Simulation of adaptive optics for the Vacuum Tower Telescope

Anita Enmark · Thomas Berkefeld · Oskar von der Lühe · Torben Andersen

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Abstract A simulation model of the adaptive optics of the German Vacuum Tower Telescope (VTT), Observatorio del Teide, Tenerife, is presented. The model uses modules from the integrated model of the Euro50 extremely large telescope, and includes submodels of a Shack-Hartmann wavefront sensor, a de-formable mirror, a tip-tilt mirror, high-voltage amplifier low-pass filters, a reconstructor and a controller. We investigate the impact on the closed loop bandwidth of changes in controller configuration and certain system parameters, such as low pass filter bandwidth and camera integration and readout time. Control strategies were tested on simple models before implementation on the full VTT model. Using the models, different control strategies are compared.

Keywords Adaptive optics · Simulation · Control algorithms · Solar telescope · Modelling

1 Introduction

The Euro50 is a proposed 50 m telescope for optical and infrared wavelengths [1]. To study and predict performance of the complete telescope system, an integrated model combining the structure of the telescope, the optics, the control systems, the adaptive optics and the atmosphere has been established [2]. The model is general, easy to maintain and adapt to different types of telescopes. The adaptive optics (AO) part can be run as a stand-alone module.

The Kiepenheuer-Institut für Sonnenphysik (KIS) in Freiburg, Germany, has a solar telescope, the Vacuum Tower Telescope (VTT), placed at Tenerife, Spain. It has an aperture of 70 cm and a coelostat to feed the light. The telescope is almost exclusively used with adaptive optics. The initial adaptive optics system performs single-conjugate compensation [3] but a multi-conjugate facility is also being introduced and tested [4].
A simulation model of the single-conjugate adaptive optics of the VTT has been set up using modules from the Euro50 integrated model. The purpose has been two-fold. First, applying the model on an existing telescope is an excellent way to validate and test the AO simulation software. Secondly, it was desired to investigate options for increasing the AO closed-loop bandwidth for the VTT by simulating the temporal behaviour of the deformable mirror (DM), the wavefront sensor (WFS) and the controller.

The VTT AO differs from that of the Euro50 system in several ways. The DM type and geometry, the WFS geometry, the gradient determination, the control algorithm, tip/tilt off-loading are all different from the projected Euro50 AO design. Hence, the VTT AO has been a good candidate for testing the modularity of the Euro50 software.

2 VTT adaptive optics system

The main components of the VTT Single-Conjugate Adaptive Optics (SCAO) system, KAOS, are shown in Figure 1.

The system has a Shack-Hartmann WFS, a deformable mirror and a tip/tilt mirror. The mirror actuators are driven by high-voltage amplifiers. The DM is conjugate to the telescope pupil. It is a 100 mm bimorph mirror with 35 electrodes (see Figure 2). The outer ring is not illuminated and provides boundary conditions for the inner 50 mm illuminated part. The TT mirror has three actuators separated by 120°.

The WFS operates at 0.51 μm, with a 12′ Field-Of-View (FOV) and 36 subapertures. The geometry of the WFS pupil plane is shown in Figure 3. Each subaperture image covers 24 × 24 pixels, giving a scale of 0.5″/pixel. FFT cross-correlation is used to determine local wavefront gradients. A discrete servo controller sends the commands to the high-voltage amplifiers. In the original configuration the wavefront was sampled at 955 Hz by a 260×260 pixel DALSA