Puntino Minisensor: setup and use

Version 2.0
September 2011

1. Puntino Minisensor: overview

Telescope flange

Cooled camera

Calibration LED

5V DC, 20mA. Tip: +ve

Puntino minisensor

1. Puntino Minisensor can test telescopes from about F/2 to F/18
2. The current Puntino Minisensor is designed for a telescope of focal ratio F/6
3. The Shack-Hartmann lenslet array has a pitch of 0.3mm and focal length 41mm
4. It has a collimator of focal length 50mm with an aperture of 9mm, giving 30x30 spots with the reference source
5. With the F/6 telescope, the pupil diameter is 50/6=8.3mm, giving 28x28 spots
6. The reference image is taken with a LED with a pinhole of 10μ
7. The peak wavelength of emission of the reference image is 623±15nm
8. The power supply for the LED is 5V DC with a current of 20mA. The polarity is center (or tip) positive

2. Sensoft: overview

Sensoft controls the SH camera and performs the Shack-Hartmann analysis

Important points:

1. **Reference image**: This is the calibration image used to remove the aberrations of the optics inside Puntino Minisensor
2. **Mir image**: This is the SH image from the telescope
3. **Loop (coma)**: Very useful for alignment of M1 and M2 by looking at the coma plot in loop mode
4. **Loop (Ast):** Very useful for adjustment of telescope supports looking at the Ast plot in loop mode
5. **Loop (aberrations)**: For following Zernike aberrations in loop mode
6. **Loop (WF zonal - AQ)**: For following zonal WF in loop mode after subtraction of tilt or tilt and defocus. Called AQ (Actual Quality)
7. **Loop (WF zonal - PQ)**: For following zonal WF in loop mode after subtraction of first seven Zernike terms: tilt, defocus, coma, 3rd order spherical aberration, astigmatism, triangular coma and quadratic astigmatism. Called PQ (Potential Quality)
8. **Loop (WF modal - AQ)**: For following modal WF in loop mode after subtraction of tilt or tilt and defocus
9. **CAlign**: For alignment of the Mirror and Reference image with center of CCD
10. **Align**: For alignment of the Mirror image with reference image
11. **Coll**: Used to collimate the light from the telescope in loop mode

## 3. Unpacking and setting up Puntino Minisensor
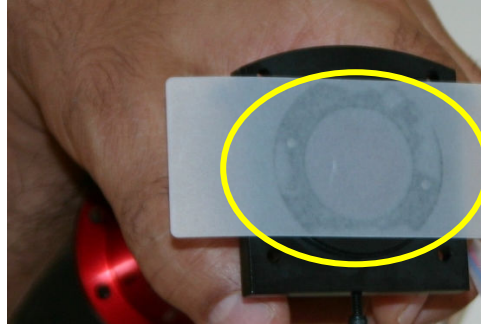
1. Unpack Puntino Minisensor.
2. The calibration LED is packaged separately
3. Remove the protective adapter and tape as shown above from the 'D'-mount
4. Using 4 screws, mount the 'D'-mount on the SBIG camera body
5. Screw in the calibration LED mount into the Puntino Minisensor body till the end (Tip: Hold the wire vertical as you rotate the mount)


Inserting the calibration LED

6. Connect a 5V DC power supply to the LED and check that it is working
7. Connect the SBIG camera to the PC and start Sensoft and get the SH image by clicking Live
8. You can use 2x2 binning to speed up the download and display of the image

4. Alignment of Puntino lenslet with rows & columns of CCD

Screws for coarse alignment of Puntino and CCD

Setscrews for fine alignment of lenslet

1

2

3
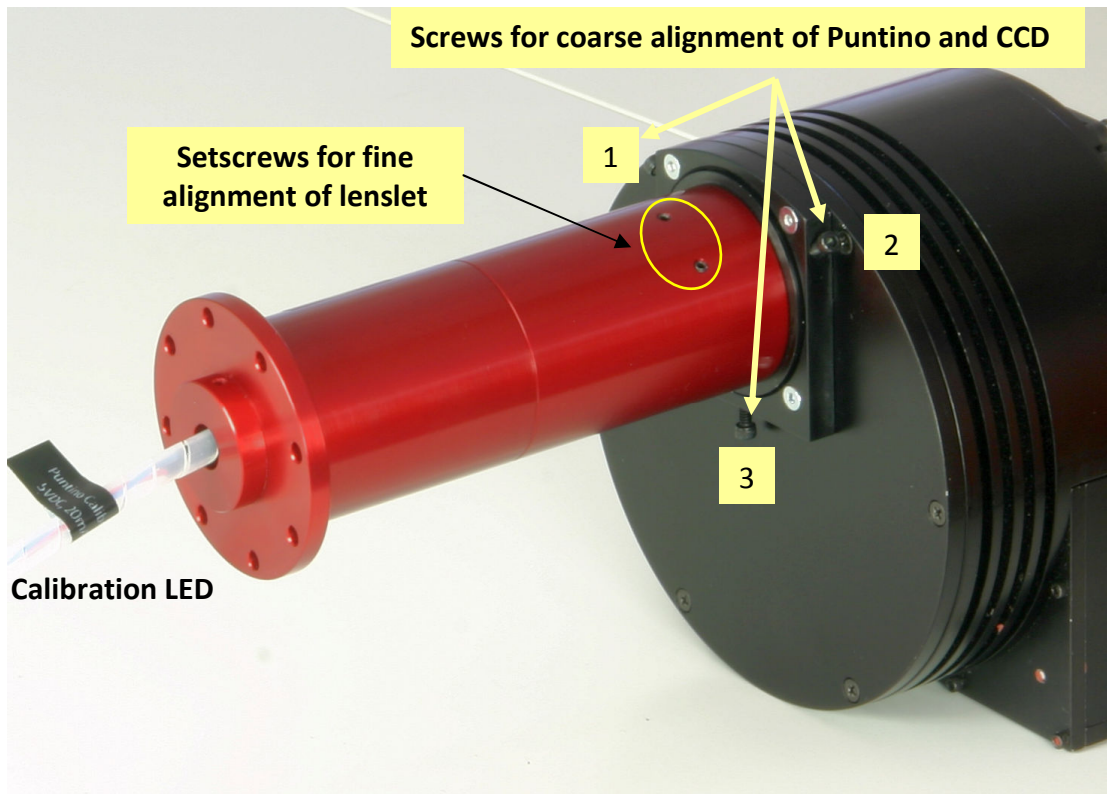
Calibration LED

Steps:

1. Screw-in the calibration LED mount into the telescope flange
2. Connect a 5VDC (> 50mA) power supply to the LED
3. Switch on-the camera
4. Use Sensoft to get the Live SH image using 2x2 or 3x3 binning (if available)
5. After unscrewing the T-mount adapter, rotate it along with Puntino along with the till the spots are aligned along the rows of the CCD
6. The tolerance for the alignment is about 2 pixels from the center of the extreme left to the extreme right spot
7. Once Puntino has been aligned, tighten the screws
8. If required, do fine alignment using the two set screws on the body of Puntino
9. To allow easier circulation of air inside Puntino, the lenslet array mount is held only by the two set-screws. Though it fits snugly into the housing, avoid unscrewing the screws completely to avoid it slipping out.
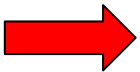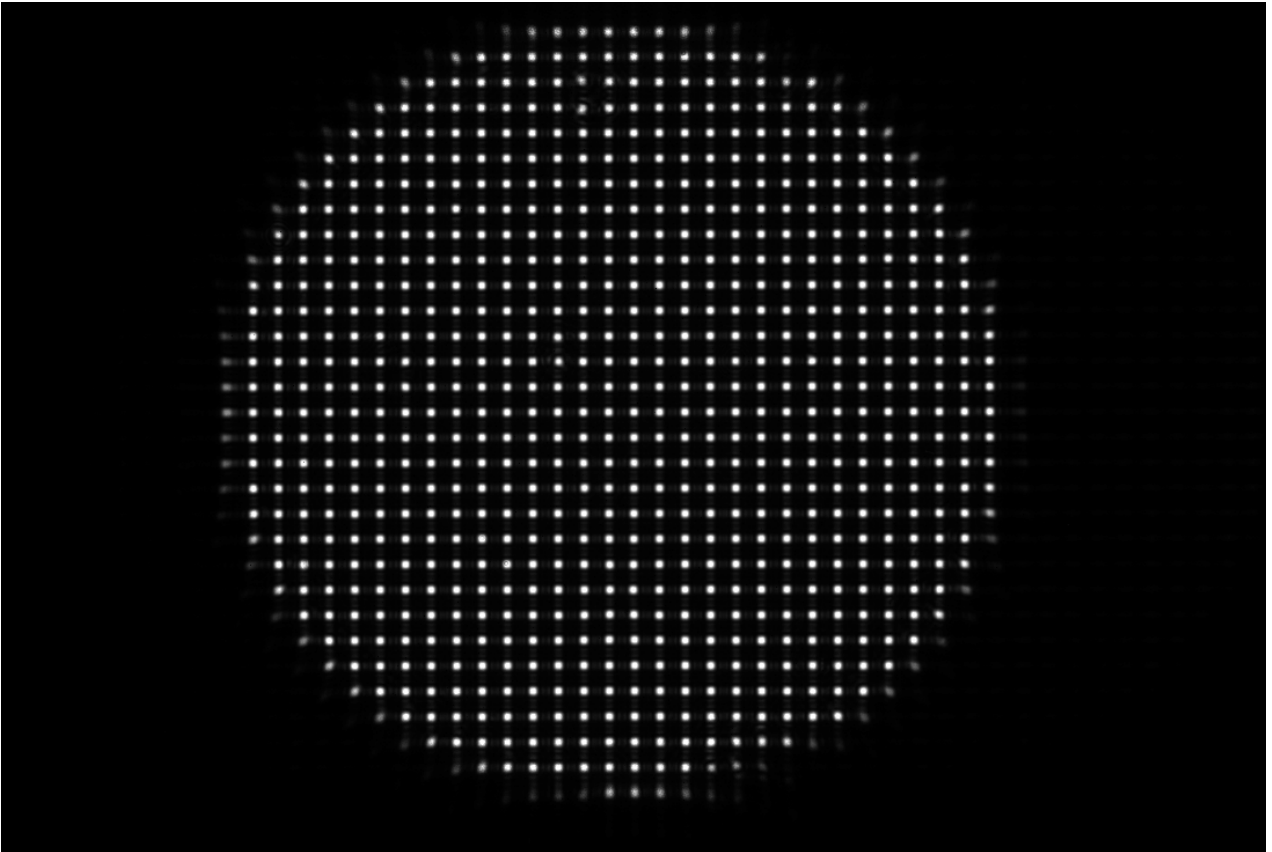
A well-aligned image is shown above. You can either use the artificial grid generated by Sensoft or the cursor to check the x coordinates of the extreme left and extreme right spots on a row. They should agree to about 1-2 pixels.

5. First tests in the lab

1. Take the Reference image by clicking the Ref button - making sure that the image is not saturated. This will automatically give you the reference centroids
2. Click the Mir button
3. Sensoft should go through the full analysis and show you the output as shown below

Sensoft - Shack-Hartmann wavefront sensor software for Puntino Minisensor - CCD camera

File Edit Toolbars Image arithmetic Tools Motor Simulation Utilities Window Help

Sensoft results Repeat0001.cofx

Image	Date	Time	Exp.time	Thresh.	Ellipt.
Test: Repeat0001	2011-08-11	17:29:00	25.000 sec	0.147	0.70
Ref: REF0001	2011-08-11	17:27:32	25.000 sec	0.143	0.70

Standard Zernike coefficients

Aber	m n	Cx(nm)	Cy(nm)	C(nm)	D(")	Angle(°)
Defocus	0 2			0.5	0.30	
Tilt	1 1	5.1	-0.0	5.1	0.45	-0.2
Coma3	1 3	0.1	0.1	0.1	0.14	65.2
SA3	0 4			-0.3	-0.32	
Ast3	2 2	0.9	1.0	1.4	0.60	47.6
TComa	3 3	0.6	0.8	1.0	0.74	50.9
QAst	4 4	0.6	-0.2	0.6	0.69	-23.4

Surface (values in nm)

Quality	Max	Min	Average	P-V	Rms	Strehl
Residual	13.3	-13.5	0.0	26.8	1.5	0.999
Actual *	15.1	-12.7	0.0	27.7	1.8	0.999

4. You should get a PV of about 30nm and an rms of about 2nm
5. You can choose the graphs to be displayed in the SH-Graphics section

6. Considerations on the reference image

1. The reference image should be well exposed without being saturated
2. The saturation for this CCD is at 65500 counts (16-bit). It changes with the model. For a 12-bit CCD it is 4095 and for an 8-bit it is 255.
3. Use the Histogram button on the toolbar to generate the histogram and check the saturation
4. The recommend exposure time is approximately 30 seconds for the F/6 Puntino
5. The reference image can be saved on the PC and Sensoft will pick it up automatically
6. In general only the defocus will change with temperature, so you can use one reference image taken at the start of the night
7. If you do not change anything (rotation of the Puntino Minisensor with respect to the CCD), then the same reference image can be used subsequently. The key point is to avoid rotation
8. You may, in the long run, take a series of calibration images during the night (or at different temperatures) and storing them on the PC. You can then ask the software to pick up the correct reference image according to the current temperature that you are observing at
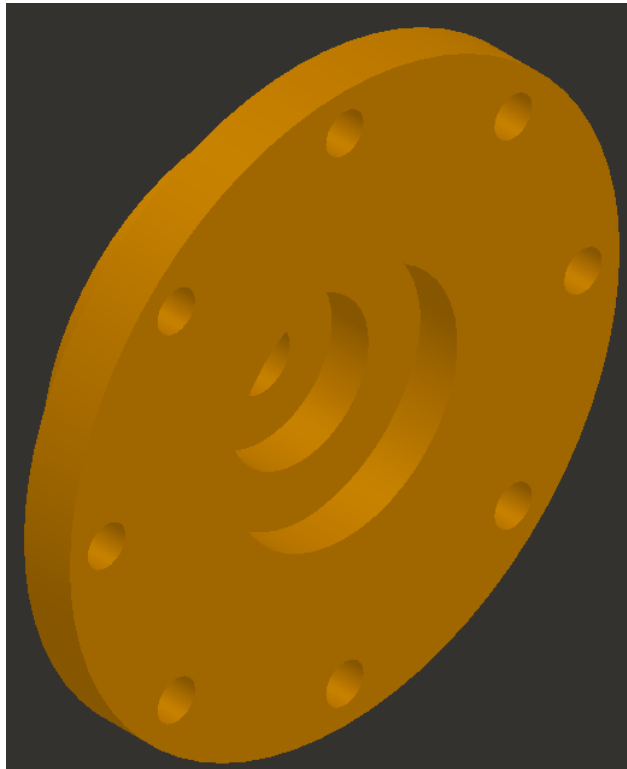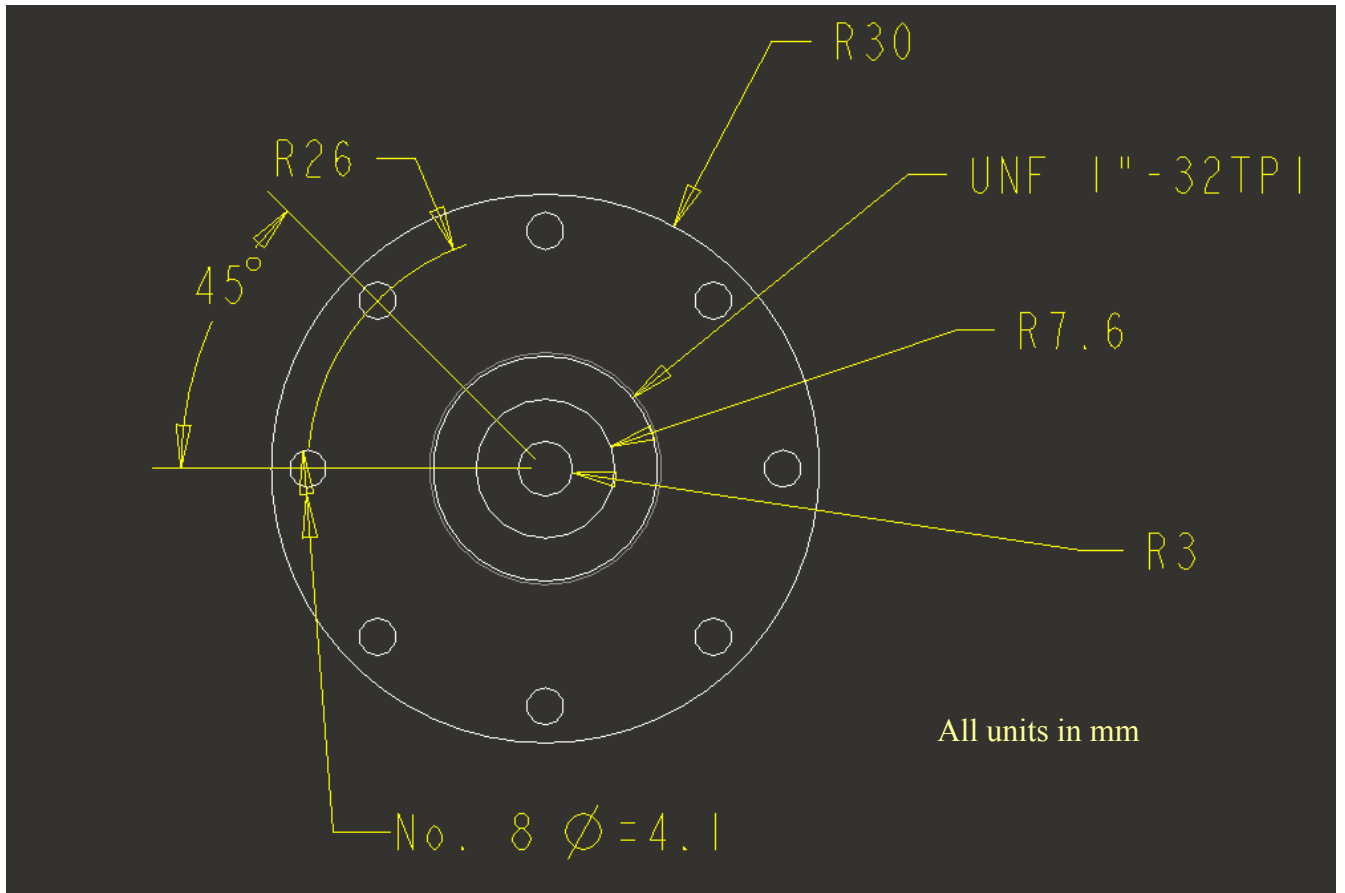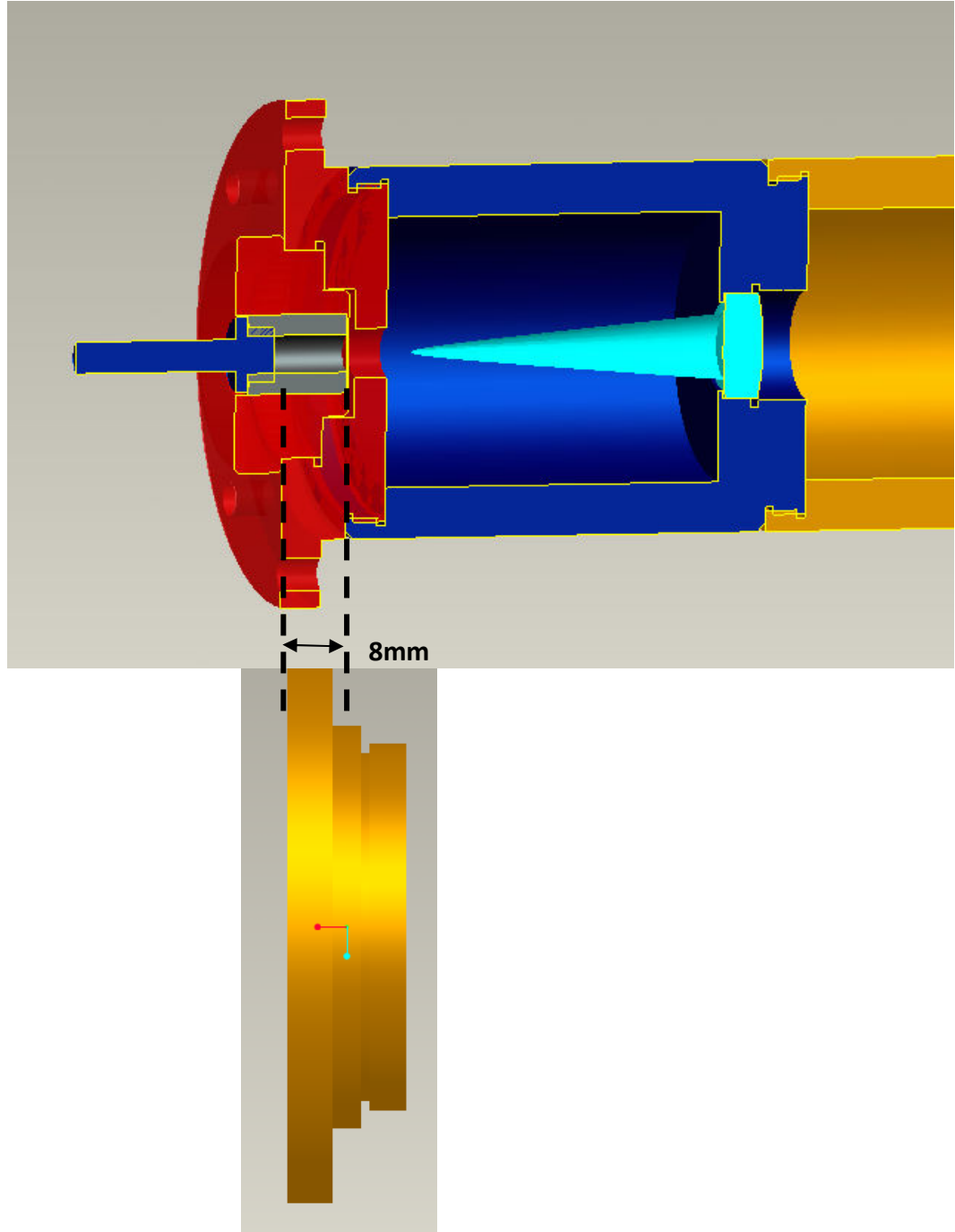
Appendix A

Definitions

1. **Zonal wavefront (WF):** Wavefront constructed after numerical integration of the residuals. This is the 'real' WF. It includes low frequency symmetrical effects (represented by Zernike coefficients) as well as high frequency effects (that cannot be represent by Zernike aberrations, e.g. ripple and micro ripple)
2. **Modal wavefront (WF):** Obtained after summing up the Zernike coefficients obtained from the SH analysis. Thus, they only represent the low frequency symmetrical aberrations that can be represented by Zernike coefficients
3. **Actual Quality (AQ)**: WF after subtracting tilt or tilt and defocus (that are computed from the Zernike analysis) from the raw WF
4. **Loop (WF zonal - PQ)**: WF after subtracting first seven Zernike terms: tilt, defocus, coma, 3rd order spherical aberration, astigmatism, triangular coma and quadratic astigmatism from the raw WF

Appendix B: Telescope flange dimensions

All units in mm

Appendix C: Position of focal plane
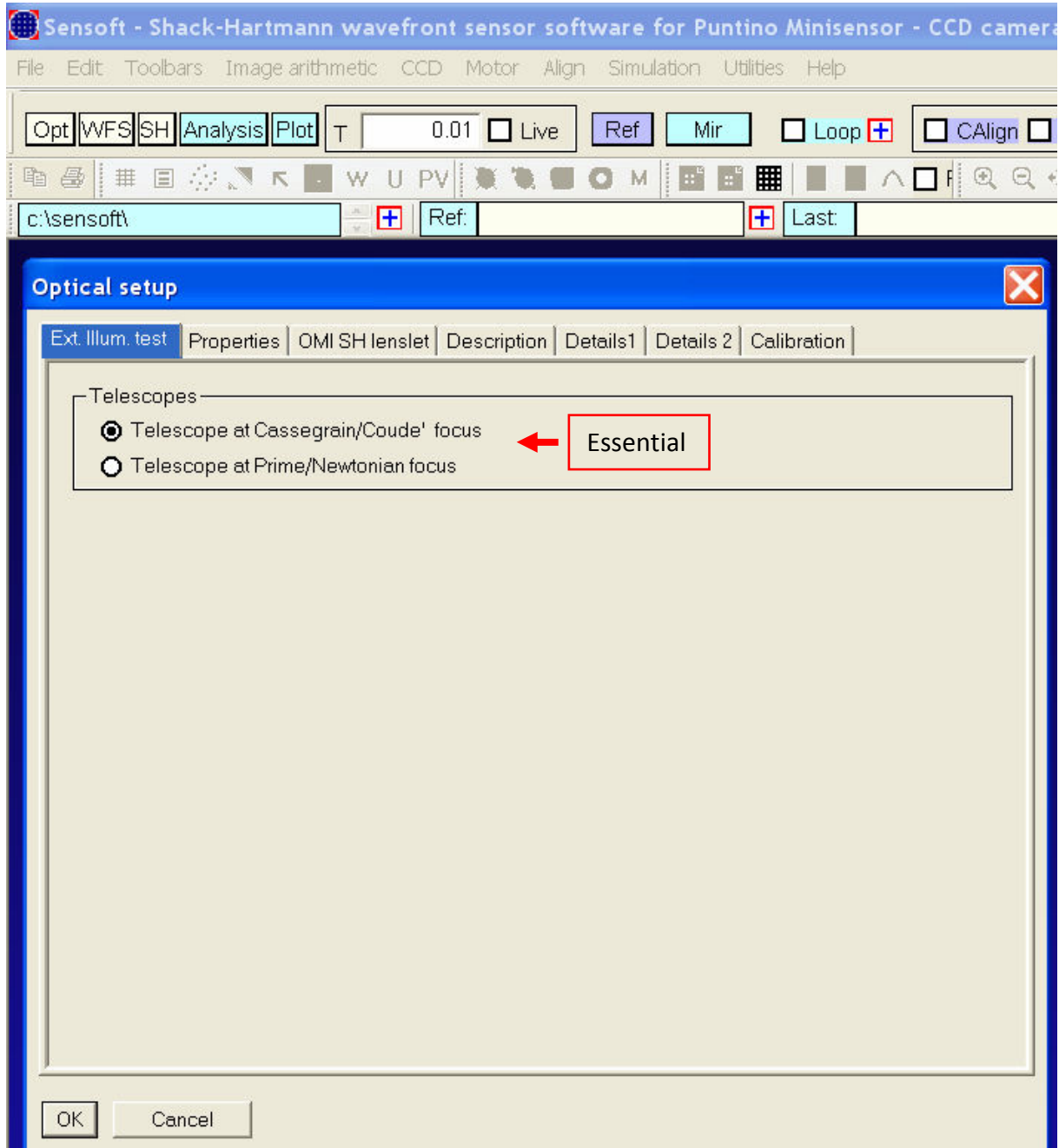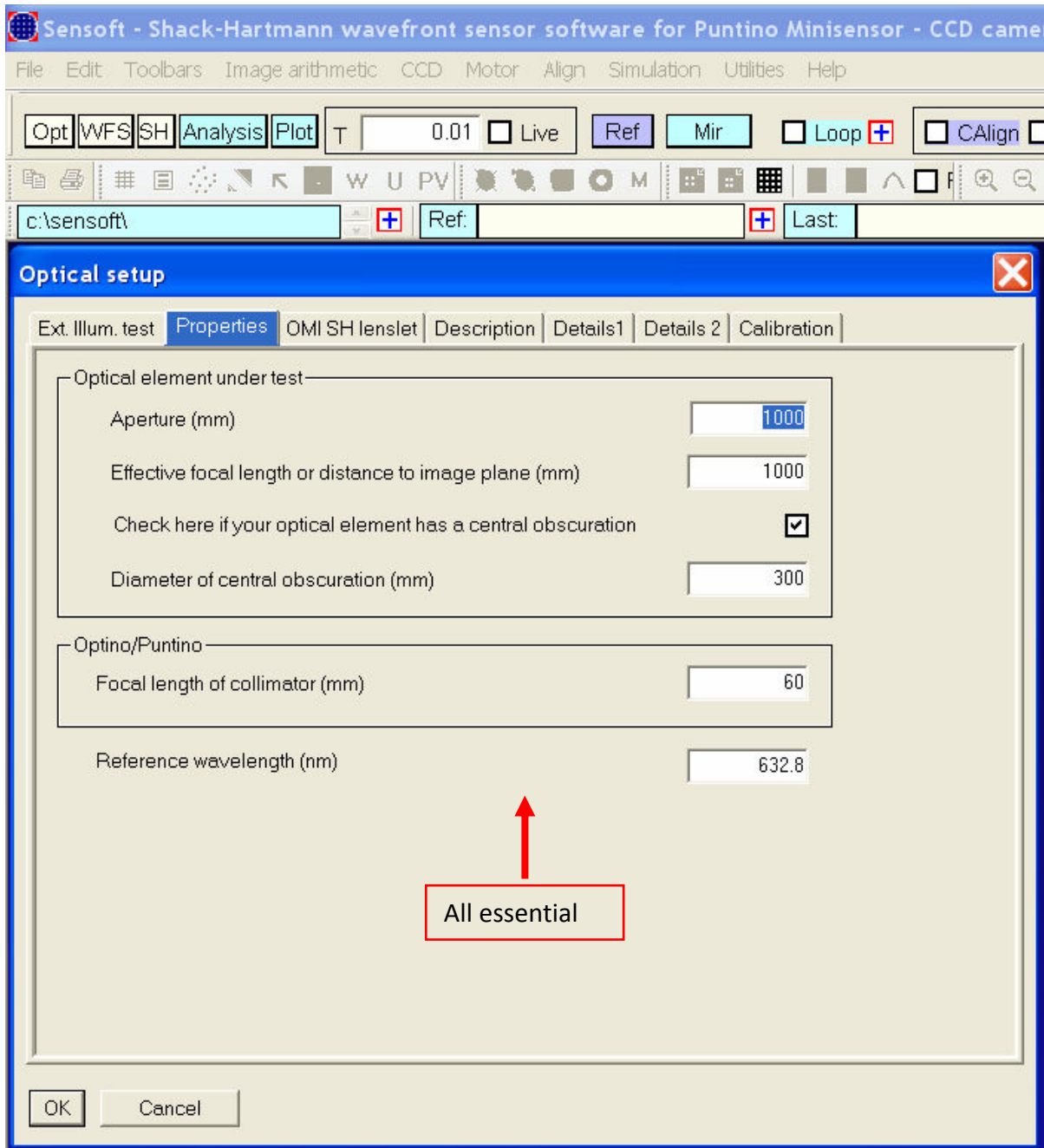
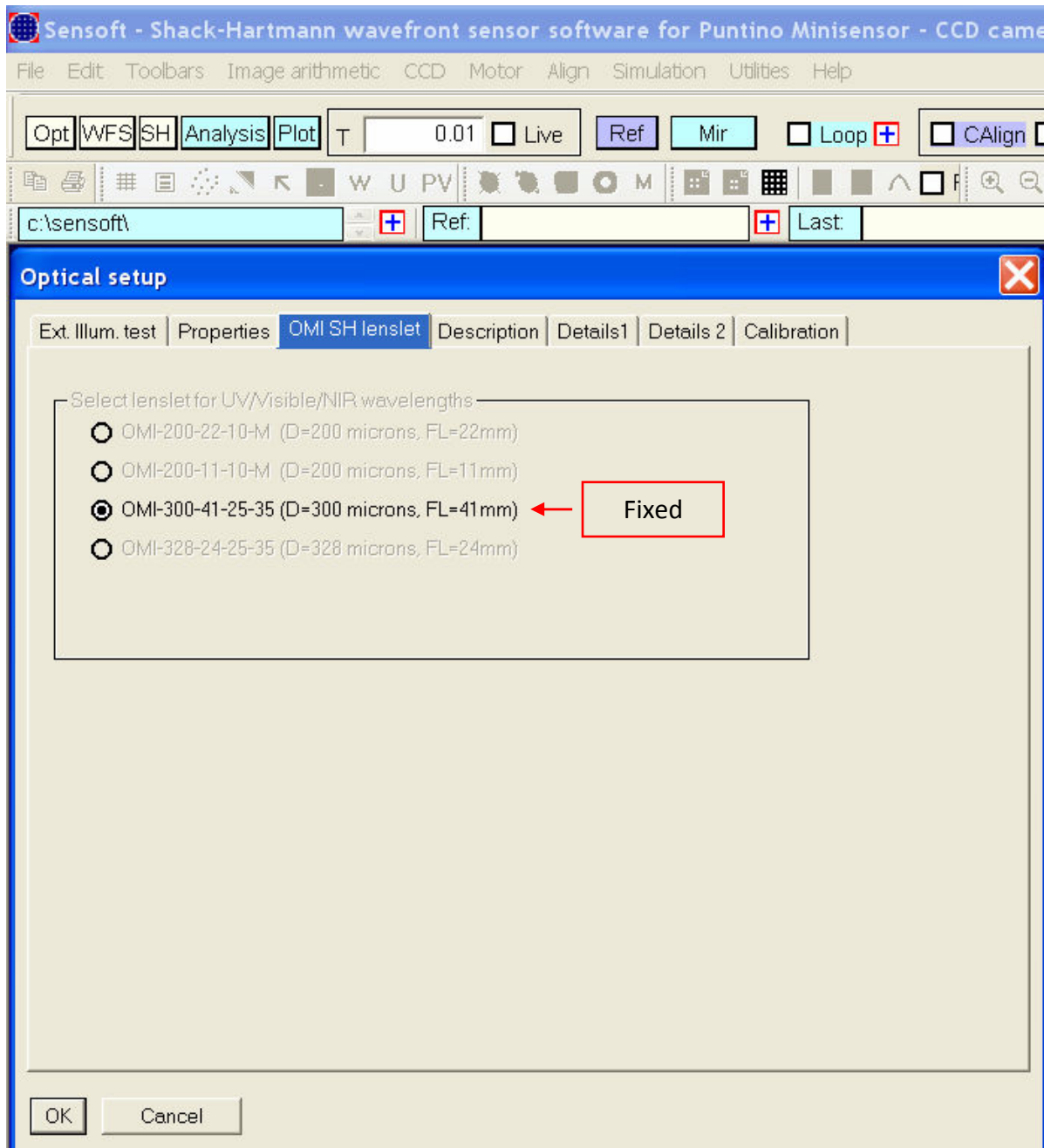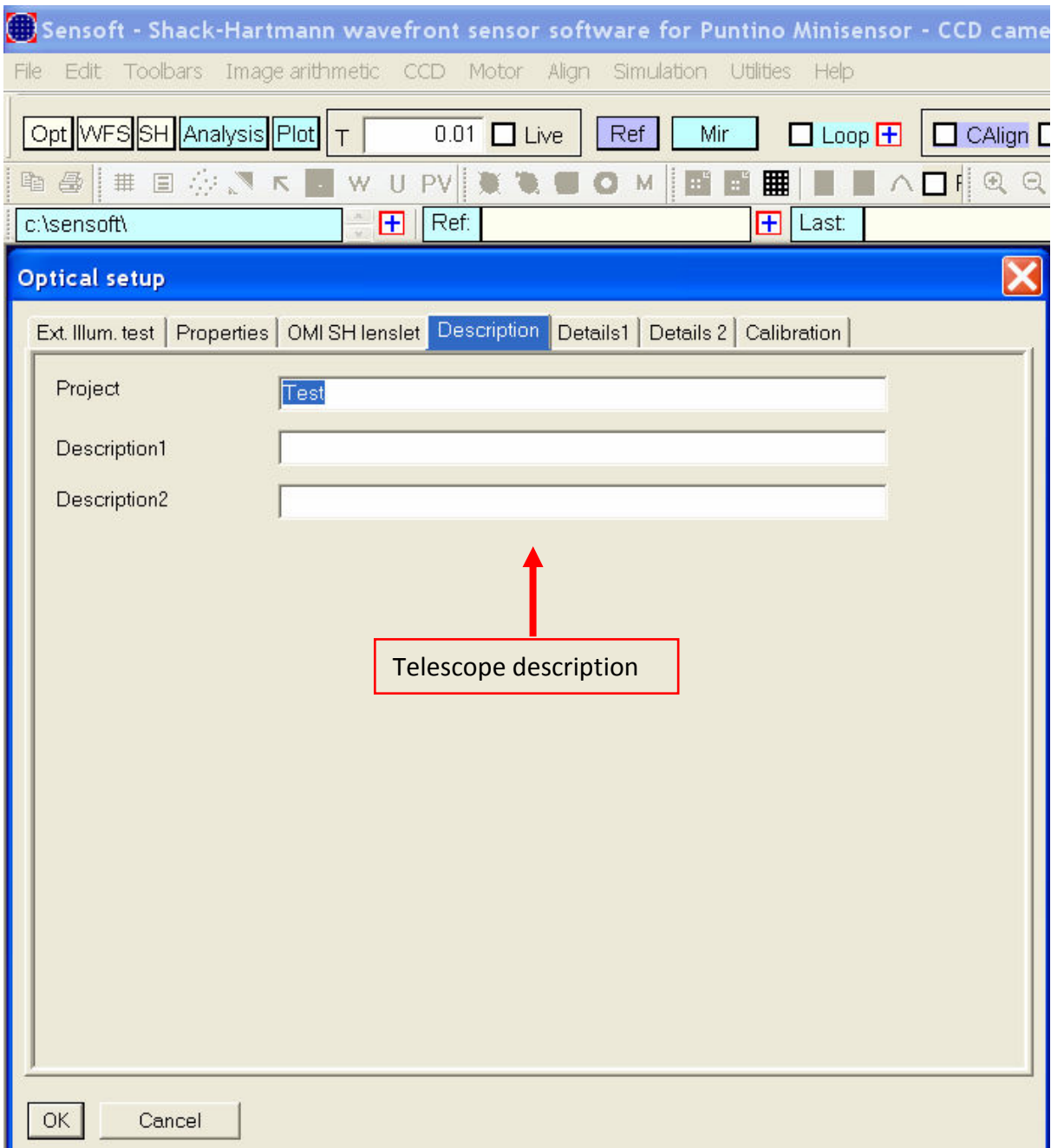The focal plane is 8mm from the outer flange as shown below

8mm

Appendix D: Optical parameters for Sensoft

The optical parameters for Sensoft are entered in the Opt page. Not all parameters are essential. Those that are essential have been marked accordingly. See detailed explanation below, taken from the Puntino Manual (Appendix A)

All essential

Telescope description

Sensoft - Shack-Hartmann wavefront sensor software for Puntino Minisensor - CCD came

File Edit Toolbars Image arithmetic CCD Motor Align Simulation Utilities Help

Opt WFS SH Analysis Plot T 0.01 ☐ Live   Ref   Mir   ☐ Loop ⊞   ☐ CAlign

c:\sensoft\ ⊞ Ref: ⊞ Last:

Optical setup

Ext. Illum. test | Properties | OMI SH lenslet | Description | Details1 | Details 2 | Calibration

Site

Latitude (o,',") 0 0 0

Longitude (o,',") 0 0 0

Focal length of telescope (mm) * 1000.000

Normalized obscuration ratio 0.3

Normalized back focal distance** 0.25

Distance M1-M2 (mm) 3166.67

Distance M2-focal plane (mm) 4166.67

The normalized back focal is essential and is used in the computation of coma correction. It is the distance form the vertex of M1 to the telescope focus. Other parameters are optional and are not used by Sensoft

*Entered in Optical properties page

**In units of the focal length of the primary mirror

OK Cancel

16

Sensoft - Shack-Hartmann wavefront sensor software for Puntino Minisensor - CCD came

File   Edit   Toolbars   Image arithmetic   CCD   Motor   Align   Simulation   Utilities   Help

Opt WFS SH Analysis Plot T 0.01 ☐ Live   Ref   Mir   ☐ Loop ⊞   ☐ CAlign

c:\sensoft\   ⊞   Ref: ⊞   Last:

Optical setup   ✕

Ext. Illum. test | Properties | OMI SH lenslet | Description | Details1 | Details 2 | Calibration

Configuration
Cassegrain   ◉   Gregorian   ○

	M1	M2
Diameter (mm) *	1000	435.09
Radius of curvature (mm)	-8000	-2083.33	← Essential
Conic coefficient K	-1.02105	-2.44737	← Essential

Nasmyth ☐

The radii of curvature and conic coefficients are required in the computation of coma correction using analytic formulae. See full manual

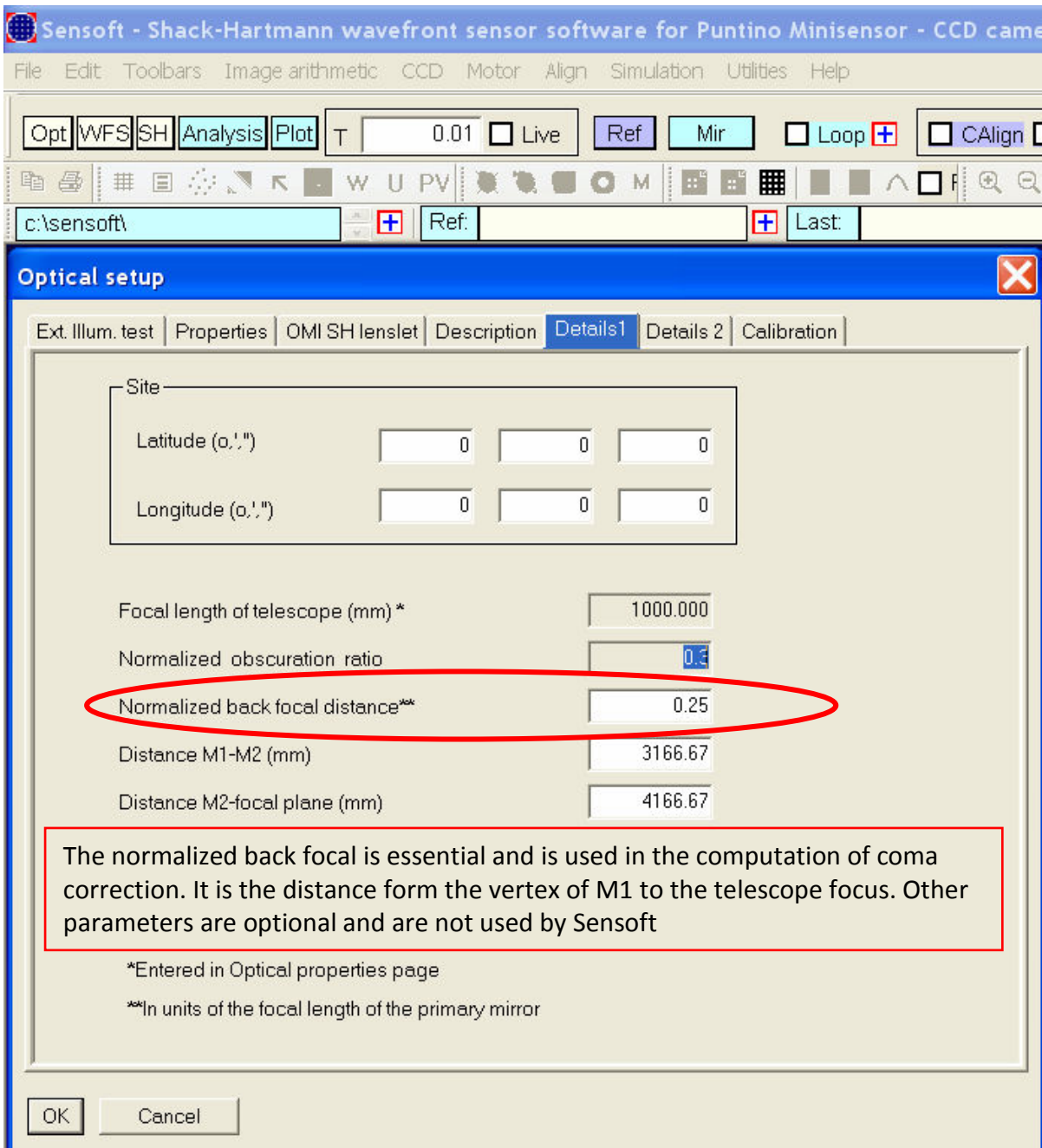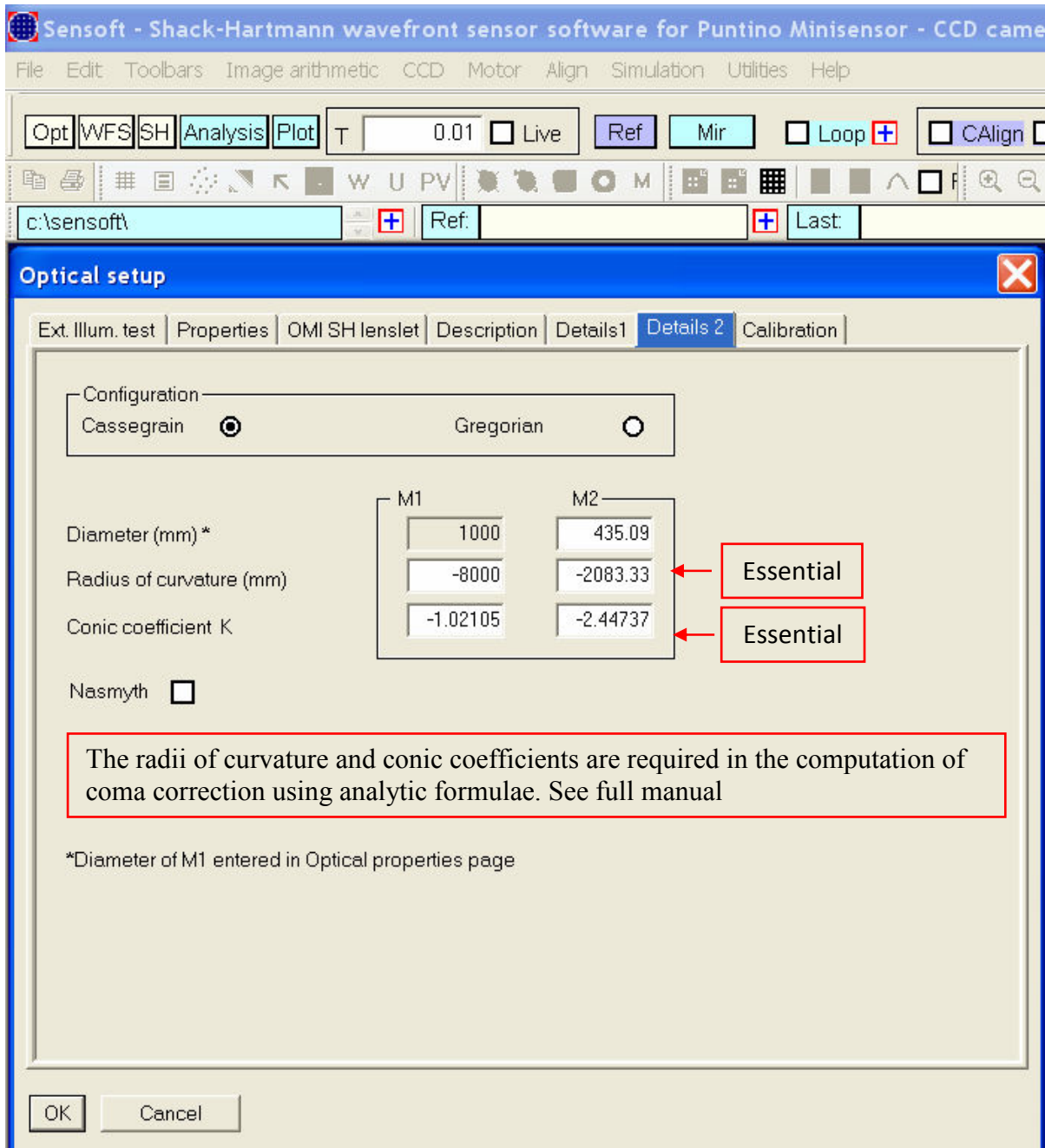*Diameter of M1 entered in Optical properties page

OK   Cancel

Appendix E: The input parameters for Puntino: Introduction (from Puntino Manual – Appendix A)

In the [Opt] section of Sensoft, the following details are required for the analysis. All the parameters are not required for the test. Some are requested for the sake of completeness only, so that all the parameters are available in one place.

Please see Chapter 12-20 of Puntino manual for definitions and sign-conventions.
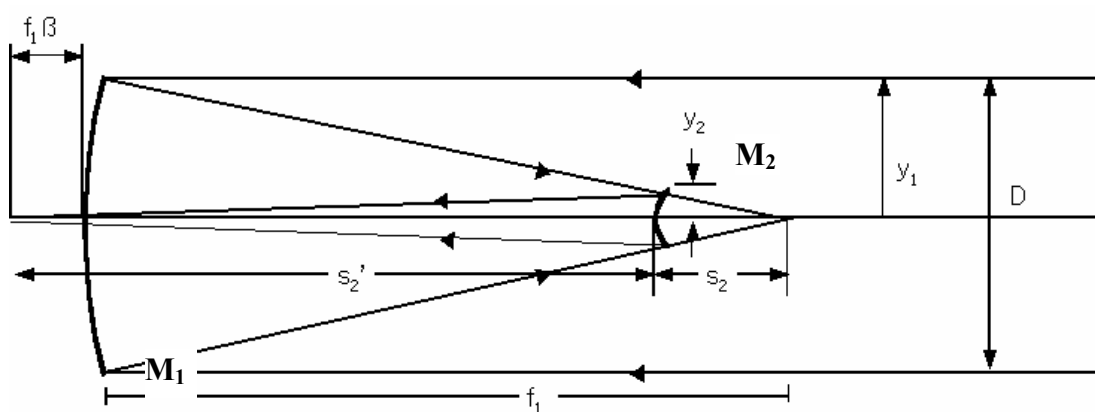
Here:

- D: Diameter or Aperture of M1
- M_1: primary mirror
- M_2: secondary mirror
- M_3: flat (Newtonian focus) or tertiary (Nasmyth focus) (not shown above)
- f_1: focal length of primary mirror
- f: focal length of telescope
- $f_1\beta$: back focal distance
- s_2: distance from vertex of M_2 to focus of M_1
- s_2': distance from vertex of M_2 to telescope focus
- y_1: height of marginal ray on M_1
- y_2: height of marginal ray on M_2

Appendix E1: Parameters for the analysis

No	Parameter	Where	Explanation	Units
		Table E1		
1	Test mode	[Optics/Test mode]		
2	Configuration[1]	[Optics/Details2]	Cassegrain or Gregorian	
3	Aperture (or diameter) of test optic (or diameter of M1)	[Optics/Properties]		mm
4	Effective focal length of telescope (or distance from the principal plane to the image plane of test optic)	[Optics/Properties]		mm
5	Normalized central hole	[Optics/Properties]	Greater of the two: 1. (Diameter of hole of M_1/Diameter of M_1) 2. (Obscuration of M_2 or M_3/Diameter of M_1)	none
6	Focal length of collimator of Puntino[1]	[Optics/Properties]		mm
7	Reference wavelength	[Optics/Properties]		mm
8	Aperture (or size) of M3 (if test is being done at Nasmyth or Newtonian focus)	[Optics/Details2]	Size of folding flat (Nasmyth or Newtonian focus)	mm

Notes:

[1] For test at Coude focus, use Cassegrain configuration

[2] The cover of Puntino shows the focal length of the collimator being used (models after the year 2004). For earlier models, please see the collimator mounting inside Puntino

Appendix E2: Parameters for coma and spherical aberration correction

See Chapters 13-15 of Puntino Manual

No	Parameter	Details	Where	Units
Table E2				
1	Type of calibration	Based on analytic formulae or empirical	[Optics/Calibration]	
If you are using the analytic formulae for the calibration (recommended) then the following parameters are required				
2	Normalized back focal distance	[Optics/Details 1]	(Distance from vertex of M_1/Focal length of M_1)	None
3	R_2	[Optics/Details 2]	Radius of curvature of M_2	mm
4	K_2	[Optics/Details 2]	Conic coefficient of M_2)	None
If you are using empirical calibration (for example using ray-tracing), the following parameters are required				
5	The size of the image containing 100% energy (unit: mm) as M_2 is moved by 1 (unit: mm)			
6	The length of tangential coma (TC) image as M_2 is tilted (unit: 1 radian) or decentered by 1mm			

Appendix E3: Additional parameters

No	Parameter	Where	Units
	Table E3		
1	Description	[Optics/ Description]	None
2	Distance vertex of M_1 to the vertex of M_2	[Optics/Details 1]	mm
3	Distance from vertex of M_2 to the focal the focal plane/image plane	[Optics/Details 1]	mm
4	R_1 (Radius of curvature of M_1)	[Optics/Details 2]	mm
5	K_1 (Conic coefficient of M_1)	[Optics/Details 2]	None
6	Aperture (or diameter) of M_2	[Optics/Details 2]	mm
7	Latitude	[Optics/Details 1]	Deg, min, sec
8	Longitude	[Optics/Details 1]	Deg, min, sec

AppendixE4: Saving and loading the configuration file (.OPT)

The parameters of the optical configuration are saved in a file with extension .opt [File Menu]. It can also be reloaded.

Additional parameters saved to the .opt file are:

- Parameters of the cameras [WFS/Data]

- The orientation of the SH telescope image (defined in [WFS/Orientation]) is also saved