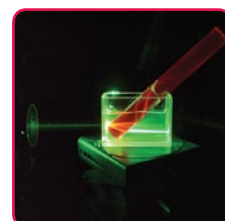
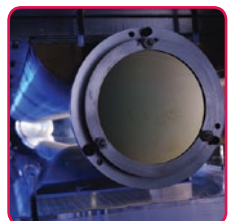


## Characterization of a 10” Schmidt-Cassegrain telescope using HASO R-Flex™

Imagine Optic's HASO™ wavefront sensors, based on patented Shack-Hartmann technology, are excellent tools for the precision metrology of optical systems. Easy to use and integrate, HASO's wide dynamic range and exceptional precision allow users to characterise a wide range of dioptrical and catadioptrical systems.

This document explains how using HASO R-Flex 32 enabled us to precisely characterize the wide-aperture optical system found in a Schmidt-Cassegrain telescope. The data acquired provided the information necessary to assess the effects of the secondary mirror's misalignment and to use that information to correct its alignment.



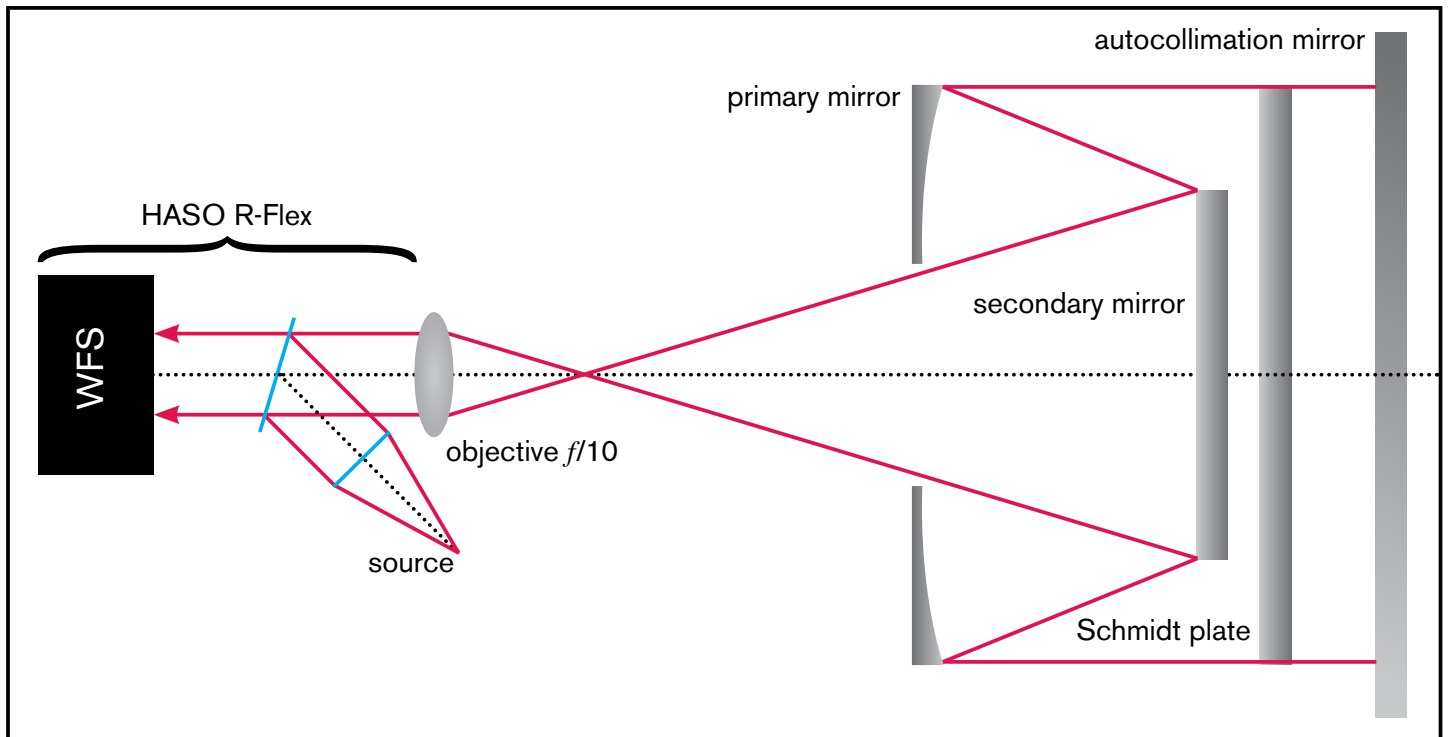
## Configuring the test



The diagram below shows an easy to configure method for measuring the wavefront error (WFE) of a Schmidt-Cassegrain telescope using an Imagine Optic HASO R-Flex 32 on a standard optical workbench. In this example, the source was adapted to the numerical aperture of the telescope by using a standard  $f/10$  objective.



Laser Diode (included with all models) being attached to a HASO R-Flex 32 with an  $f/10$  objective.



## Measuring the telescope's WFE

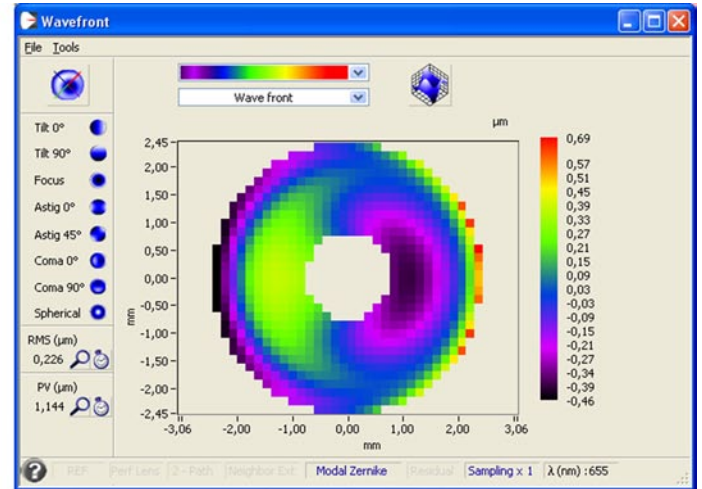
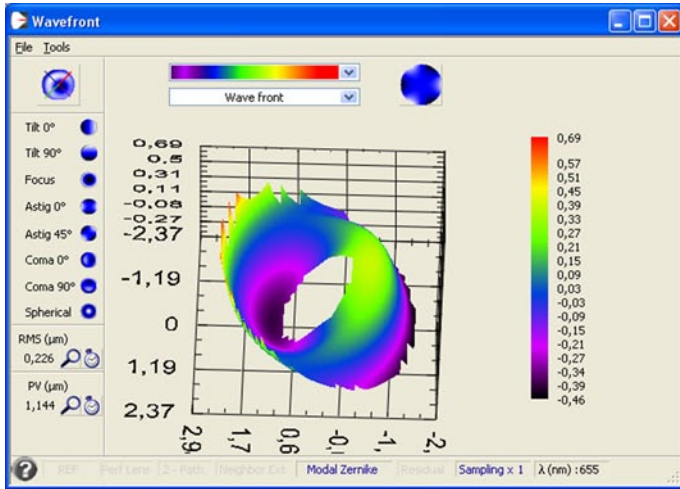
The first step in measuring the telescope is choosing an adapted experimental configuration - in this case a vertical setup was chosen. In order to ensure maximum accuracy, and based on the telescope's 10" aperture, an 8"  $\lambda/150$  rms (Root Mean Square) flat mirror was employed for autocollimation. The mirror's flatness is very important as it will directly impact the accuracy of the measurements obtained (several tests are available to verify your mirror's flatness). Once the experimental set-up was in place, we performed the following:

- 1) Calibrated the HASO R-Flex 32 to a perfect sphere and saved its WFE reference file. This was done by placing a spherical reference mirror in front of the device. Although HASO wavefront sensors can measure in both absolute and relative ("referenced") modes, we chose to work in referenced mode to ensure WFE calibration with the referenced optical elements. In this configuration, WFE measurement accuracy was better than  $\lambda/150$  rms.

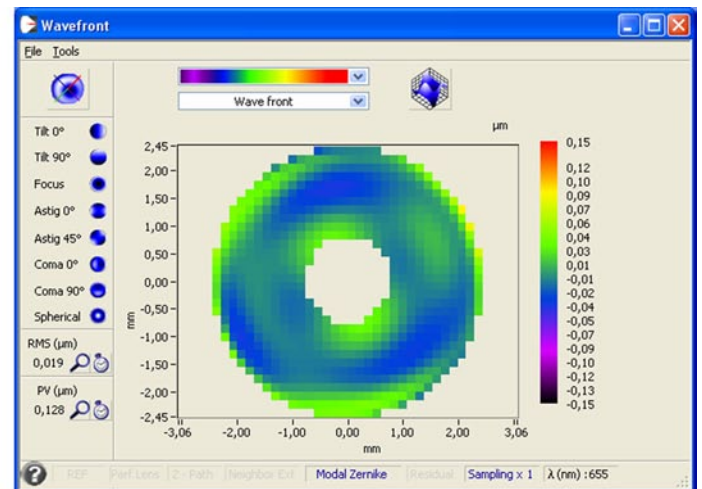
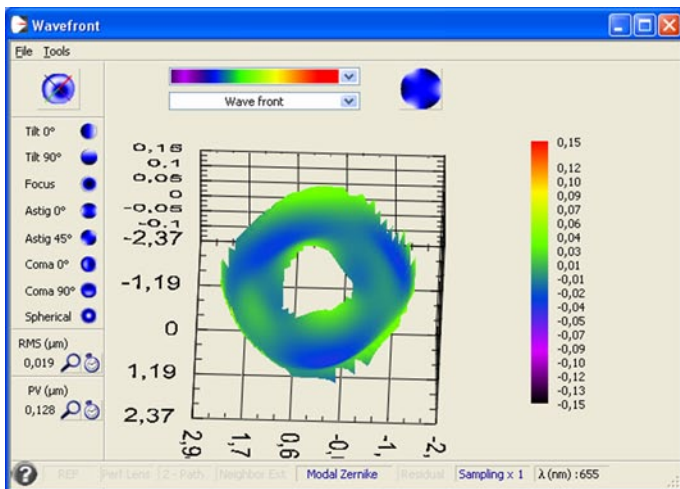
- 2) Aligned HASO R-Flex in-line with the telescope's aperture (rotation of the autocollimation mirror)
- 3) Measured the telescope's WFE in referenced mode using the data file acquired in step 1.

## Results

**Before alignment** - The wavefront display windows below shows us that there was a significant field aberration. When HASO R-Flex was aligned to the telescope's mechanical axis we discovered that the secondary mirror orientation had introduced coma aberrations into the optical system.



**After alignment** - HASO's real-time measurement features enabled us to correct the telescope's alignment and observe the effects of our adjustments as we worked. We were able to align the secondary mirror to the primary mirror, thereby reducing the optical system's field aberrations to almost 0. Both the rms and PV (Peak to Valley) measurement images below allow us to appreciate the effects of the telescope mirrors' proper alignment (WFE improvement from 226 nm rms to 19 nm rms).



## Conclusion

This test, performed on a simple optical system, was designed to demonstrate HASO R-Flex's precision as a stand-alone metrology system. Systems of this kind from Imagine Optic are ideal for characterizing optical elements ranging from small-diameter mirrors through to large-aperture telescopes. For example, a customized HASO R-Flex solution was used to characterize and align the 3m Herschel telescope's optical system, and the CFHT uses HASO R-Flex to perform regular maintenance.

Many of the world's most advanced astronomical facilities depend on Imagine Optic's metrology platforms to detect high-spatial frequency aberrations caused by polishing defects and to precisely position dependant devices including cameras and spectrometers. If you would like more information, please call +33 (0)1 64 48 15 60 or visit [www.imagine-optic.com](http://www.imagine-optic.com).