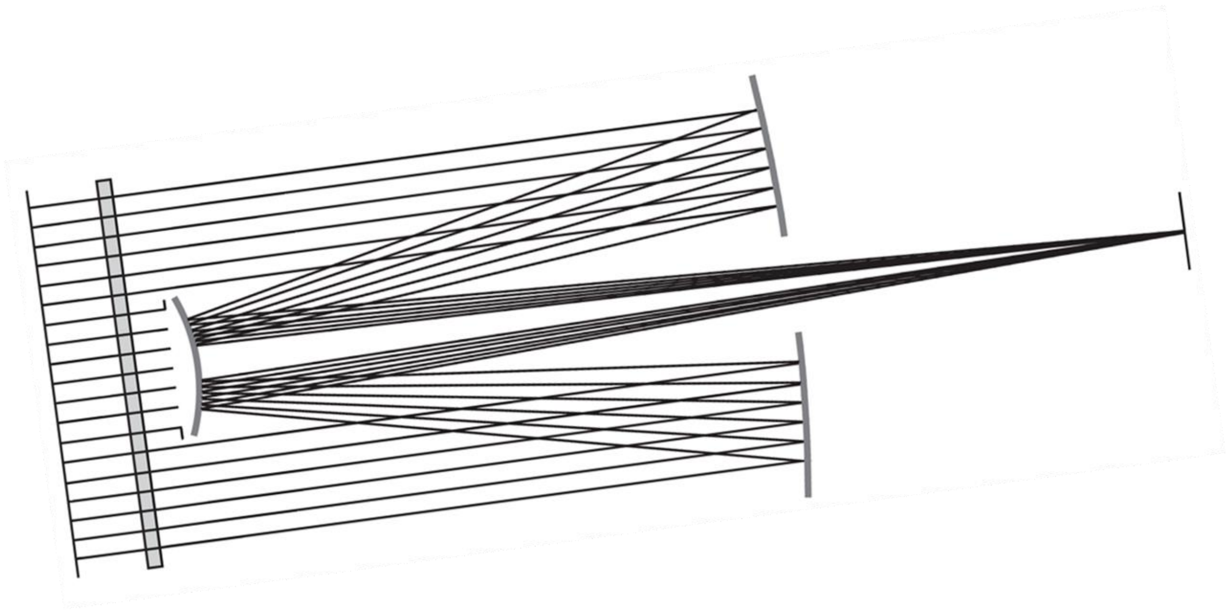
Schmidt-Cassegrain Telescope

Abstract



The Schmidt-Cassegrain telescope is a very popular design for amateur astronomical telescopes for its high contrast and low aberration effects. It consists of a Schmidt corrector plate and a Cassegrain reflector. The Cassegrain reflector is made up of a concave primary mirror for focusing the light and a convex secondary mirror that redirects the light back through a hole in the primary. This provides a long focal length even with a short tube length. The Schmidt plate itself is an aspherical lens used to correct spherical aberrations.

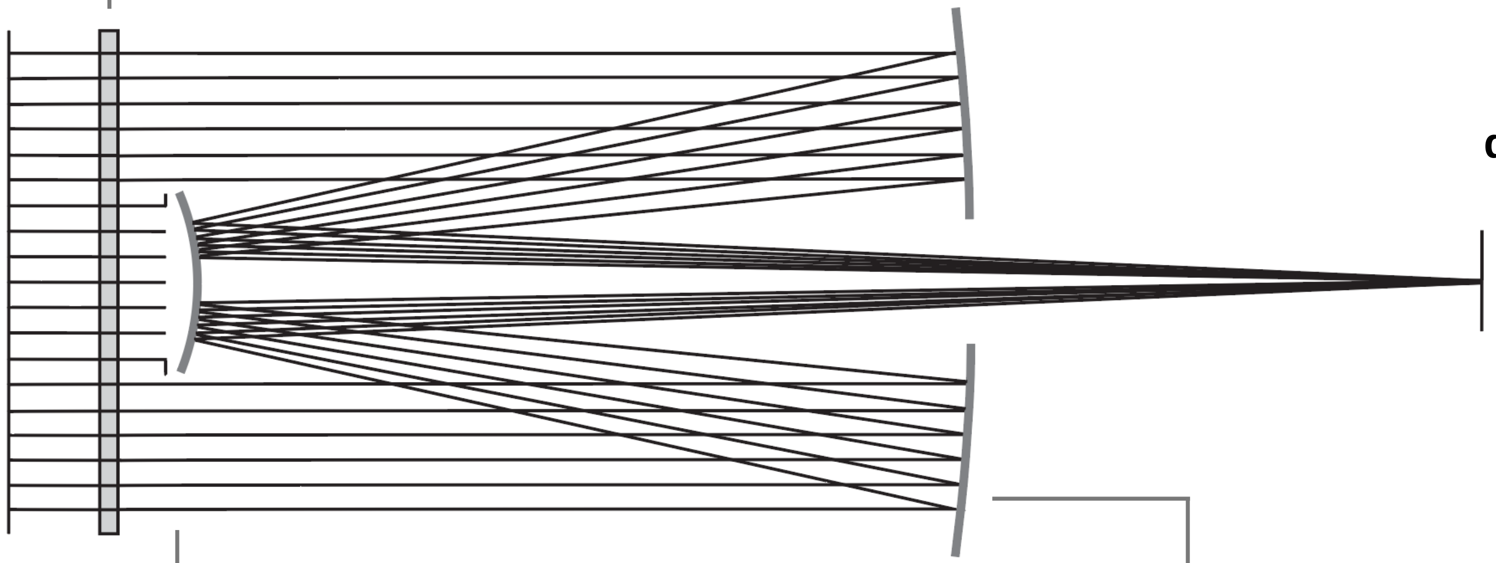
Modeling Task

How to model a Schmidt-Cassegrain telescope?

Schmidt corrector plate
aspherical lens for the correction of spherical aberration

telescope parameters from:
https://www.bay-astronomers.org

detector



plane wave

- wavelength (473, 532, 635) nm
- linearly polarized along x-axis
- maximum inclination: 0.25°
- aperture 200 mm × 200 mm

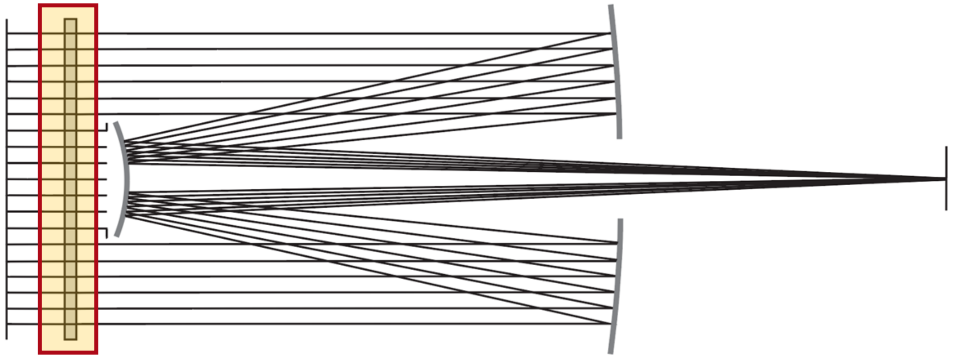
secondary mirror

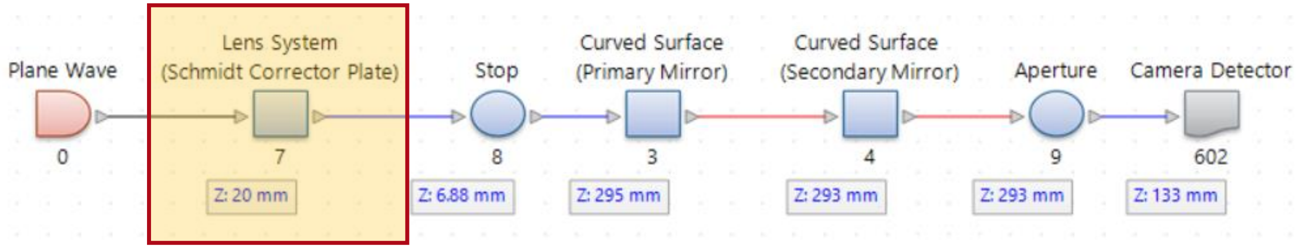
- hyperbolic mirror with radius -281 mm and conical constant -1.16
- mirror size 70 mm × 70 mm

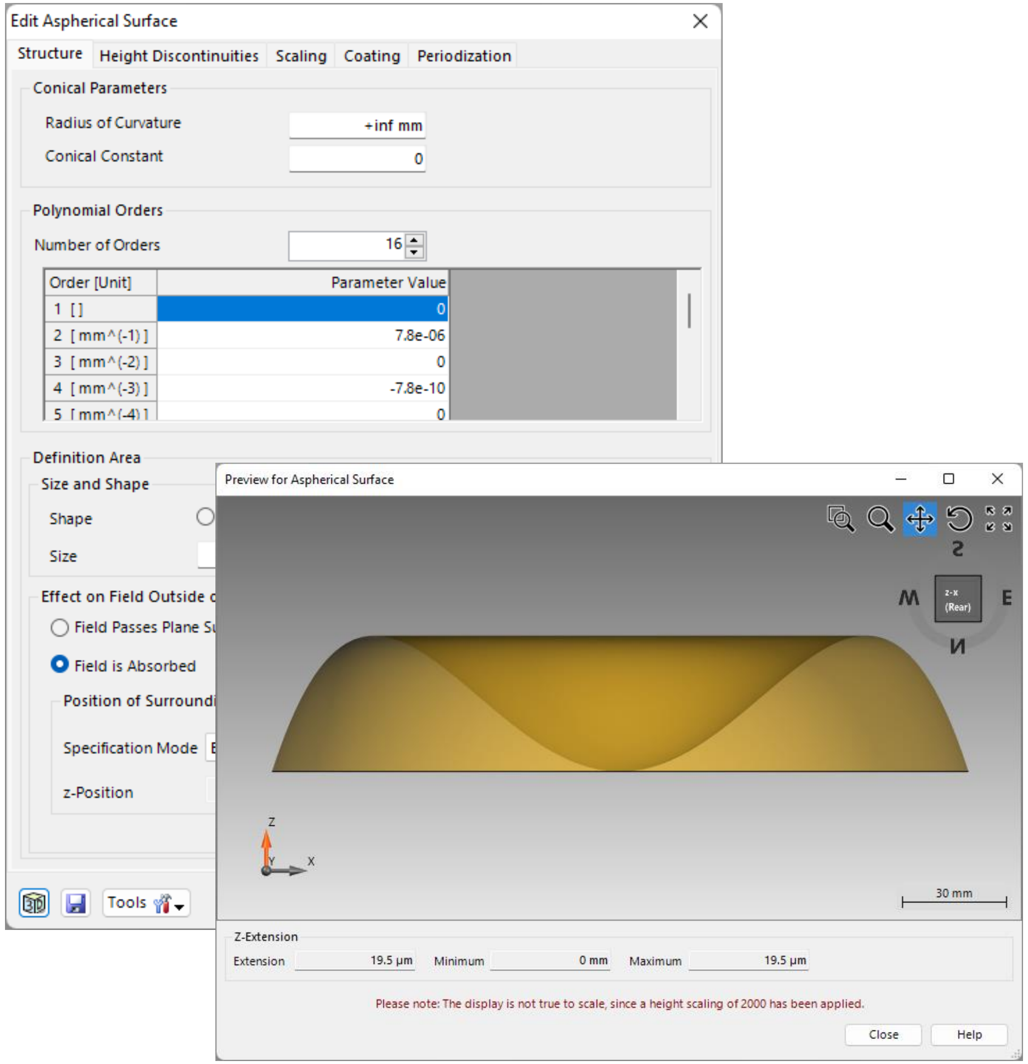
primary mirror

- spherical mirror with radius -800 mm
- mirror size 206 mm × 206 mm
- a hole on the mirror with size 36 mm × 36 mm

Schmidt Corrector Plate

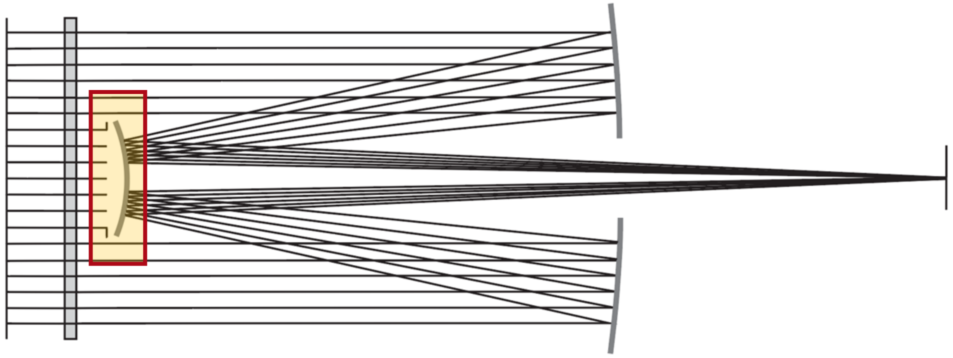


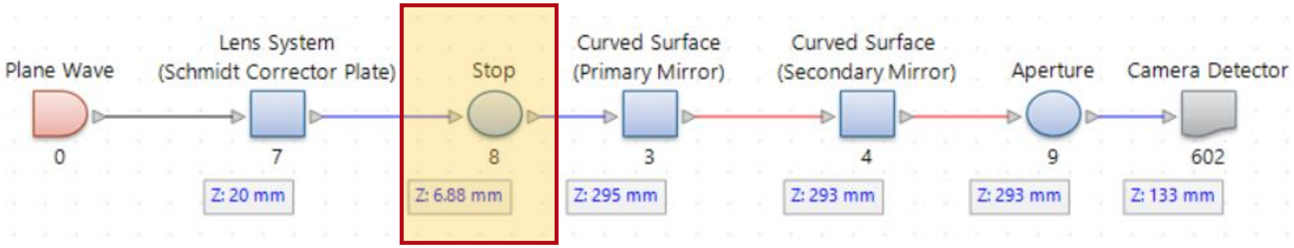


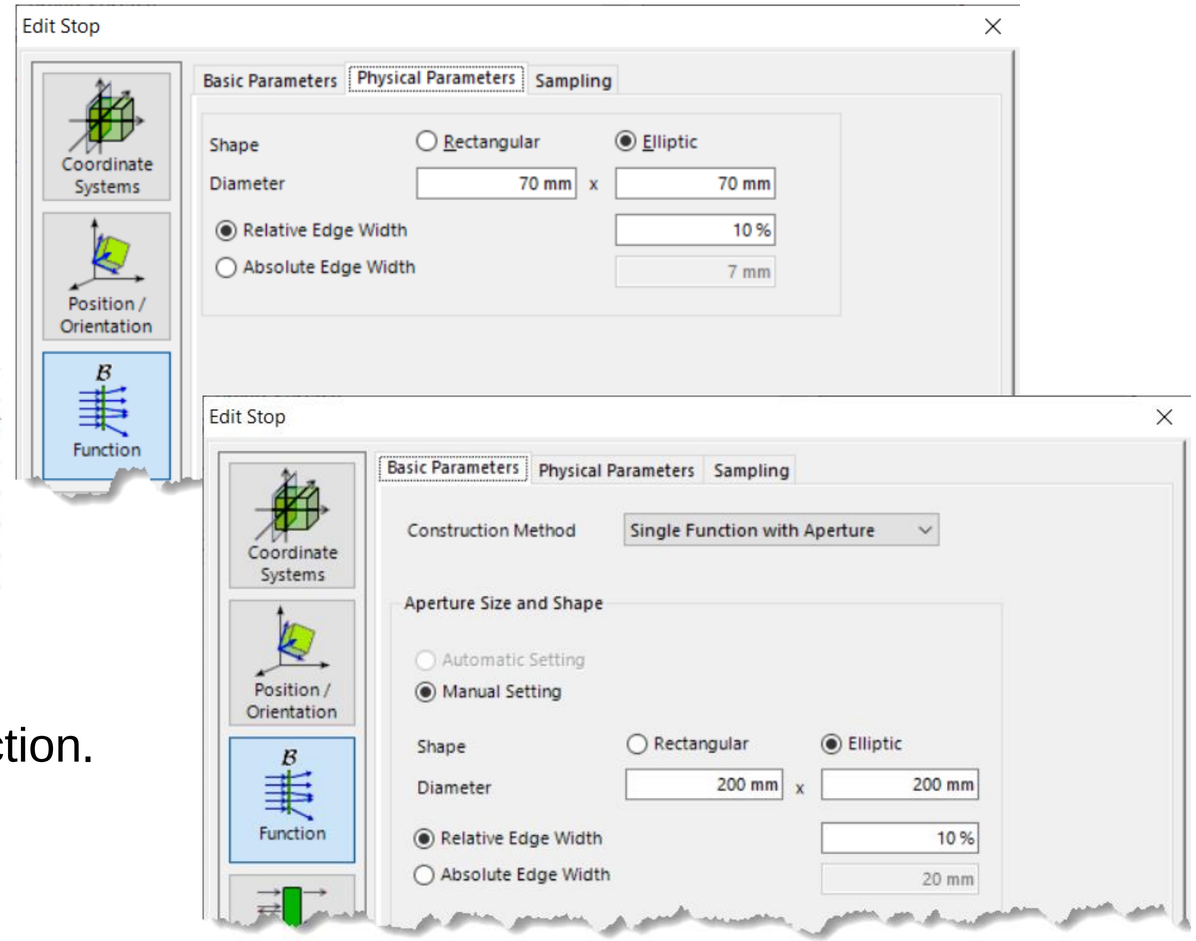


One important component of the Schmidt Cassegrain Telescope is the so-called Schmidt corrector plate, which is used to pre-compensate spherical aberrations of the optical system. We model it using an *Aspherical Surface* in a *Lens System Component*.

Back Side of the First Mirror

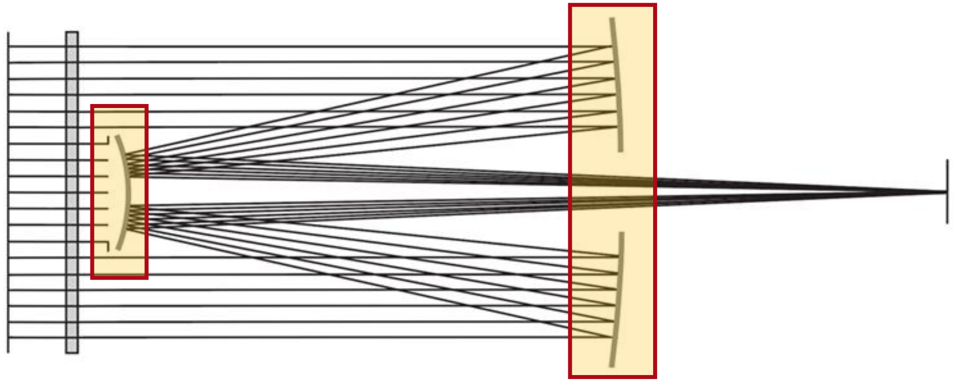


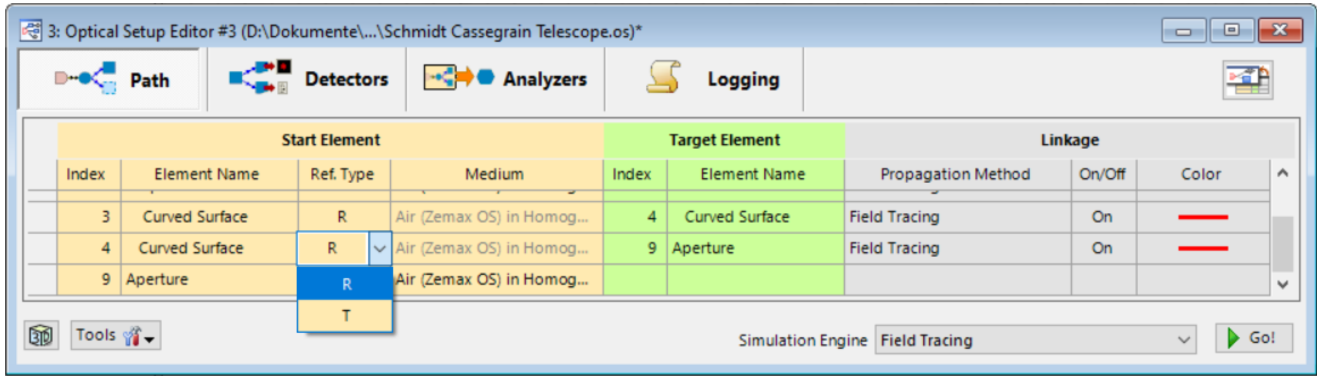


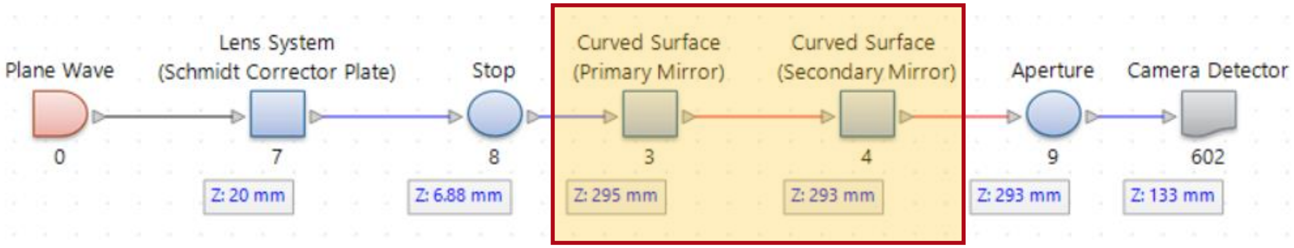


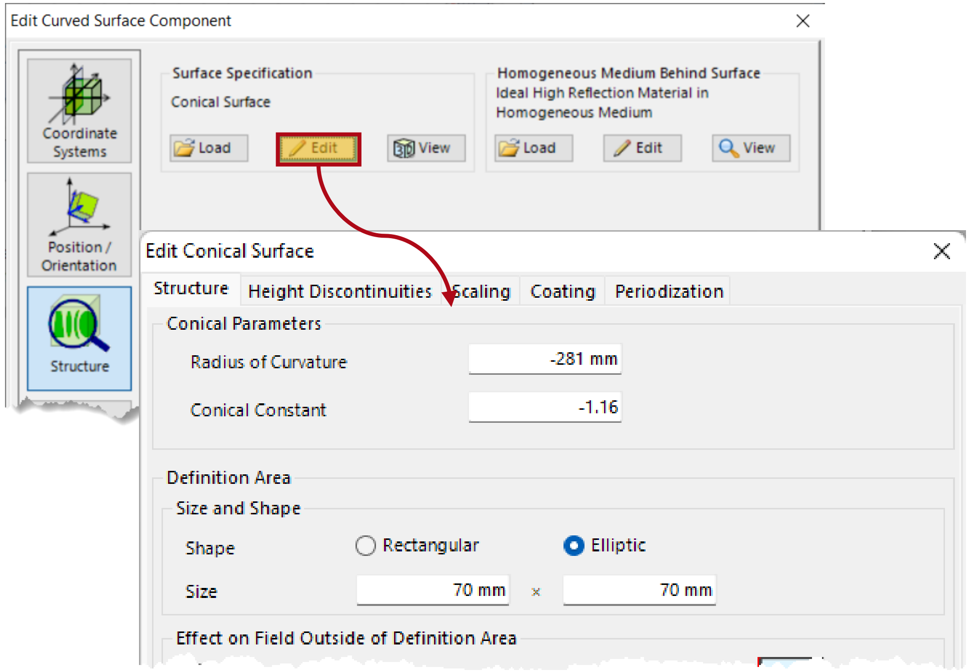
The small convex mirror blocks the central part of the incoming light. This is modeled by introducing a *Stop* function.

Front Side of Mirrors



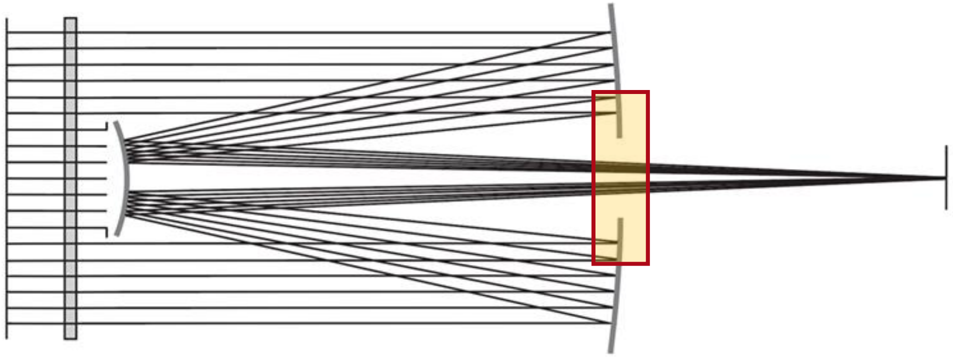


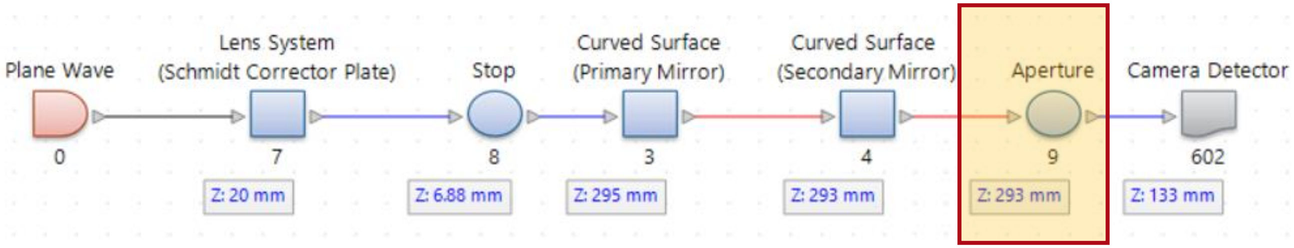




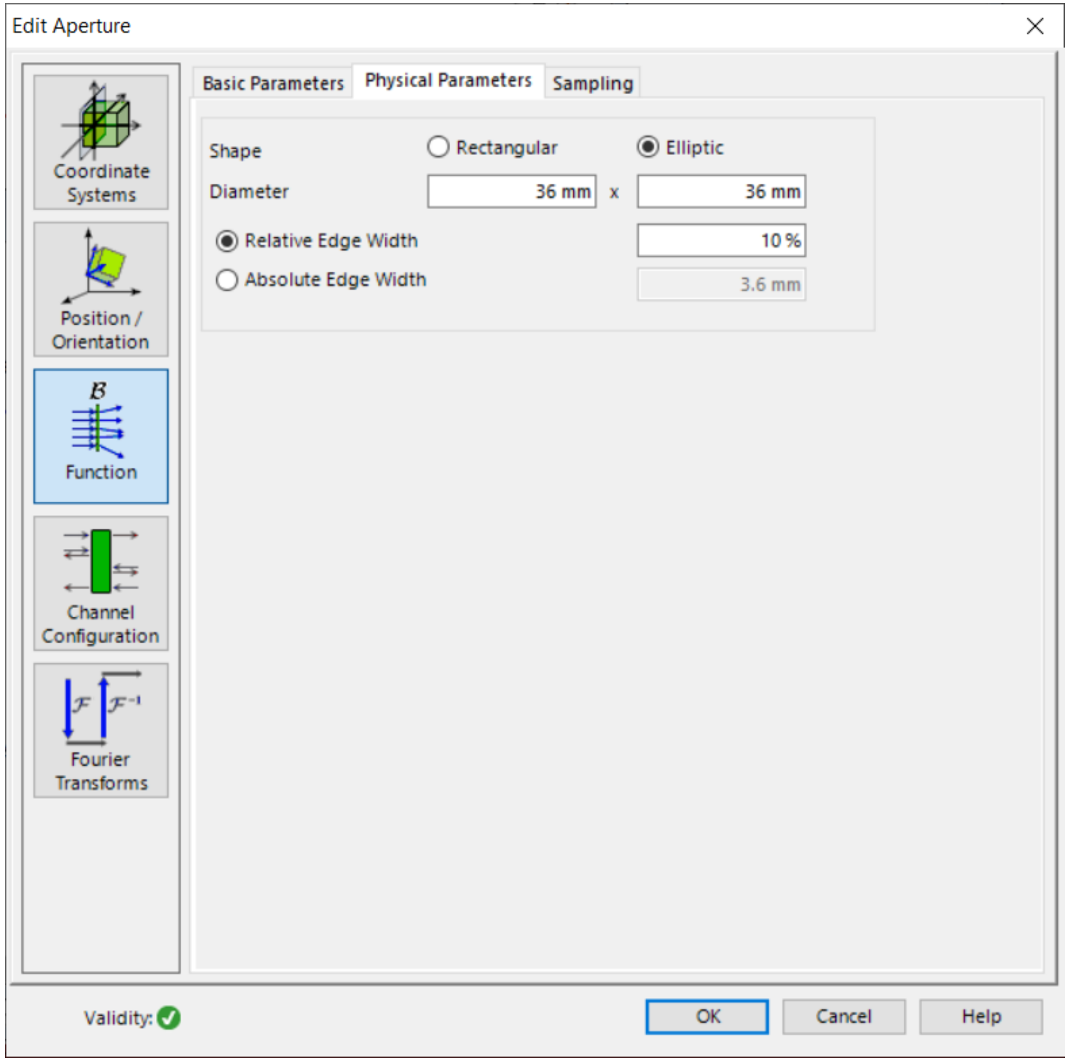
The mirrors themselves are modeled using *Curved Surfaces.* These can be used to introduce several different surface types, including spherical and hyperbolic shapes with the corresponding conical constants. In order to achieve high reflectivity, an ideal reflecting material is chosen, but it would also be possible to configure high-reflective coatings on the surfaces.

Aperture

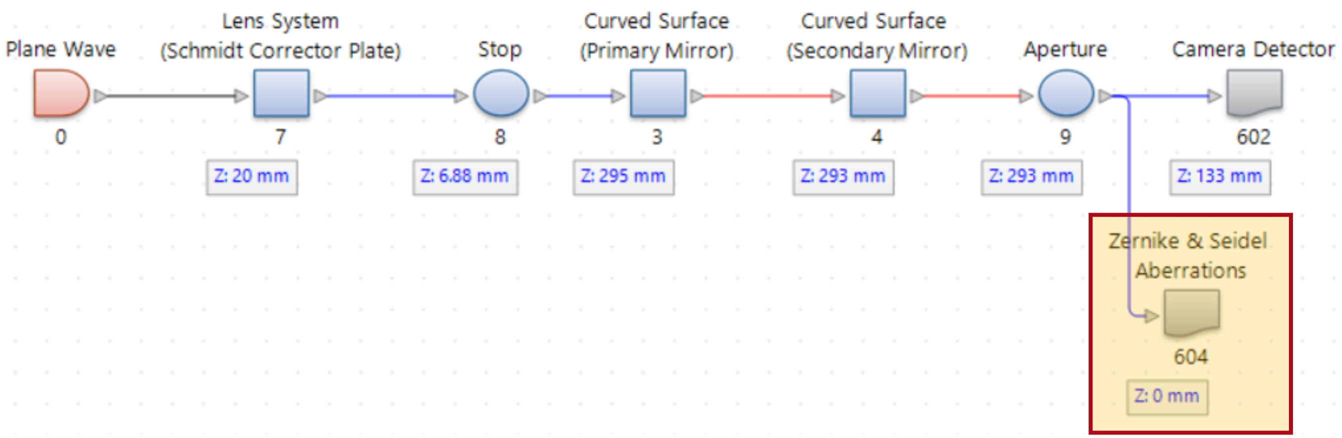


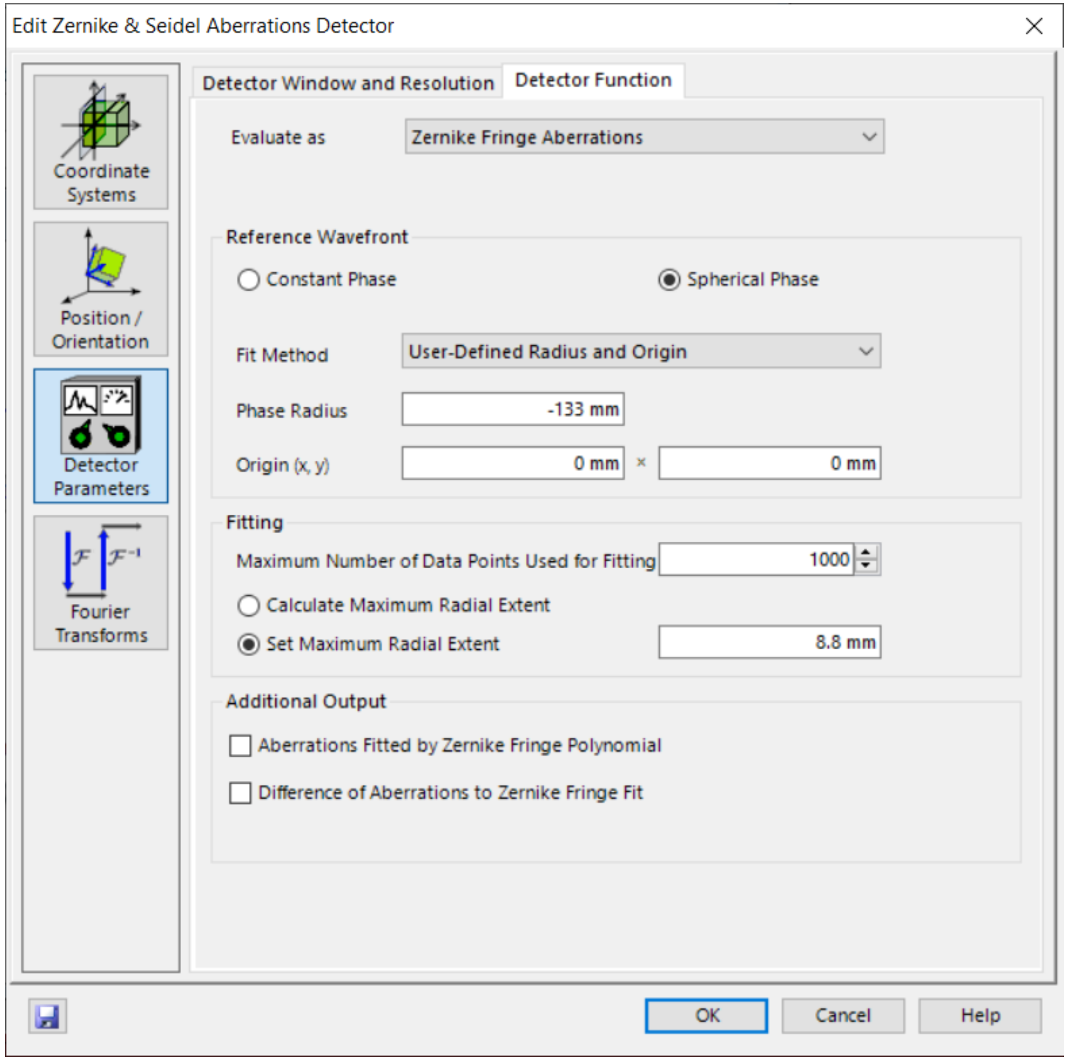


The hole in the primary mirror allows the light reflected by the small mirror to propagate past the first mirror and onwards to the detector. This is modeled by introducing a circular *Aperture* with the desired *Diameter*.



Zernike & Seidel Aberrations Detector



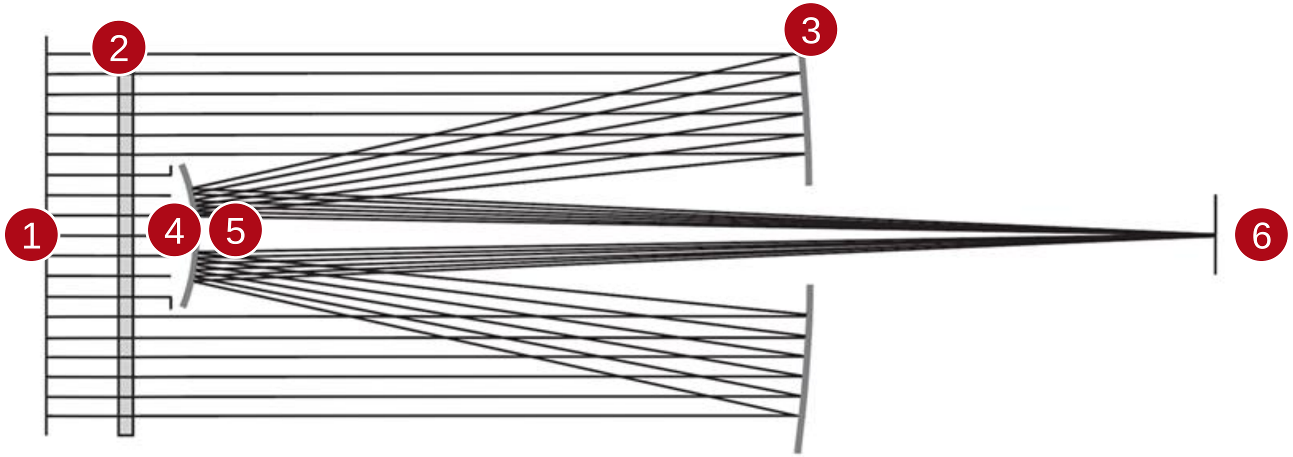


The *Zernike & Seidel Aberrations Detector* can be used to calculate wavefront aberrations including:

- defocus
- coma
- spherical aberration
- astigmatism

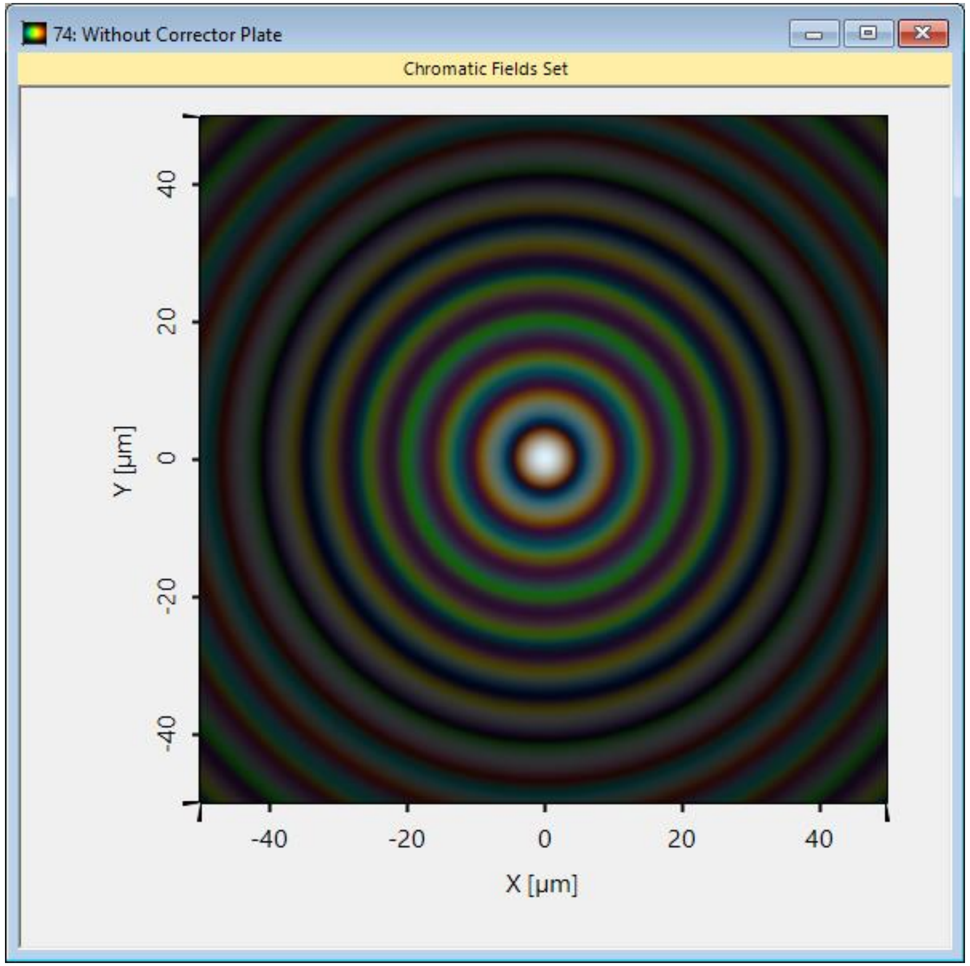
Here we select *Zernike Fringe Aberrations* to show the result. The detector is placed right after the aperture.

Summary – Components...

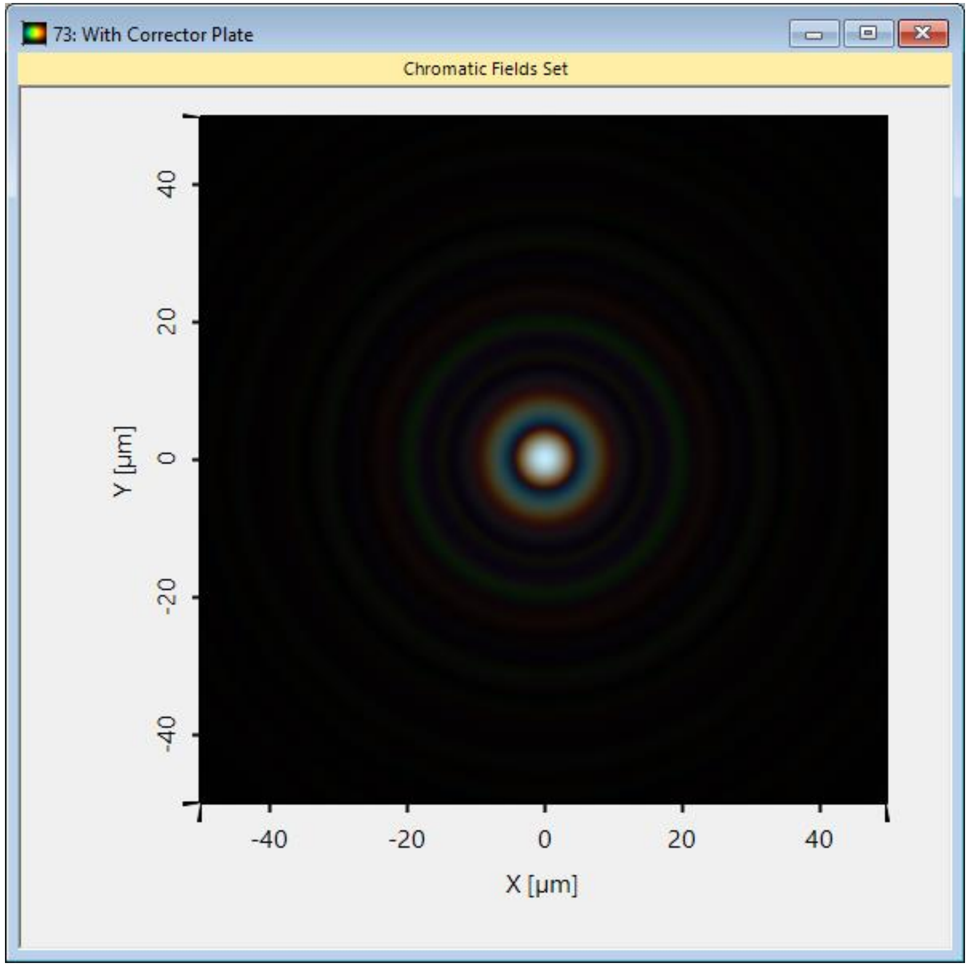


… of Optical System	… in VirtualLab Fusion	Model/Solver/Detected Magnitude
1. source	*Plane Wave*	Truncated ideal plane wave
2. Schmidt corrector plate	*Lens System Component* (with Aspherical and Plane Surface)	Linear Plane Interface Approximation (LPIA)
3. primary mirror 4. secondary mirror	*Conical Surface*	Linear Plane Interface Approximation (LPIA)
5. wave aberration detector	*Zernike & Seidel Aberrations Detector*	Zernike polynomials
6. detector	*Camera Detector*	energy density measurement

Spherical Aberration



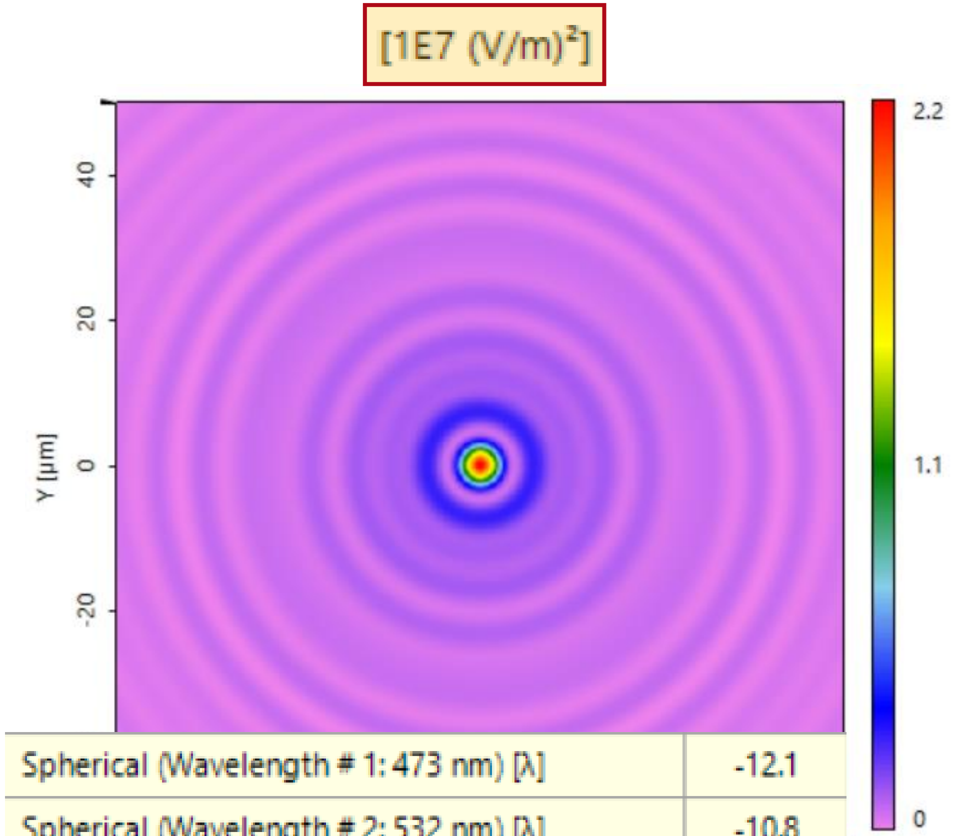
without corrector plate



with corrector plate

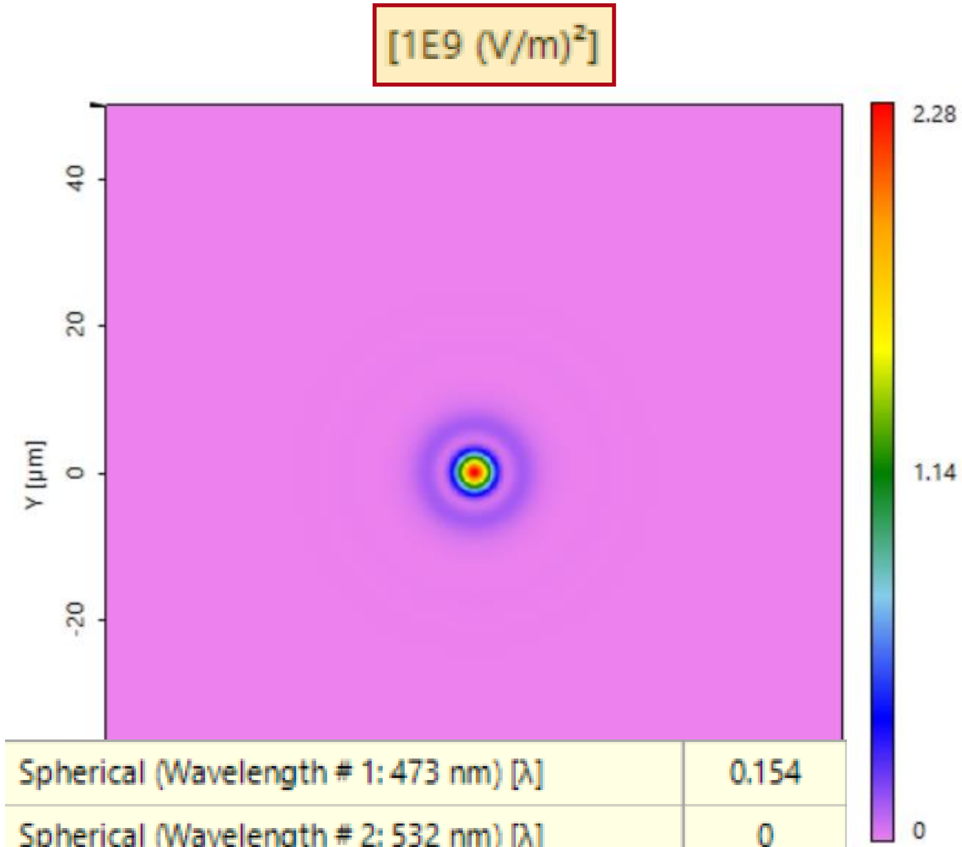
To demonstrate the effect of the Schmidt corrector plate, simulations were performed with and without it. Without the corrector plate strong spherical aberrations are present at the focal plane (real color view).

Spherical Aberration



Spherical (Wavelength # 1: 473 nm) [λ]	-12.1
Spherical (Wavelength # 2: 532 nm) [λ]	-10.8
Spherical (Wavelength # 3: 635 nm) [λ]	-9.03

without corrector plate

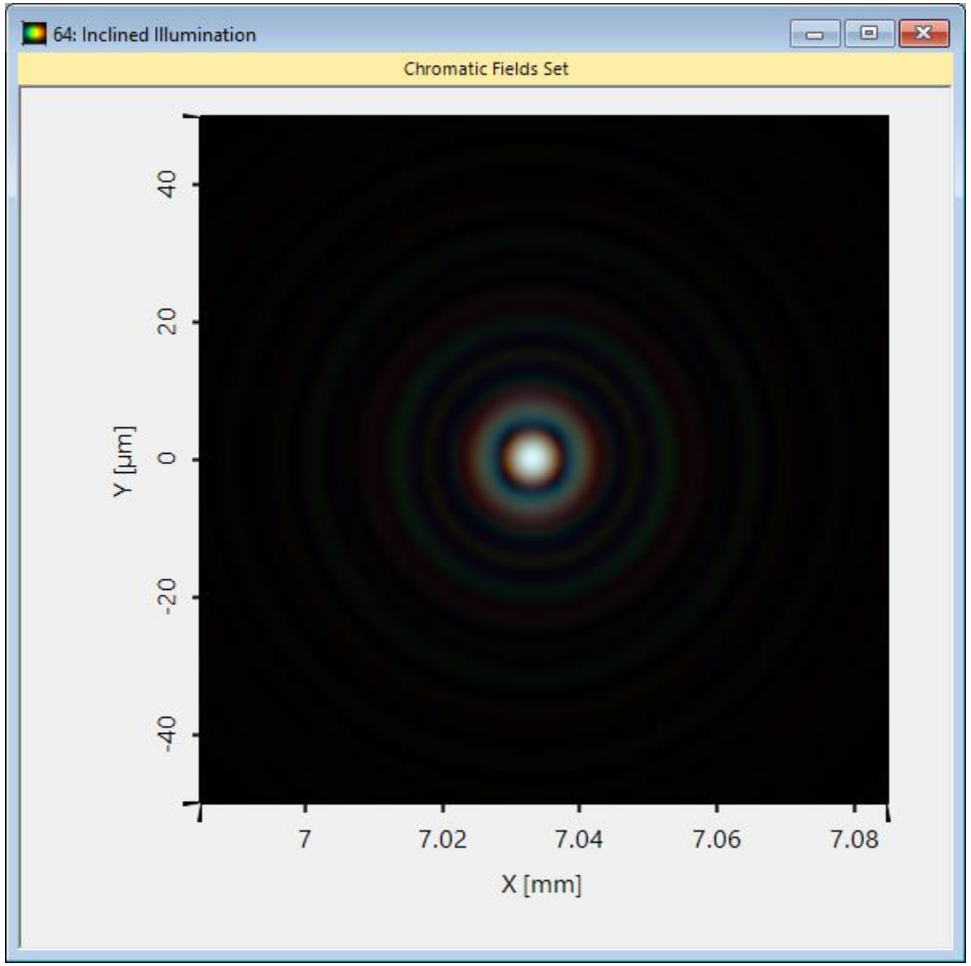


Spherical (Wavelength # 1: 473 nm) [λ]	0.154
Spherical (Wavelength # 2: 532 nm) [λ]	0
Spherical (Wavelength # 3: 635 nm) [λ]	-0.107

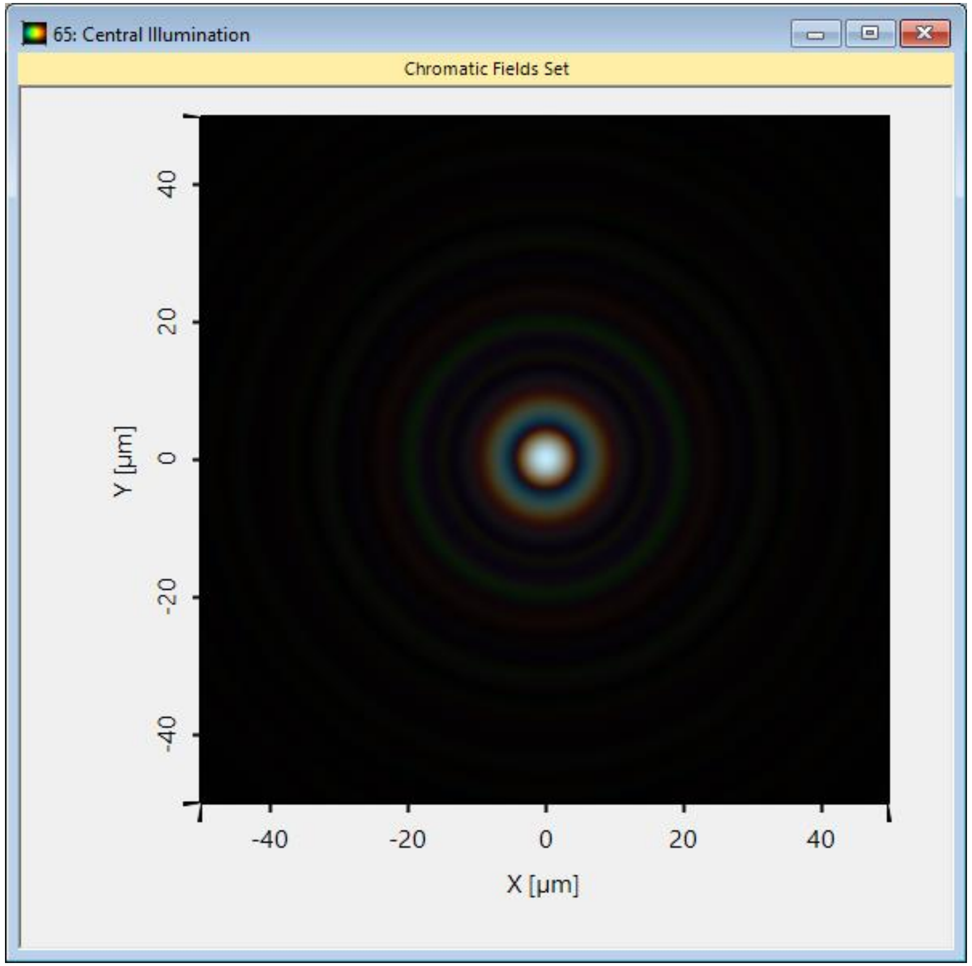
with corrector plate

In false color, the correcting effect can be assessed more quantitatively. It turns out that the corrected focus exhibits a two orders of magnitude larger energy density. Moreover, the measured error of the wavefront is reduced from about 10λ to about 0.1λ for all wavelengths (measured subsequent to the aperture against a spherical reference).

Inclined Illumination



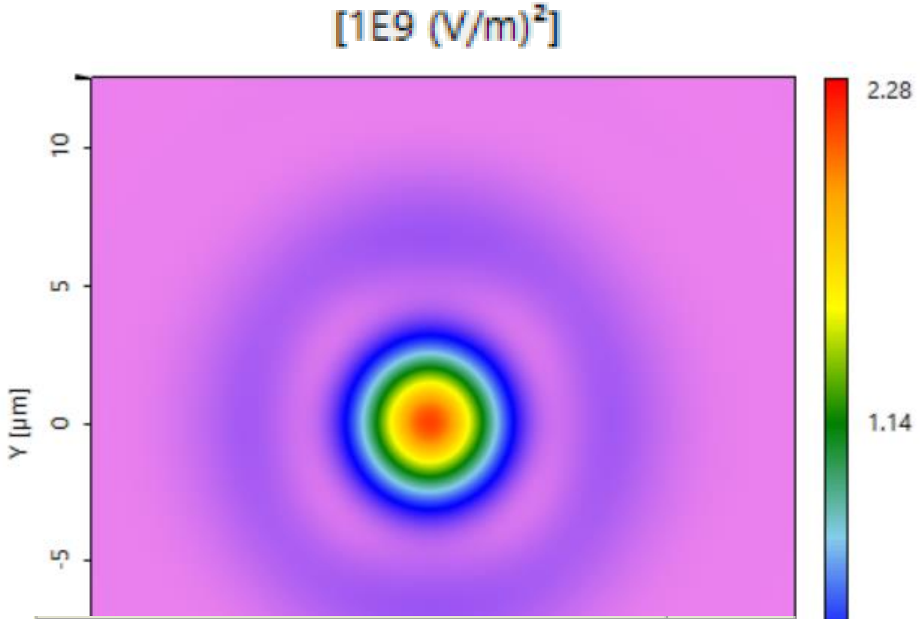
inclined illumination



normal illumination

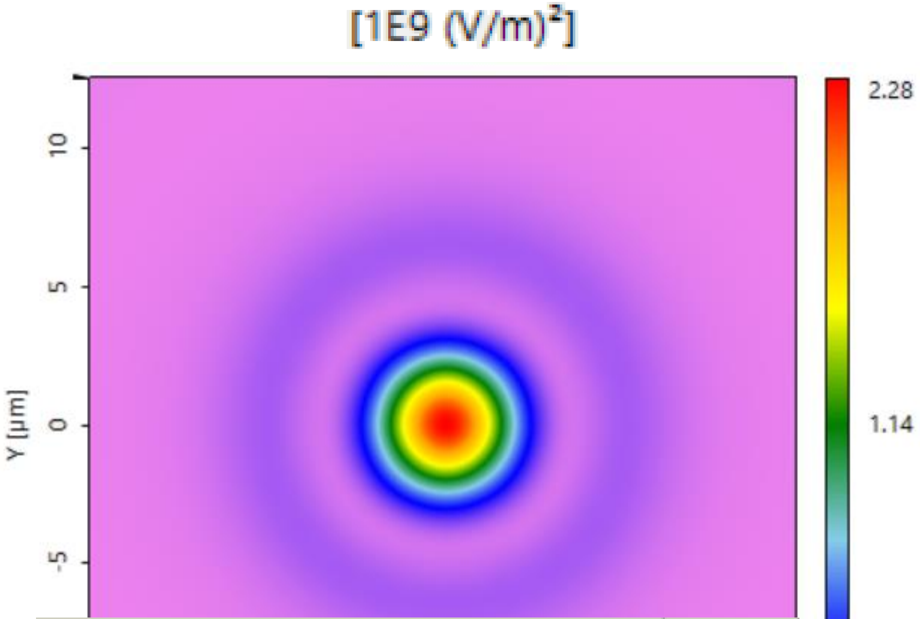
In order to investigate other aberrations, the simulation is repeated with a small inclination (0.25°) of the impinging light. It is observed that the correction of aberrations also works for non-normally incident light.

Inclined Illumination



Astigmatism X (Wavelength # 1: 473 nm) [λ]	0.716
Coma X (Wavelength # 1: 473 nm) [λ]	-0.627
Astigmatism X (Wavelength # 2: 532 nm) [λ]	0.0907
Coma X (Wavelength # 2: 532 nm) [λ]	0.0418
Astigmatism X (Wavelength # 3: 635 nm) [λ]	-0.46
Coma X (Wavelength # 3: 635 nm) [λ]	0.623

inclined illumination



Astigmatism X (Wavelength # 1: 473 nm) [λ]	0
Coma X (Wavelength # 1: 473 nm) [λ]	0
Astigmatism X (Wavelength # 2: 532 nm) [λ]	0
Coma X (Wavelength # 2: 532 nm) [λ]	0
Astigmatism X (Wavelength # 3: 635 nm) [λ]	0
Coma X (Wavelength # 3: 635 nm) [λ]	0

normal illumination

The measured aberrations in case of inclined illumination exhibit very small values of coma and astigmatism below a single wavelength and hence are not very significant.

Document Information

title	Schmidt-Cassegrain Telescope
document code	MISC.0095
document version	1.0
software edition	VirtualLab Fusion Basic
software version	2021.1 (Build 1.180)
category	Feature Use Case
further reading	• Herrig Schiefspiegler Telescope • Afocal Systems for Laser Guide Stars • Wavefront Error Detector