This document describes the nominal optical system up to the level which has been currently analysed.
Change History:
This is the first issue of this document.

It includes all of TC-RAL-33D which has been modified to accommodate the change in filter thicknesses. The design was re-optimised by varying the air gaps, keeping the overall length, distortion, image quality and pupil aberrations to be very similar to TC-RAL-33D.

Related Documents:

- TC-RAL-33D: Baseline Optical description
- TC-RAL-046A: Scatter measurements and analysis of lens and filter coatings
- TC-RAL-047 AND 47A: Ghost analysis
- TC-RAL-048B: Diffraction analysis
- TC-RAL-049A: Criteria for aperture sizes
- TC-RAL-055: IFOV performance
General:

The layout is that of an off-axis Gregorian telescope with a lens relay system after the second image plane to give the correct image scale and aberration control (fig 1,2,3).

The optical system was optimised for good image quality and small ILS to SAS pupil aberrations, consequently neither can be changed without due regard to the other.

The telescope has an entrance pupil diameter (EPD) of ~160mm on-axis.

The geometrical image scale is such that a 1km object height (at 3000km object distance) subtends 0.0818mm at the focal plane on axis. The effects of diffraction, aberrations and distortion will spread the resulting IFOV for each channel.

There are two sets of spectral filters. The set at the second image plane define the spectral shape of each channel and the set adjacent to the final image plane reduce the out-of-field signal reaching the detectors.

The apertures described in this document are a consistent and related set as used in TC-RAL-48. No individual aperture can be changed in isolation without due regard to the effect of stray light and the requirements on the other aperture sizes.

The plane of the chopper blade is close to the first image plane.

The fold mirror after the second lens is [TBD] but it’s position and orientation doesn’t significantly impact on the optical design.

The ZnSe dewar window also provides additional long wave blocking.

The reflections from the refractive components contribute to an out-of-field problem, consequently there is a requirement of low reflection from these surfaces.

The wavelength used for each channel is the centre of the 50% passband (in cm⁻¹) as defined in SP-HIR-13M table 3.4.1-1.

The data in this document is taken from the higher accuracy CodeV model.
Optical Components: (Refer to Figs 1,2,3)

- **Scan Mirror (FM0).**  
  A flat mirror whose centre of rotation is 550.000mm from the parabolic segment.  
  The nominal angle of the normal to the on axis chief ray is 25.3deg.  
  Minimum clear aperture size [TBD]

- **Primary Diffraction Baffle (PDB).**  
  Positioned 250mm from the scan mirror.  
  Circular aperture radius 90.000mm.

- **Parabolic Primary Mirror (M1).**  
  Positioned 300mm from the PDB  
  Radius of curvature at the pole of the parent = 860.0mm.  
  The used portion is 187.0mm off-axis.  
  Minimum clear aperture size [TBD]

- **First Field Stop (PFM).**  
  Positioned at the focus of the paraboloid and normal to the on-axis chief ray.  
  It is a 10x10mm square aperture aligned with the image of the detectors.

- **Chopper Plane**  
  [TBD]

- **Ellipsoidal Secondary Mirror (M2).**  
  One of the foci of the ellipsoid is coincident with the focus of the paraboloid.  
  The major axis of the ellipsoid is inclined by 3.2° (See fig 1 for direction) to the axis of the paraboloid.  
  Conic Constant (k) = -0.25  
  Radius of curvature at the pole = 195.0mm  
  Minimum clear aperture size [TBD]

- **Intermediate Lyot STOP (ILS)**  
  Positioned at 111.823mm from the used portion of the ellipsoidal secondary mirror,  
  normal to the on axis chief ray.  
  Circular aperture radius 18.250mm.

- **Warm Filters (WF1 thro’ 21)**  
  (Narrow Spectral Band-Pass)  
  The ‘equivalent Ge’ thickness of the filter and substrate is 0.9mm.  
  The front surface of the filter is positioned at the second image plane and normal to the on-axis chief ray and 273mm from the ILS.  
  There is a field mask on the ellipsoid side of the filters, each aperture is placed at the geometrical image of the detectors and sized 5.96mm x 2.56mm
• **First Ge Lens (L1).**
  Ge lens 85.305mm from the back of the secondary filters
  Front surface radius of curvature = -52.343mm
  Conic constant of front surface = +0.20
  Back surface radius of curvature = -48.902mm
  Centre Thickness = 3.500mm
  Minimum clear aperture size [TBD]

• **Fold Mirror (FM4).**
  Position and alignment [TBD].
  Used to align the image plane with the detectors on the optical bench.
  Minimum clear aperture size [TBD]

• **Aperture STOP (SAS).**
  233.810mm from the first lens.
  Circular aperture radius 10.690mm

• **Second Ge Lens (L2).**
  Ge lens 20.466mm from the aperture STOP.
  Front surface radius of curvature = -36.427mm
  Back surface radius of curvature = -55.384mm
  Conic constant of front surface = -0.610
  Centre Thickness = 3.000mm
  Minimum clear aperture size [TBD]

• **Dewar Window (W1).**
  Flat ZnSe window 2.0mm thick.
  5.744mm from the back of the lens.
  Minimum clear aperture size [TBD]

• **Cold Filters (CF1 thro’ 21).**
  (Wide Spectral Band)
  The back of the filters are 25.4mm from the back of the dewar window.
  Table 1 gives their optimised values.
  Minimum clear aperture size [TBD]

• **Anti-Reflection Coatings.**
  Anti-reflection coatings are required on all Ge and ZnSe surfaces.
  Reflection is required to be <2.7% between 6.18μm at each surface (ref ITS).

• **Detector Positions**
  The detectors are 0.100mm from the back of the focal plane filters.
Table 1: Filter Thicknesses Required at the Detector Plane

<table>
<thead>
<tr>
<th>Channel</th>
<th>Wavelength (nm)</th>
<th>Optimised Focal Plane Filter Thicknesses (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17376</td>
<td>0.405</td>
</tr>
<tr>
<td>2</td>
<td>16461</td>
<td>0.397</td>
</tr>
<tr>
<td>3</td>
<td>16000</td>
<td>0.402</td>
</tr>
<tr>
<td>4</td>
<td>15552</td>
<td>0.413</td>
</tr>
<tr>
<td>5</td>
<td>14981</td>
<td>0.419</td>
</tr>
<tr>
<td>6</td>
<td>12070</td>
<td>0.418</td>
</tr>
<tr>
<td>7</td>
<td>11848</td>
<td>0.411</td>
</tr>
<tr>
<td>8</td>
<td>11331</td>
<td>0.406</td>
</tr>
<tr>
<td>9</td>
<td>10822</td>
<td>0.418</td>
</tr>
<tr>
<td>10</td>
<td>10000</td>
<td>0.429</td>
</tr>
<tr>
<td>11</td>
<td>9713</td>
<td>0.436</td>
</tr>
<tr>
<td>12</td>
<td>8850</td>
<td>0.418</td>
</tr>
<tr>
<td>13</td>
<td>8264</td>
<td>0.429</td>
</tr>
<tr>
<td>14</td>
<td>8035</td>
<td>0.436</td>
</tr>
<tr>
<td>15</td>
<td>7880</td>
<td>0.450</td>
</tr>
<tr>
<td>16</td>
<td>7761</td>
<td>0.451</td>
</tr>
<tr>
<td>17</td>
<td>7427</td>
<td>0.467</td>
</tr>
<tr>
<td>18</td>
<td>7092</td>
<td>0.479</td>
</tr>
<tr>
<td>19</td>
<td>7097</td>
<td>0.486</td>
</tr>
<tr>
<td>20</td>
<td>6748</td>
<td>0.496</td>
</tr>
<tr>
<td>21</td>
<td>6219</td>
<td>0.519</td>
</tr>
</tbody>
</table>

1. Notes:
All thicknesses are for an 'equivalent Ge' thickness
(i.e. NOT the total physical thickness of the substrate and the multilayer stacks).
Table 2 Refractive Index Data

<table>
<thead>
<tr>
<th>Channel</th>
<th>Wavelength</th>
<th>Ge @ 293K</th>
<th>Ge @ 65K</th>
<th>ZnSe @ 293K</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17376</td>
<td>4.0007</td>
<td>3.9257</td>
<td>2.3396</td>
</tr>
<tr>
<td>2</td>
<td>16461</td>
<td>4.0009</td>
<td>3.9259</td>
<td>2.3510</td>
</tr>
<tr>
<td>3</td>
<td>16000</td>
<td>4.0010</td>
<td>3.9260</td>
<td>2.3563</td>
</tr>
<tr>
<td>4</td>
<td>15552</td>
<td>4.0011</td>
<td>3.9260</td>
<td>2.3613</td>
</tr>
<tr>
<td>5</td>
<td>14981</td>
<td>4.0012</td>
<td>3.9262</td>
<td>2.3673</td>
</tr>
<tr>
<td>6</td>
<td>12070</td>
<td>4.0022</td>
<td>3.9270</td>
<td>2.3931</td>
</tr>
<tr>
<td>7</td>
<td>11848</td>
<td>4.0023</td>
<td>3.9271</td>
<td>2.3948</td>
</tr>
<tr>
<td>8</td>
<td>11331</td>
<td>4.0026</td>
<td>3.9273</td>
<td>2.3985</td>
</tr>
<tr>
<td>9</td>
<td>10822</td>
<td>4.0029</td>
<td>3.9275</td>
<td>2.4020</td>
</tr>
<tr>
<td>10</td>
<td>10000</td>
<td>4.0036</td>
<td>3.9281</td>
<td>2.4072</td>
</tr>
<tr>
<td>11</td>
<td>9713</td>
<td>4.0038</td>
<td>3.9283</td>
<td>2.4089</td>
</tr>
<tr>
<td>12</td>
<td>8850</td>
<td>4.0046</td>
<td>3.9290</td>
<td>2.4137</td>
</tr>
<tr>
<td>13</td>
<td>8264</td>
<td>4.0055</td>
<td>3.9296</td>
<td>2.4167</td>
</tr>
<tr>
<td>14</td>
<td>8035</td>
<td>4.0058</td>
<td>3.9299</td>
<td>2.4178</td>
</tr>
<tr>
<td>15</td>
<td>7888</td>
<td>4.0061</td>
<td>3.9301</td>
<td>2.4185</td>
</tr>
<tr>
<td>16</td>
<td>7761</td>
<td>4.0063</td>
<td>3.9303</td>
<td>2.4191</td>
</tr>
<tr>
<td>17</td>
<td>7427</td>
<td>4.0069</td>
<td>3.9309</td>
<td>2.4206</td>
</tr>
<tr>
<td>18</td>
<td>7092</td>
<td>4.0077</td>
<td>3.9315</td>
<td>2.4221</td>
</tr>
<tr>
<td>19</td>
<td>7097</td>
<td>4.0076</td>
<td>3.9315</td>
<td>2.4220</td>
</tr>
<tr>
<td>20</td>
<td>6748</td>
<td>4.0085</td>
<td>3.9321</td>
<td>2.4235</td>
</tr>
<tr>
<td>21</td>
<td>6219</td>
<td>4.0101</td>
<td>3.9334</td>
<td>2.4256</td>
</tr>
</tbody>
</table>

Notes:
   Data @ 65K is extrapolated from 100K.
2. ZnSe data from CodeV data base.
3. Refractive indices converted to their vacuum values
Fig 1: Optical System Layout (Not to scale - for reference only)
Fig 2 Optical System after the second image plane.
(Not to scale - for reference only)

Fig 3 STOP to Detector Layout
(Not to scale - for reference only)
Fig 5 Global Co-ordinates Reference Axes.
(Not to scale - for reference only)

Global axes aligned with these but displaced by:

\[
\begin{align*}
X &= -1095.880 \\
Y &= -397.000 \\
Z &= 617.320
\end{align*}
\]
Table 3: Global System Co-ordinates for the Pole of Each Component.

<table>
<thead>
<tr>
<th>Surface</th>
<th>X-Coord</th>
<th>Y-Coord</th>
<th>Z-Coord</th>
<th>L-Dir Cosine</th>
<th>M-Dir Cosine</th>
<th>N-Dir Cosine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan Mirror</td>
<td>1095.880</td>
<td>397.000</td>
<td>617.320</td>
<td>1.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>PDB</td>
<td>869.859</td>
<td>397.000</td>
<td>510.481</td>
<td>0.9041</td>
<td>0.0000</td>
<td>0.4274</td>
</tr>
<tr>
<td>Paraboloid</td>
<td>660.170</td>
<td>397.000</td>
<td>204.521</td>
<td>0.9041</td>
<td>0.0000</td>
<td>0.4274</td>
</tr>
<tr>
<td>First image plane normal</td>
<td>1048.925</td>
<td>397.000</td>
<td>388.285</td>
<td>0.9999</td>
<td>0.0000</td>
<td>0.0133</td>
</tr>
<tr>
<td>Ellipsoid</td>
<td>1163.172</td>
<td>397.000</td>
<td>450.316</td>
<td>0.8788</td>
<td>0.0000</td>
<td>0.4772</td>
</tr>
<tr>
<td>ILS</td>
<td>1078.417</td>
<td>397.000</td>
<td>335.515</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Second Image plane and Warm Filter Front</td>
<td>820.433</td>
<td>397.000</td>
<td>264.224</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Warm Filter Back</td>
<td>819.582</td>
<td>397.000</td>
<td>263.929</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Lens 1 front</td>
<td>739.182</td>
<td>397.000</td>
<td>236.102</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Lens 1 back</td>
<td>735.875</td>
<td>397.000</td>
<td>234.957</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>STOP</td>
<td>514.925</td>
<td>397.000</td>
<td>158.484</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Lens 2 front</td>
<td>495.584</td>
<td>397.000</td>
<td>151.790</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Lens 2 back</td>
<td>492.749</td>
<td>397.000</td>
<td>150.809</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Window Front</td>
<td>487.321</td>
<td>397.000</td>
<td>148.930</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Window Back</td>
<td>485.431</td>
<td>397.000</td>
<td>148.276</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Cold Filter Front</td>
<td>461.806</td>
<td>397.000</td>
<td>140.099</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Cold Filter back</td>
<td>461.428</td>
<td>397.000</td>
<td>139.968</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Final Image plane</td>
<td>461.333</td>
<td>397.000</td>
<td>139.935</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
</tbody>
</table>

Note: Cold Filter Plane Front is variable
Table 4: Global system Co-ordinates of the Surface Intersection with the On-axis Chief Ray

<table>
<thead>
<tr>
<th>Surface</th>
<th>X-Coord (mm)</th>
<th>Y-Coord (mm)</th>
<th>Z-Coord (mm)</th>
<th>Distance from last surface (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan Mirror</td>
<td>1095.880</td>
<td>397.000</td>
<td>617.320</td>
<td>-------</td>
</tr>
<tr>
<td>PDB</td>
<td>869.859</td>
<td>397.000</td>
<td>510.481</td>
<td>250.000</td>
</tr>
<tr>
<td>Paraboloid</td>
<td>598.635</td>
<td>397.000</td>
<td>382.273</td>
<td>300.000</td>
</tr>
<tr>
<td>First image plane normal</td>
<td>1048.925</td>
<td>397.000</td>
<td>388.285</td>
<td>450.331</td>
</tr>
<tr>
<td>Ellipsoid</td>
<td>1184.090</td>
<td>397.000</td>
<td>390.090</td>
<td>135.177</td>
</tr>
<tr>
<td>ILS</td>
<td>1078.417</td>
<td>397.000</td>
<td>353.515</td>
<td>118.823</td>
</tr>
<tr>
<td>Second Image plane and Warm Filter Front</td>
<td>820.433</td>
<td>397.000</td>
<td>264.224</td>
<td>273.000</td>
</tr>
<tr>
<td>Warm Filter Back</td>
<td>819.582</td>
<td>397.000</td>
<td>263.929</td>
<td>0.900</td>
</tr>
<tr>
<td>Lens 1 front</td>
<td>739.182</td>
<td>397.000</td>
<td>236.102</td>
<td>85.080</td>
</tr>
<tr>
<td>Lens 1 back</td>
<td>735.875</td>
<td>397.000</td>
<td>234.957</td>
<td>3.500</td>
</tr>
<tr>
<td>STOP</td>
<td>514.925</td>
<td>397.000</td>
<td>158.484</td>
<td>233.810</td>
</tr>
<tr>
<td>Lens 2 front</td>
<td>495.584</td>
<td>397.000</td>
<td>151.790</td>
<td>20.466</td>
</tr>
<tr>
<td>Lens 2 back</td>
<td>492.749</td>
<td>397.000</td>
<td>150.809</td>
<td>3.000</td>
</tr>
<tr>
<td>Window Front</td>
<td>487.321</td>
<td>397.000</td>
<td>148.930</td>
<td>5.744</td>
</tr>
<tr>
<td>Window Back</td>
<td>485.431</td>
<td>397.000</td>
<td>148.276</td>
<td>2.000</td>
</tr>
<tr>
<td>Cold Filter Front</td>
<td>461.806</td>
<td>397.000</td>
<td>140.099</td>
<td>25.000</td>
</tr>
<tr>
<td>Cold Filter back</td>
<td>461.428</td>
<td>397.000</td>
<td>139.968</td>
<td>0.400</td>
</tr>
<tr>
<td>Final Image plane</td>
<td>461.333</td>
<td>397.000</td>
<td>139.935</td>
<td>0.100</td>
</tr>
</tbody>
</table>

Note: Cold Filter Plane Front is variable
This document describes the nominal optical system up to the level which has been currently analysed.
Change History:
This is the first issue of this document.
It includes all of TC-RAL-33D which has been modified to accommodate the change in filter thicknesses. The design was re-optimised by varying the air gaps, keeping the overall length, distortion, image quality and pupil aberrations to be very similar to TC-RAL-33D

Related Documents:

<table>
<thead>
<tr>
<th>Document</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC-RAL-33D</td>
<td>Baseline Optical description</td>
</tr>
<tr>
<td>TC-RAL-046A</td>
<td>Scatter measurements and analysis of lens and filter coatings</td>
</tr>
<tr>
<td>TC-RAL-047 AND 47A</td>
<td>Ghost analysis</td>
</tr>
<tr>
<td>TC-RAL-048B</td>
<td>Diffraction analysis</td>
</tr>
<tr>
<td>TC-RAL-049A</td>
<td>Criteria for aperture sizes</td>
</tr>
<tr>
<td>TC-RAL-055</td>
<td>IFOV performance</td>
</tr>
<tr>
<td>SP-HIR-13</td>
<td>Instrument Technical Specification</td>
</tr>
</tbody>
</table>
General:

The layout is that of an off-axis Gregorian telescope with a lens relay system after the second image plane to give the correct image scale and aberration control (fig 1,2,3).

The optical system was optimised for good image quality and small ILS to SAS pupil aberrations, consequently neither can be changed without due regard to the other.

The telescope has an entrance pupil diameter (EPD) of ~160mm on-axis.

The geometrical image scale is such that a 1km object height (at 3000km object distance) subtends 0.0818mm at the focal plane on axis. The effects of diffraction, aberrations and distortion will spread the resulting IFOV for each channel.

There are two sets of spectral filters. The set at the second image plane define the spectral shape of each channel and the set adjacent to the final image plane reduce the out-of-field signal reaching the detectors.

The apertures described in this document are a consistent and related set as used in TC-RAL-48. No individual aperture can be changed in isolation without due regard to the effect of stray light and the requirements on the other aperture sizes.

The plane of the chopper blade is close to the first image plane.

The fold mirror after the second lens is [TBD] but it’s position and orientation doesn’t significantly impact on the optical design.

The ZnSe dewar window also provides additional long wave blocking.

The reflections from the refractive components contribute to an out-of-field problem, consequently there is a requirement of low reflection from these surfaces.

The wavelength used for each channel is the centre of the 50% passband (in cm⁻¹) as defined in SP-HIR-13M table 3.4.1-1.

The data in this document is taken from the higher accuracy CodeV model.
Optical Components: (Refer to Figs 1,2,3)

- **Scan Mirror (FM0).**
  A flat mirror whose centre of rotation is 550.000mm from the parabolic segment. The nominal angle of the normal to the on axis chief ray is 25.3deg. Minimum clear aperture size [TBD]

- **Primary Diffraction Baffle (PDB).**
  Positioned 250mm from the scan mirror. Circular aperture radius 90.000mm.

- **Parabolic Primary Mirror (M1).**
  Positioned 300mm from the PDB
  Radius of curvature at the pole of the parent = 860.0mm.
  The used portion is 187.0mm off-axis.
  Minimum clear aperture size [TBD]

- **First Field Stop (PFM).**
  Positioned at the focus of the paraboloid and normal to the on-axis chief ray. It is a 10x10mm square aperture aligned with the image of the detectors.

- **Chopper Plane**
  [TBD]

- **Ellipsoidal Secondary Mirror (M2).**
  One of the foci of the ellipsoid is coincident with the focus of the paraboloid.
  The major axis of the ellipsoid is inclined by 3.2° (See fig 1 for direction) to the axis of the paraboloid.
  Conic Constant (k) = -0.25
  Radius of curvature at the pole = 195.0mm
  Minimum clear aperture size [TBD]

- **Intermediate Lyot STOP (ILS)**
  Positioned at 111.823mm from the used portion of the ellipsoidal secondary mirror, normal to the on axis chief ray.
  Circular aperture radius 18.250mm.

- **Warm Filters (WF1 throu’ 21)**
  (Narrow Spectral Band-Pass)
  The ‘equivalent Ge’ thickness of the filter and substrate is 0.9mm.
  The front surface of the filter is positioned at the second image plane and normal to the on-axis chief ray and 273mm from the ILS.
  There is a field mask on the ellipsoid side of the filters, each aperture is placed at the geometrical image of the detectors and sized 5.96mm x 2.56mm
• First Ge Lens (L1).
  Ge lens 85.305mm from the back of the secondary filters
  Front surface radius of curvature = -52.343mm
  Conic constant of front surface = +0.20
  Back surface radius of curvature = -48.902mm
  Centre Thickness = 3.500mm
  Minimum clear aperture size [TBD]

• Fold Mirror (FM4).
  Position and alignment [TBD].
  Used to align the image plane with the detectors on the optical bench.
  Minimum clear aperture size [TBD]

• Aperture STOP (SAS).
  233.810mm from the first lens.
  Circular aperture radius 10.690mm

• Second Ge Lens (L2).
  Ge lens 20.466mm from the aperture STOP.
  Front surface radius of curvature = -36.427mm
  Back surface radius of curvature = -55.384mm
  Conic constant of front surface = -0.610
  Centre Thickness = 3.000mm
  Minimum clear aperture size [TBD]

• Dewar Window (W1).
  Flat ZnSe window 2.0mm thick.
  5.744mm from the back of the lens.
  Minimum clear aperture size [TBD]

• Cold Filters (CF1 thro’ 21).
  (Wide Spectral Band)
  The back of the filters are 25.4mm from the back of the dewar window.
  Table 1 gives their optimised values.
  Minimum clear aperture size [TBD]

• Anti-Reflection Coatings.
  Anti-reflection coatings are required on all Ge and ZnSe surfaces.
  Reflection is required to be <2.7% between 6..18μm at each surface (ref ITS).

• Detector Positions
  The detectors are 0.100mm from the back of the focal plane filters.
### Table 1: Filter Thicknesses Required at the Detector Plane

<table>
<thead>
<tr>
<th>Channel</th>
<th>Wavelength (nm)</th>
<th>Optimised Focal Plane Filter Thicknesses (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17376</td>
<td>0.405</td>
</tr>
<tr>
<td>2</td>
<td>16461</td>
<td>0.397</td>
</tr>
<tr>
<td>3</td>
<td>16000</td>
<td>0.402</td>
</tr>
<tr>
<td>4</td>
<td>15552</td>
<td>0.413</td>
</tr>
<tr>
<td>5</td>
<td>14981</td>
<td>0.419</td>
</tr>
<tr>
<td>6</td>
<td>12070</td>
<td>0.418</td>
</tr>
<tr>
<td>7</td>
<td>11848</td>
<td>0.411</td>
</tr>
<tr>
<td>8</td>
<td>11331</td>
<td>0.406</td>
</tr>
<tr>
<td>9</td>
<td>10822</td>
<td>0.418</td>
</tr>
<tr>
<td>10</td>
<td>10000</td>
<td>0.429</td>
</tr>
<tr>
<td>11</td>
<td>9713</td>
<td>0.436</td>
</tr>
<tr>
<td>12</td>
<td>8850</td>
<td>0.418</td>
</tr>
<tr>
<td>13</td>
<td>8264</td>
<td>0.429</td>
</tr>
<tr>
<td>14</td>
<td>8035</td>
<td>0.436</td>
</tr>
<tr>
<td>15</td>
<td>7880</td>
<td>0.450</td>
</tr>
<tr>
<td>16</td>
<td>7761</td>
<td>0.451</td>
</tr>
<tr>
<td>17</td>
<td>7427</td>
<td>0.467</td>
</tr>
<tr>
<td>18</td>
<td>7092</td>
<td>0.479</td>
</tr>
<tr>
<td>19</td>
<td>7097</td>
<td>0.486</td>
</tr>
<tr>
<td>20</td>
<td>6748</td>
<td>0.496</td>
</tr>
<tr>
<td>21</td>
<td>6219</td>
<td>0.519</td>
</tr>
</tbody>
</table>

1. Notes:
   All thicknesses are for an 'equivalent Ge' thickness (i.e. NOT the total physical thickness of the substrate and the multilayer stacks).
Table 2 Refractive Index Data

<table>
<thead>
<tr>
<th>Channel</th>
<th>Wavelength</th>
<th>Ge @ 293K</th>
<th>Ge @ 65K</th>
<th>ZnSe @ 293K</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17376</td>
<td>4.0007</td>
<td>3.9257</td>
<td>2.3396</td>
</tr>
<tr>
<td>2</td>
<td>16461</td>
<td>4.0009</td>
<td>3.9259</td>
<td>2.3510</td>
</tr>
<tr>
<td>3</td>
<td>16000</td>
<td>4.0010</td>
<td>3.9260</td>
<td>2.3563</td>
</tr>
<tr>
<td>4</td>
<td>15552</td>
<td>4.0011</td>
<td>3.9260</td>
<td>2.3613</td>
</tr>
<tr>
<td>5</td>
<td>14981</td>
<td>4.0012</td>
<td>3.9262</td>
<td>2.3673</td>
</tr>
<tr>
<td>6</td>
<td>12070</td>
<td>4.0022</td>
<td>3.9270</td>
<td>2.3931</td>
</tr>
<tr>
<td>7</td>
<td>11848</td>
<td>4.0023</td>
<td>3.9271</td>
<td>2.3948</td>
</tr>
<tr>
<td>8</td>
<td>11331</td>
<td>4.0026</td>
<td>3.9273</td>
<td>2.3985</td>
</tr>
<tr>
<td>9</td>
<td>10822</td>
<td>4.0029</td>
<td>3.9275</td>
<td>2.4020</td>
</tr>
<tr>
<td>10</td>
<td>10000</td>
<td>4.0036</td>
<td>3.9281</td>
<td>2.4072</td>
</tr>
<tr>
<td>11</td>
<td>9713</td>
<td>4.0038</td>
<td>3.9283</td>
<td>2.4089</td>
</tr>
<tr>
<td>12</td>
<td>8850</td>
<td>4.0046</td>
<td>3.9290</td>
<td>2.4137</td>
</tr>
<tr>
<td>13</td>
<td>8264</td>
<td>4.0055</td>
<td>3.9296</td>
<td>2.4167</td>
</tr>
<tr>
<td>14</td>
<td>8035</td>
<td>4.0058</td>
<td>3.9299</td>
<td>2.4178</td>
</tr>
<tr>
<td>15</td>
<td>7888</td>
<td>4.0061</td>
<td>3.9301</td>
<td>2.4185</td>
</tr>
<tr>
<td>16</td>
<td>7761</td>
<td>4.0063</td>
<td>3.9303</td>
<td>2.4191</td>
</tr>
<tr>
<td>17</td>
<td>7427</td>
<td>4.0069</td>
<td>3.9309</td>
<td>2.4206</td>
</tr>
<tr>
<td>18</td>
<td>7092</td>
<td>4.0077</td>
<td>3.9315</td>
<td>2.4221</td>
</tr>
<tr>
<td>19</td>
<td>7097</td>
<td>4.0076</td>
<td>3.9315</td>
<td>2.4220</td>
</tr>
<tr>
<td>20</td>
<td>6748</td>
<td>4.0085</td>
<td>3.9321</td>
<td>2.4235</td>
</tr>
<tr>
<td>21</td>
<td>6219</td>
<td>4.0101</td>
<td>3.9334</td>
<td>2.4256</td>
</tr>
</tbody>
</table>

Notes:
   Data @ 65K is extrapolated from 100K.
2. ZnSe data from CodeV data base.
3. Refractive indices converted to their vacuum values
Fig 1: Optical System Layout (Not to scale - for reference only)
Fig 2 Optical System after the second image plane.
(Not to scale - for reference only)

Fig 3 STOP to Detector Layout
(Not to scale - for reference only)
Fig 5 Global Co-ordinates Reference Axes.
(Not to scale - for reference only)

Global axes aligned with these but displaced by:
X = -1095.880
Y = 397.000
Z = 617.320
Table 3: Global System Co-ordinates for the Pole of Each Component.

<table>
<thead>
<tr>
<th>Surface</th>
<th>X-Coord</th>
<th>Y-Coord</th>
<th>Z-Coord</th>
<th>L-Dir Cosine</th>
<th>M-Dir Cosine</th>
<th>N-Dir Cosine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan Mirror</td>
<td>1095.880</td>
<td>397.000</td>
<td>617.320</td>
<td>1.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>PDB</td>
<td>869.859</td>
<td>397.000</td>
<td>510.481</td>
<td>0.9041</td>
<td>0.0000</td>
<td>0.4274</td>
</tr>
<tr>
<td>Paraboloid</td>
<td>660.170</td>
<td>397.000</td>
<td>204.521</td>
<td>0.9041</td>
<td>0.0000</td>
<td>0.4274</td>
</tr>
<tr>
<td>First image plane normal</td>
<td>1048.925</td>
<td>397.000</td>
<td>388.285</td>
<td>0.9999</td>
<td>0.0000</td>
<td>0.0133</td>
</tr>
<tr>
<td>Ellipsoid</td>
<td>1163.172</td>
<td>397.000</td>
<td>450.316</td>
<td>0.8788</td>
<td>0.0000</td>
<td>0.4772</td>
</tr>
<tr>
<td>ILS</td>
<td>1078.417</td>
<td>397.000</td>
<td>353.515</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Second Image plane and Warm Filter Front</td>
<td>820.433</td>
<td>397.000</td>
<td>264.224</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Warm Filter Back</td>
<td>819.582</td>
<td>397.000</td>
<td>263.929</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Lens 1 front</td>
<td>739.182</td>
<td>397.000</td>
<td>236.102</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Lens 1 back</td>
<td>735.875</td>
<td>397.000</td>
<td>234.957</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>STOP</td>
<td>514.925</td>
<td>397.000</td>
<td>158.484</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Lens 2 front</td>
<td>495.584</td>
<td>397.000</td>
<td>151.790</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Lens 2 back</td>
<td>492.749</td>
<td>397.000</td>
<td>150.809</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Window Front</td>
<td>487.321</td>
<td>397.000</td>
<td>148.930</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Window Back</td>
<td>485.431</td>
<td>397.000</td>
<td>148.276</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Cold Filter Front</td>
<td>461.806</td>
<td>397.000</td>
<td>140.099</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Cold Filter back</td>
<td>461.428</td>
<td>397.000</td>
<td>139.968</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Final Image plane</td>
<td>461.333</td>
<td>397.000</td>
<td>139.935</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
</tbody>
</table>

Note: Cold Filter Plane Front is variable as "Rear Mask"
Table 4 Global system Co-ordinates of the Surface Intersection with the On-axis Chief Ray

<table>
<thead>
<tr>
<th>Surface</th>
<th>X-Coord (mm)</th>
<th>Y-Coord (mm)</th>
<th>Z-Coord (mm)</th>
<th>Distance from last surface (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan Mirror</td>
<td>1095.880</td>
<td>397.000</td>
<td>617.320</td>
<td>------</td>
</tr>
<tr>
<td>PDB</td>
<td>869.859</td>
<td>397.000</td>
<td>510.481</td>
<td>250.000</td>
</tr>
<tr>
<td>Paraboloid</td>
<td>598.635</td>
<td>397.000</td>
<td>382.273</td>
<td>300.000</td>
</tr>
<tr>
<td>First image plane normal</td>
<td>1048.925</td>
<td>397.000</td>
<td>388.285</td>
<td>450.331</td>
</tr>
<tr>
<td>Ellipsoid</td>
<td>1184.090</td>
<td>397.000</td>
<td>390.090</td>
<td>135.177</td>
</tr>
<tr>
<td>ILS</td>
<td>1078.417</td>
<td>397.000</td>
<td>353.515</td>
<td>118.823</td>
</tr>
<tr>
<td>Second Image plane and Warm Filter Front</td>
<td>820.433</td>
<td>397.000</td>
<td>264.224</td>
<td>273.000</td>
</tr>
<tr>
<td>Warm Filter Back</td>
<td>819.582</td>
<td>397.000</td>
<td>263.929</td>
<td>0.900</td>
</tr>
<tr>
<td>Lens 1 front</td>
<td>739.182</td>
<td>397.000</td>
<td>236.102</td>
<td>85.080</td>
</tr>
<tr>
<td>Lens 1 back</td>
<td>735.875</td>
<td>397.000</td>
<td>234.957</td>
<td>3.5000</td>
</tr>
<tr>
<td>STOP</td>
<td>514.925</td>
<td>397.000</td>
<td>158.484</td>
<td>233.810</td>
</tr>
<tr>
<td>Lens 2 front</td>
<td>495.584</td>
<td>397.000</td>
<td>151.790</td>
<td>20.466</td>
</tr>
<tr>
<td>Lens 2 back</td>
<td>492.749</td>
<td>397.000</td>
<td>150.809</td>
<td>3.000</td>
</tr>
<tr>
<td>Window Front</td>
<td>487.321</td>
<td>397.000</td>
<td>148.930</td>
<td>5.744</td>
</tr>
<tr>
<td>Window Back</td>
<td>485.431</td>
<td>397.000</td>
<td>148.276</td>
<td>2.000</td>
</tr>
<tr>
<td>Cold Filter Front</td>
<td>461.806</td>
<td>397.000</td>
<td>140.099</td>
<td>25.000</td>
</tr>
<tr>
<td>Cold Filter back</td>
<td>461.428</td>
<td>397.000</td>
<td>139.968</td>
<td>0.4000</td>
</tr>
<tr>
<td>Final Image plane</td>
<td>461.333</td>
<td>397.000</td>
<td>139.935</td>
<td>0.1000</td>
</tr>
</tbody>
</table>

Note: Cold Filter Plane Front is variable
HIRDLS
High Resolution Dynamics Limb Sounder

Originator: Ian A J Tosh

Date: 2nd January 1995

Subject/Title: Optical System Specification Document

Description/summary/contents:

This document describes the nominal optical system upto the level which has been currently analysed.

Keywords: Optics, Telescope, Lens, Baseline

Purpose of this Document:
(20 Characters Maximum)

Reviewed/approved by:

Date:(day-mon-yr):

Rutherford Appleton Laboratory
Chilton, DIDCOT, OX11 0QX
United Kingdom

EOS
Change History:

This is the first issue of this document.

It includes all of TC-RAL-33D which has been modified to accommodate the change in filter thicknesses. The design was re-optimised by varying the air gaps, keeping the overall length, distortion, image quality and pupil aberrations to be very similar to TC-RAL-33D.

Related Documents:

<table>
<thead>
<tr>
<th>Document</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC-RAL-33D</td>
<td>Baseline Optical description</td>
</tr>
<tr>
<td>TC-RAL-046A</td>
<td>Scatter measurements and analysis of lens and filter coatings</td>
</tr>
<tr>
<td>TC-RAL-047 AND 47A</td>
<td>Ghost analysis</td>
</tr>
<tr>
<td>TC-RAL-048B</td>
<td>Diffraction analysis</td>
</tr>
<tr>
<td>TC-RAL-049A</td>
<td>Criteria for aperture sizes</td>
</tr>
<tr>
<td>TC-RAL-055</td>
<td>IFOV performance</td>
</tr>
<tr>
<td>SP-HIR-13</td>
<td>Instrument Technical Specification</td>
</tr>
</tbody>
</table>
General:

The layout is that of an off-axis Gregorian telescope with a lens relay system after the second image plane to give the correct image scale and aberration control (fig 1.2.3).

The optical system was optimised for image quality and stray light performance, consequently the layout cannot be modified until the analysis of both aspects has shown the changes are acceptable.

The telescope has an entrance pupil diameter (EPD) of ~160mm on-axis.

The geometrical image scale is such that a 1km object height (at 3000km object distance) subtends 0.0818mm at the focal plane on axis. The effects of diffraction, aberrations and distortion will spread the resulting IFOV for each channel.

There are two sets of spectral filters. The set at the second image plane define the spectral shape of each channel and the set adjacent to the final image plane reduce the out-of-field signal reaching the detectors.

The apertures described in this document are a consistent and related set as used in TC-RAL-48. No individual aperture can be changed in isolation without due regard to the effect of stray light and the requirements on the other aperture sizes.

The plane of the chopper blade is close to the first image plane.

The fold mirror after the second lens is [TBD] but it's position and orientation doesn't significantly impact on the optical design.

The ZnSe dewar window also provides additional long wave blocking.

The reflections from the refractive components contribute to an out-of-field problem, consequently there is a requirement of low reflection from these surfaces.

The wavelength used for each channel is the centre of the 50% passband (in cm⁻¹) as defined in SP-HIR-13M table 3.4.1-1.

The data in this document is taken from the higher accuracy CodeV model.
Optical Components: (Refer to Figs 1, 2, 3)

- Scan Mirror (FM0).
  A flat mirror whose centre of rotation is 550.000mm from the parabolic segment.
  The nominal angle of the normal to the on axis chief ray is 25.3deg.
  Minimum clear aperture size [TBD]

- Primary Diffraction Baffle (PDB).
  Positioned 250mm from the scan mirror.
  Circular aperture radius 90.000mm.

- Parabolic Primary Mirror (M1).
  Positioned 300mm from the PDB
  Radius of curvature at the pole of the parent = 860.0mm.
  The used portion is 187.0mm off-axis.
  Minimum clear aperture size [TBD]

- First Field Stop (PFM).
  Positioned at the focus of the paraboloid and normal to the on-axis chief ray.
  It is a 10x10mm square aperture aligned with the image of the detectors.

- Chopper Plane
  [TBD]

- Ellipsoidal Secondary Mirror (M2).
  One of the foci of the ellipsoid is coincident with the focus of the paraboloid.
  The major axis of the ellipsoid is inclined by 3.2° (See fig 1 for direction) to the axis of the
  paraboloid.
  Conic Constant (k) = -0.25
  Radius of curvature at the pole = 195.0mm
  Minimum clear aperture size [TBD]

- Intermediate Lyot STOP (ILS)
  Positioned at 111.823mm from the used portion of the ellipsoidal secondary mirror,
  normal to the on axis chief ray.
  Circular aperture radius 18.250mm.

- Warm Filters (WF1 thro’ 21)
  (Narrow Spectral Band-Pass)
  The ‘equivalent Ge’ thickness of the filter and substrate is 0.9mm.
  The front surface of the filter is positioned at the second image plane and normal to the on-
  axis chief ray and 273mm from the ILS.
  There is a field mask on the ellipsoid side of the filters, each aperture is placed at the
  geometrical image of the detectors and sized 5.96mm x 2.56mm
  7.4 x 2.8 in sploct39

TC-HIR-32 2nd January 1995 page 4
- First Ge Lens (L1).
  Ge lens 85.305mm from the back of the secondary filters
  Front surface radius of curvature = -52.343mm
  Conic constant of front surface = +0.20
  Back surface radius of curvature = -48.902mm
  Centre Thickness = 3.500mm
  Minimum clear aperture size [TBD]

- Fold Mirror (FM4).
  Position and alignment [TBD].
  Used to align the image plane with the detectors on the optical bench.
  Minimum clear aperture size [TBD]

- Aperture STOP (SAS).
  233.810mm from the first lens.
  Circular aperture radius 10.690mm

- Second Ge Lens (L2).
  Ge lens 20.466mm from the aperture STOP.
  Front surface radius of curvature = -36.427mm
  Back surface radius of curvature = -55.384mm
  Conic constant of front surface = -0.610
  Centre Thickness = 3.000mm
  Minimum clear aperture size [TBD]

- Dewar Window (W1).
  Flat ZnSe window 2.0mm thick.
  5.744mm from the back of the lens.
  Minimum clear aperture size [TBD]

- Cold Filters (CF1 thro’ 21).
  (Wide Spectral Band)
  The back of the filters are coplanar and 25.4mm from the back of the dewar window.
  Table 1 gives their optimised values.
  Minimum clear aperture size [TBD]

- Anti-Reflection Coatings.
  Anti-reflection coatings are required on all Ge and ZnSe surfaces.
  Reflection is required to be <2.7% between 6..18μm at each surface (ref ITS).

- Detector Positions
  The detectors are 0.100mm from the back of the focal plane filters.
### Table 1: Filter Thicknesses Required at the Detector Plane

<table>
<thead>
<tr>
<th>Channel</th>
<th>Wavelength (nm)</th>
<th>Optimised Focal Plane Filter Thicknesses (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17376</td>
<td>0.405</td>
</tr>
<tr>
<td>2</td>
<td>16461</td>
<td>0.397</td>
</tr>
<tr>
<td>3</td>
<td>16000</td>
<td>0.402</td>
</tr>
<tr>
<td>4</td>
<td>15552</td>
<td>0.413</td>
</tr>
<tr>
<td>5</td>
<td>14981</td>
<td>0.419</td>
</tr>
<tr>
<td>6</td>
<td>12070</td>
<td>0.418</td>
</tr>
<tr>
<td>7</td>
<td>11848</td>
<td>0.411</td>
</tr>
<tr>
<td>8</td>
<td>11331</td>
<td>0.406</td>
</tr>
<tr>
<td>9</td>
<td>10822</td>
<td>0.432</td>
</tr>
<tr>
<td>10</td>
<td>10000</td>
<td>0.418</td>
</tr>
<tr>
<td>11</td>
<td>9713</td>
<td>0.429</td>
</tr>
<tr>
<td>12</td>
<td>8850</td>
<td>0.436</td>
</tr>
<tr>
<td>13</td>
<td>8264</td>
<td>0.450</td>
</tr>
<tr>
<td>14</td>
<td>8035</td>
<td>0.451</td>
</tr>
<tr>
<td>15</td>
<td>7880</td>
<td>0.459</td>
</tr>
<tr>
<td>16</td>
<td>7761</td>
<td>0.465</td>
</tr>
<tr>
<td>17</td>
<td>7427</td>
<td>0.467</td>
</tr>
<tr>
<td>18</td>
<td>7092</td>
<td>0.479</td>
</tr>
<tr>
<td>19</td>
<td>7097</td>
<td>0.486</td>
</tr>
<tr>
<td>20</td>
<td>6748</td>
<td>0.496</td>
</tr>
<tr>
<td>21</td>
<td>6219</td>
<td>0.519</td>
</tr>
</tbody>
</table>

1. **Notes:**
   All thicknesses are for an 'equivalent Ge' thickness
   (i.e. NOT the total physical thickness of the substrate and the multilayer stacks).
### Table 2 Refractive Index Data

<table>
<thead>
<tr>
<th>Channel</th>
<th>Wavelength</th>
<th>Ge @ 293K</th>
<th>Ge @ 65K</th>
<th>ZnSe @ 293K</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17376</td>
<td>4.0007</td>
<td>3.9257</td>
<td>2.3396</td>
</tr>
<tr>
<td>2</td>
<td>16461</td>
<td>4.0009</td>
<td>3.9259</td>
<td>2.3510</td>
</tr>
<tr>
<td>3</td>
<td>16000</td>
<td>4.0010</td>
<td>3.9260</td>
<td>2.3563</td>
</tr>
<tr>
<td>4</td>
<td>15552</td>
<td>4.0011</td>
<td>3.9260</td>
<td>2.3613</td>
</tr>
<tr>
<td>5</td>
<td>14981</td>
<td>4.0012</td>
<td>3.9262</td>
<td>2.3673</td>
</tr>
<tr>
<td>6</td>
<td>12070</td>
<td>4.0022</td>
<td>3.9270</td>
<td>2.3931</td>
</tr>
<tr>
<td>7</td>
<td>11848</td>
<td>4.0023</td>
<td>3.9271</td>
<td>2.3948</td>
</tr>
<tr>
<td>8</td>
<td>11331</td>
<td>4.0026</td>
<td>3.9273</td>
<td>2.3985</td>
</tr>
<tr>
<td>9</td>
<td>10822</td>
<td>4.0029</td>
<td>3.9275</td>
<td>2.4020</td>
</tr>
<tr>
<td>10</td>
<td>10000</td>
<td>4.0036</td>
<td>3.9281</td>
<td>2.4072</td>
</tr>
<tr>
<td>11</td>
<td>9713</td>
<td>4.0038</td>
<td>3.9283</td>
<td>2.4089</td>
</tr>
<tr>
<td>12</td>
<td>8850</td>
<td>4.0046</td>
<td>3.9290</td>
<td>2.4137</td>
</tr>
<tr>
<td>13</td>
<td>8264</td>
<td>4.0055</td>
<td>3.9296</td>
<td>2.4167</td>
</tr>
<tr>
<td>14</td>
<td>8035</td>
<td>4.0058</td>
<td>3.9299</td>
<td>2.4178</td>
</tr>
<tr>
<td>15</td>
<td>7888</td>
<td>4.0061</td>
<td>3.9301</td>
<td>2.4185</td>
</tr>
<tr>
<td>16</td>
<td>7761</td>
<td>4.0063</td>
<td>3.9303</td>
<td>2.4191</td>
</tr>
<tr>
<td>17</td>
<td>7427</td>
<td>4.0069</td>
<td>3.9309</td>
<td>2.4206</td>
</tr>
<tr>
<td>18</td>
<td>7092</td>
<td>4.0077</td>
<td>3.9315</td>
<td>2.4221</td>
</tr>
<tr>
<td>19</td>
<td>7097</td>
<td>4.0076</td>
<td>3.9315</td>
<td>2.4220</td>
</tr>
<tr>
<td>20</td>
<td>6748</td>
<td>4.0085</td>
<td>3.9321</td>
<td>2.4235</td>
</tr>
<tr>
<td>21</td>
<td>6219</td>
<td>4.0101</td>
<td>3.9334</td>
<td>2.4256</td>
</tr>
</tbody>
</table>

**Notes:**
   Data @ 65K is extrapolated from 100K.
2. ZnSe data from CodeV data base.
3. Refractive indices converted to their vacuum values
Fig 1: Optical System Layout (Not to scale - for reference only)
Fig 2 Optical System after the second image plane.
(Not to scale - for reference only)

Fig 3 STOP to Detector Layout
(Not to scale - for reference only)
Fig 5 Global Co-ordinates Reference Axes.
(Not to scale - for reference only)

Global axes aligned with these but displaced by:
X = -1095.880
Y = -397.000
Z = -617.320
### Table 3: Global System Co-ordinates for the Pole of Each Component.

<table>
<thead>
<tr>
<th>Surface</th>
<th>X-Coord</th>
<th>Y-Coord</th>
<th>Z-Coord</th>
<th>L-Dir Cosine</th>
<th>M-Dir Cosine</th>
<th>N-Dir Cosine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan Mirror</td>
<td>1095.880</td>
<td>397.000</td>
<td>617.320</td>
<td>1.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>PDB</td>
<td>869.859</td>
<td>397.000</td>
<td>510.481</td>
<td>0.9041</td>
<td>0.0000</td>
<td>0.4274</td>
</tr>
<tr>
<td>Paraboloid</td>
<td>660.170</td>
<td>397.000</td>
<td>204.521</td>
<td>0.9041</td>
<td>0.0000</td>
<td>0.4274</td>
</tr>
<tr>
<td>First image plane normal</td>
<td>1048.925</td>
<td>397.000</td>
<td>388.285</td>
<td>0.9999</td>
<td>0.0000</td>
<td>0.0133</td>
</tr>
<tr>
<td>Ellipsoid</td>
<td>1163.172</td>
<td>397.000</td>
<td>450.316</td>
<td>0.8788</td>
<td>0.0000</td>
<td>0.4772</td>
</tr>
<tr>
<td>ILS</td>
<td>1078.417</td>
<td>397.000</td>
<td>353.515</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Second Image plane and Warm Filter Front</td>
<td>820.433</td>
<td>397.000</td>
<td>264.224</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Warm Filter Back</td>
<td>819.582</td>
<td>397.000</td>
<td>263.929</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Lens 1 front</td>
<td>739.182</td>
<td>397.000</td>
<td>236.102</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Lens 1 back</td>
<td>735.875</td>
<td>397.000</td>
<td>234.957</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>STOP</td>
<td>514.925</td>
<td>397.000</td>
<td>158.484</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Lens 2 front</td>
<td>495.584</td>
<td>397.000</td>
<td>151.790</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Lens 2 back</td>
<td>492.749</td>
<td>397.000</td>
<td>150.809</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Window Front</td>
<td>487.321</td>
<td>397.000</td>
<td>148.930</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Window Back</td>
<td>485.431</td>
<td>397.000</td>
<td>148.276</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Cold Filter Front</td>
<td>461.806</td>
<td>397.000</td>
<td>140.099</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Cold Filter back</td>
<td>461.428</td>
<td>397.000</td>
<td>139.968</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
<tr>
<td>Final Image plane</td>
<td>461.333</td>
<td>397.000</td>
<td>139.935</td>
<td>0.9450</td>
<td>0.0000</td>
<td>0.3271</td>
</tr>
</tbody>
</table>

**Note:** Cold Filter Plane Front is variable.
Table 4: Global system Co-ordinates of the Surface Intersection with the On-axis Chief Ray

<table>
<thead>
<tr>
<th>Surface</th>
<th>X-Coord (mm)</th>
<th>Y-Coord (mm)</th>
<th>Z-Coord (mm)</th>
<th>Distance from last surface (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan Mirror</td>
<td>1095.880</td>
<td>397.000</td>
<td>617.320</td>
<td>------</td>
</tr>
<tr>
<td>PDB</td>
<td>869.859</td>
<td>397.000</td>
<td>510.481</td>
<td>250.000</td>
</tr>
<tr>
<td>Paraboloid</td>
<td>598.635</td>
<td>397.000</td>
<td>382.273</td>
<td>300.000</td>
</tr>
<tr>
<td>First image plane normal</td>
<td>1048.925</td>
<td>397.000</td>
<td>388.285</td>
<td>450.331</td>
</tr>
<tr>
<td>Ellipsoid</td>
<td>1184.090</td>
<td>397.000</td>
<td>390.090</td>
<td>135.177</td>
</tr>
<tr>
<td>ILS</td>
<td>1078.417</td>
<td>397.000</td>
<td>353.515</td>
<td>118.823</td>
</tr>
<tr>
<td>Second Image plane an Warm Filter Front</td>
<td>820.433</td>
<td>397.000</td>
<td>264.224</td>
<td>273.000</td>
</tr>
<tr>
<td>Warm Filter Back</td>
<td>819.582</td>
<td>397.000</td>
<td>263.929</td>
<td>0.900</td>
</tr>
<tr>
<td>Lens 1 front</td>
<td>739.182</td>
<td>397.000</td>
<td>236.102</td>
<td>85.080</td>
</tr>
<tr>
<td>Lens 1 back</td>
<td>735.875</td>
<td>397.000</td>
<td>234.957</td>
<td>3.5000</td>
</tr>
<tr>
<td>STOP</td>
<td>514.925</td>
<td>397.000</td>
<td>158.484</td>
<td>233.810</td>
</tr>
<tr>
<td>Lens 2 front</td>
<td>495.584</td>
<td>397.000</td>
<td>151.790</td>
<td>20.466</td>
</tr>
<tr>
<td>Lens 2 back</td>
<td>492.749</td>
<td>397.000</td>
<td>150.809</td>
<td>3.000</td>
</tr>
<tr>
<td>Window Front</td>
<td>487.321</td>
<td>397.000</td>
<td>148.930</td>
<td>5.744</td>
</tr>
<tr>
<td>Window Back</td>
<td>485.431</td>
<td>397.000</td>
<td>148.276</td>
<td>2.000</td>
</tr>
<tr>
<td>Cold Filter Front</td>
<td>461.806</td>
<td>397.000</td>
<td>140.099</td>
<td>25.000</td>
</tr>
<tr>
<td>Cold Filter back</td>
<td>461.428</td>
<td>397.000</td>
<td>139.968</td>
<td>0.4000</td>
</tr>
<tr>
<td>Final Image plane</td>
<td>461.333</td>
<td>397.000</td>
<td>139.935</td>
<td>0.1000</td>
</tr>
</tbody>
</table>

Note: Cold Filter Plane Front is variable