical axis. The surrounding circle has in each case radius 10 mm. While the images form a circle of radius approximately 6.3mm without lens, the image radius reduces to about 5.4 mm at the SSW detector (SFLA lens) and to 5.8 mm at the SLW detector (SFLB lens).

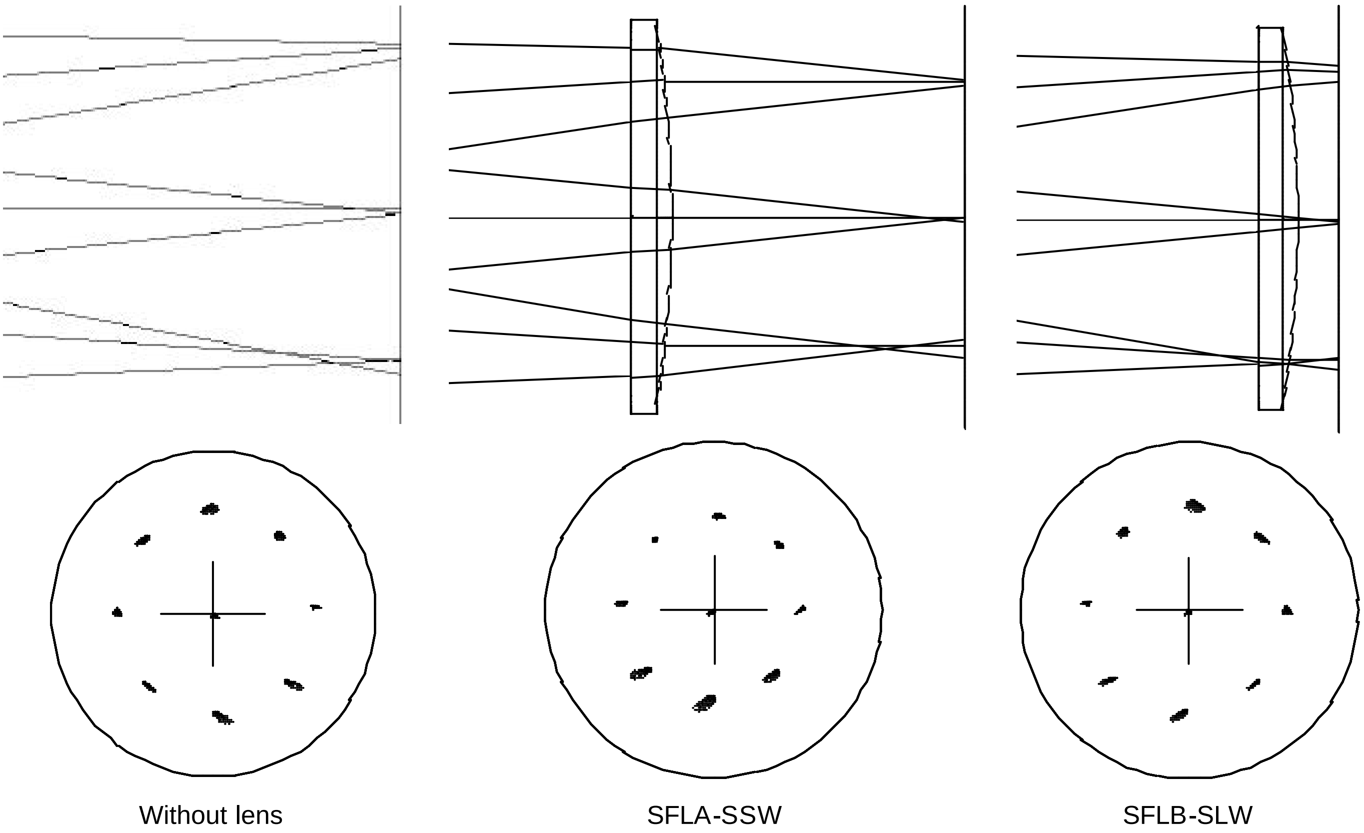
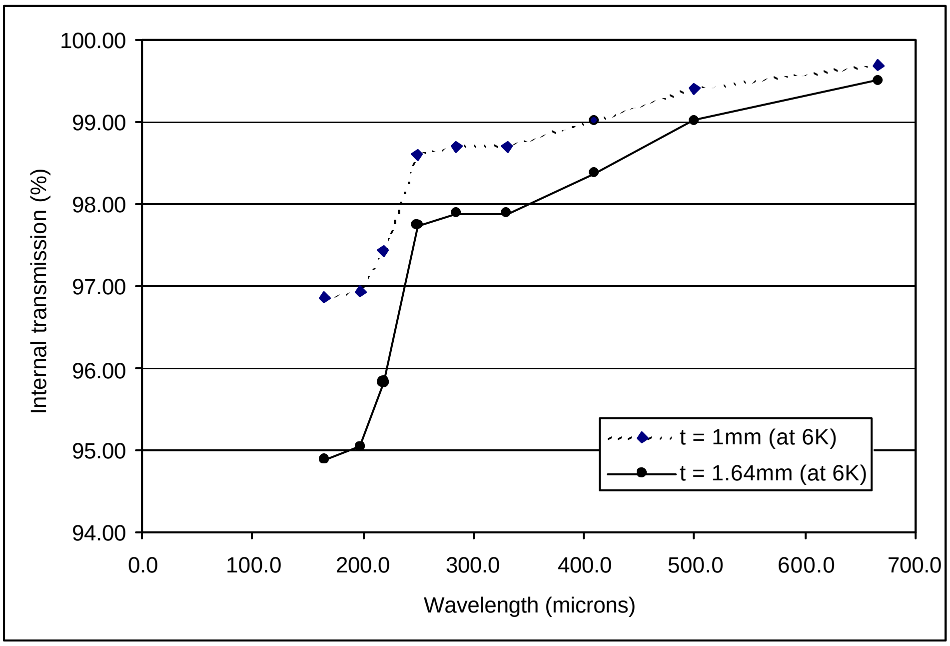


Figure 3. Ray traces and spot diagrams without and with lenses.

6. Transmission

The figure shows internal transmission as function of wavelength for LDPE (assumed to be identical for HDPE) at 6K for thickness 1.64mm (centre of lens) and 1.0mm (edge of lens). For 1.64 mm thickness, the internal transmission at 200 microns is 95%. Surface reflection from an uncoated surface is 95%. Since the filter is in optical contact with the flat surface of the lens, we only consider one surface reflection. The overall lens transmission for 1.64 mm thickness is therefore estimated to 95% x 95% = 90.3%.



Appendix: Spectrometer lens design – revision KD – 19/06/02

Following ferocious discussions between Pete and Kjetil, the position of the lens in the filter stack has been altered, as shown in Figure 1, in order to bring the lens as close as possible to the BDA. The lens now has its bulge towards the detectors. This arrangement leaves 1.36mm clearance between the lens apex and the BDA face.

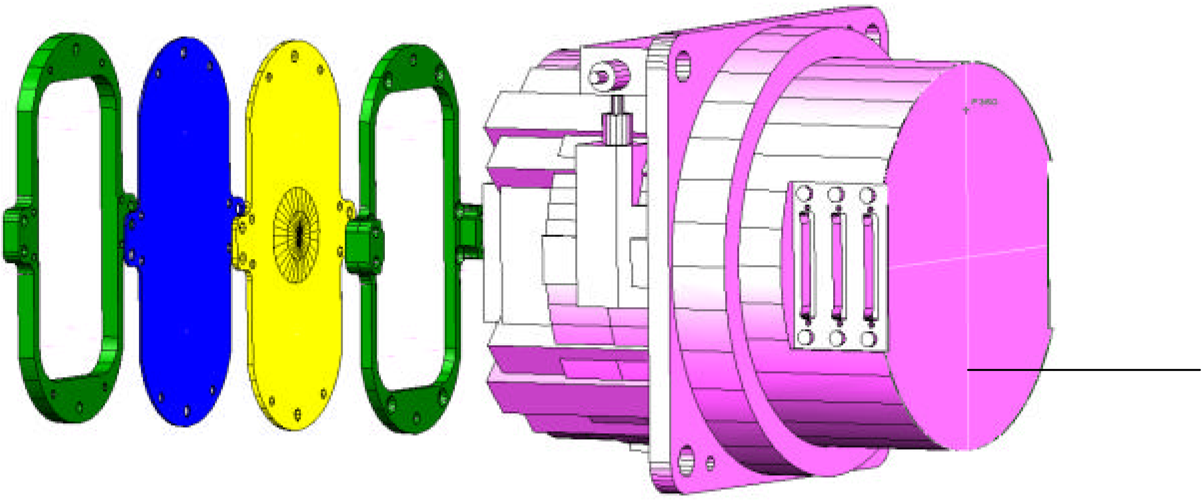


Figure 1 – Exploded view of filter & lens assembly

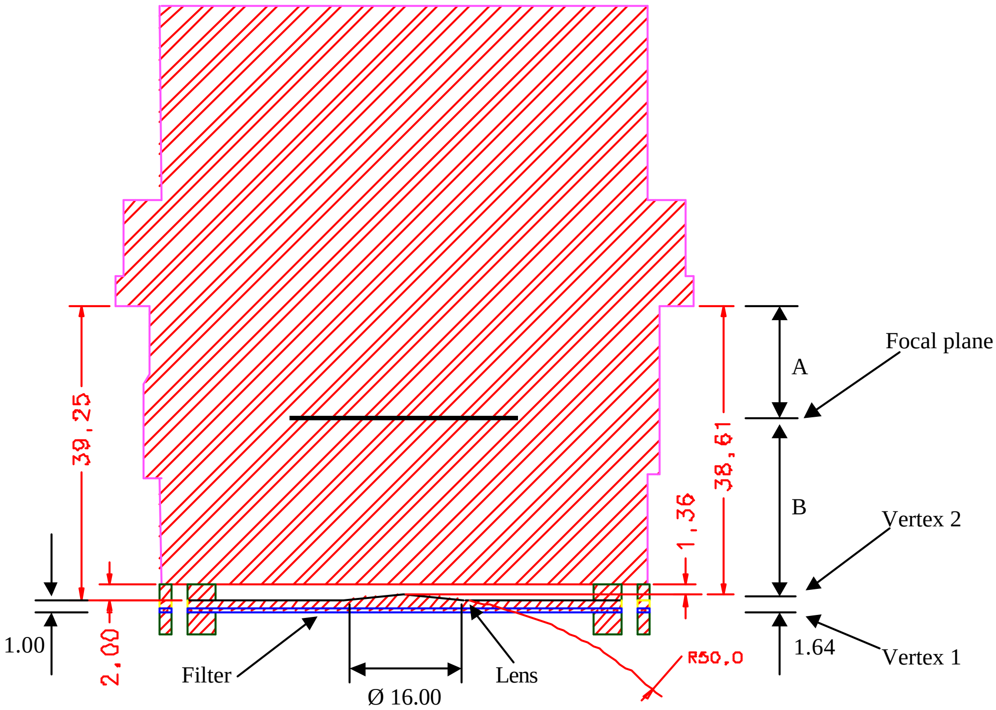


Figure 2 – Dimensions of filter – lens – detector assembly

Table 1. Position of lens vertex and focal plane wrt detector mounting flange

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