Developments towards an adaptive secondary mirror for KECK

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ABSTRACT

TNO and partners at university of Hawaii and the Center for Adaptive Optics at UCSC are developing adaptive secondary mirror technology based on a unique electromagnetic actuator, which yields high efficiency in terms or force per unit volume and unit power. This actuator technology enables an overall compact and robust adaptive secondary mirror without the need for active cooling.

Several design studies have been performed to investigate the potential of an ASM based on this technology for telescopes such as TMT, KECK, Gemini, and the European Solar Telescope.
Over the last three years several prototypes systems have been realized to verify the actuator technology and demonstrate its performance. Furthermore, a design upgrade of the actuators has been made that enable an even higher force density due to reduced size and easier manufacturing.
The current focus of the team is the realization of the ASM designed for the NASA Infra-red Telescope Facility (IRTF) and the University of Hawaii 2.2-meter Telescope with 36 and 210 actuators respectively. These systems are aimed to demonstrate the potential of this technology within a representative environment and on operational astronomical facilities on Mauna Kea.
In parallel, the team is developing the design of the Keck ASM which will have a diameter of Ø1.4 meters and between 3000 and 4000 actuators.
This paper will present the latest test results of TNO's novel actuator technology, the integration status of the UH2.2-ASM and IRTF-ASM, and the design status of the KECK-ASM.

Keywords: Adaptive Secondary Mirror, Ground Layer Adaptive Optics, UH-2.2, KECK, IRTF

1. INTRODUCTION

Adaptive secondary mirrors allow for integration of the adaptive optics system within the telescope itself, yielding an highly efficient AO corrected imaging over a large field of view. TNO developed a deformable mirror technology based on unique hybrid variable reluctance actuators that provide high efficiency in terms of force per unit energy and volume [1]. These actuators are considered highly suitable for adaptive secondary mirrors, as these enable the use of relatively thick and thus robust mirror shells, low power dissipation and overall low complexity. Figure 1-1 shows two version of this actuator, the first generation on the left developed for the UH2.2 ASM [2], and the latest version with improved force density and manufacturability on the right [4].

To develop such adaptive secondary mirrors, TNO has teamed up with industrial partners VDL ETG, and AAC Clyde Space, research partners Fraunhofer IPT and NOVA, and academic partners of the University of

Hawaii and the Center for Adaptive Optics at University of California Santa Cruz. There is a strong interest from the larger observatories for ASM's based on this technology, and concept designs have been made for TMT [1], Gemini, Keck [3], and for the European Solar Telescope (EST) a PDR study has been performed [4]. Prototype systems have been built and tested to verify the performance of these actuators in a representative deformable mirror assembly [5]. The second step in this development roadmap is on-sky demonstration on a telescope for which two ASM's are currently being manufactured and integrated, one with 210 actuators for the UH2.2 Telescope operated by the University of Hawaii [2], and one for the Nasa's Infra-Red Telescope facility. Both these telescopes are operated on mount Mauna Kea in Hawaii. In this paper the concept design status of the ASM for Keck, and the status of the ASM's for IRTF and UH2.2 are discussed.

Figure 1-1: Hybrid Variable Reluctance (HVR) actuators developed by TNO, left shows the actuators developed for the UH2.2 ASM, and right shows the latest generation of actuators enabling an even higher force density and improved manufacturability.

2. KECK ASM CONCEPT DESIGN

The current secondary mirror of the KECK telescope has a diameter of Ø1,4 meter, and a convex optical surface. This secondary mirror is mounted on a tip/tilt stage for fast corrections. Figure 2-1 shows the concept design of the ASM based on TNO's hybrid variable reluctance actuators that might replace the current passive secondary mirror. The amount of actuators is ranging from 3000-4000 and is subject to a trade between overall complexity, mass, and AO-correction potential which is further discussed in [3]. This leads to an actuator spacing of 16mm to 20mm, which is possible with the newly designed actuators shown in Figure 1-1 (right). The actuators are supported by a SiC support frame, that provides a rigid support and thermally stable support for the actuators. The mirror shell is around 3,3mm thickness and the baseline material of Borosilicate glass. The overall ASM assembly is mounted on a hexapod for coarse positioning.

The concept design study of the Keck ASM is currently ongoing. Current focus lies on the packaging of the electronics, the possible need for separate fast tip/tilt actuation to offload the actuators, and the operational aspects such as recoating of the mirror shell.

ASM Specification	
Item	Value
diameter	Ø1400 mm
number of actuators	3000-4000
actuator spacing	16-20 mm
facesheet thickness	3,3 mm
support structure material	SiC

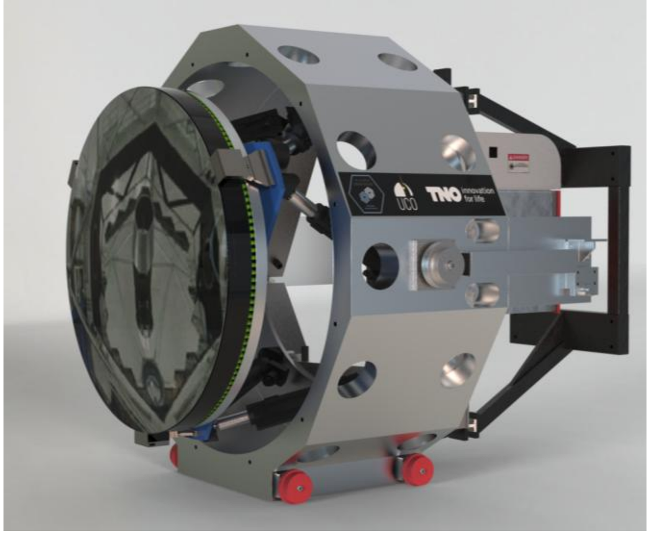

Figure 2-1: Concept design of the KECK ASM

3. IRTF ASM DESING AND STATUS

As a means to quickly demonstrate the operation of an HVR-actuator based ASM in a real telescope environment, an small size and low actuator count ASM is being realized which is aimed to be installed on the NASA IRTF telescope. Figure 3-1 shows a CAD rending of this ASM and a list of high level specifications. The actuators used for this ASM are the same as the ones designed for the UH2.2 ASM (see Figure 1-1 left). The mirror shell is has a thickness of 3,3mm, and is made of Borofloat. Three parallel paths have been pursued to manufacture this mirror shell to ensure timely delivery. Figure 3-2 (left) shows the mirror shell as realized by initially slumping the Borofloat glass to roughly the right shape via the methods described in [6], subsequently the mirror is ground and polished to the best-fit spherical shape, lastly the mirror shell is polished towards the targeted aspherical shape via Magnetorheological Finishing at TNO.
The IRTF ASM is targeted to be integrated in Q3 2023, after which it will follow a program of lab testing, and ultimately on-telescope testing in Hawaii.

ASM Specification	
Item	Value
diameter	Ø244 mm
number of actuators	36
actuator spacing	37 mm
facesheet thickness	3,3 mm
support structure material	Ti

Figure 3-1 IRTF specifications and CAD rendering.

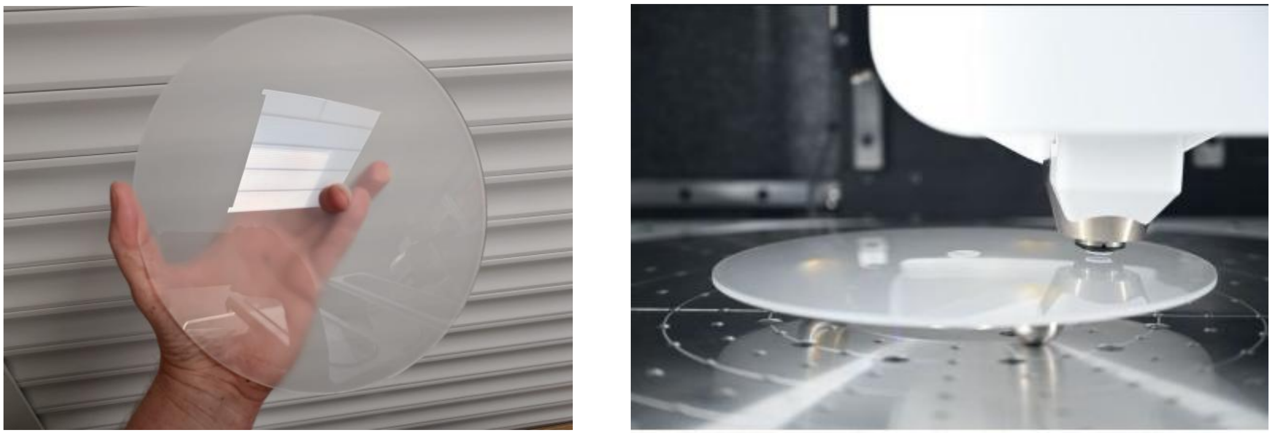

Figure 3-2: IRTF mirror shell, after spherical polishing (left), and under the DUI metrology system [8] after being polished to an asphere with MRF.

4. UH2.2 ASM MAIT STATUS

Figure 4-1 shows the CAD rendering and the high level specifications of the UH2.2 ASM.

At the time of writing of this publication, the mechanical components of this systems are already produced and tested on component level while the manufacturing of this mirror shell is still ongoing.

The mirror shell has a thickness of 3,5mm, and a convex radius of -4198mm with a conic constant of -3,6. A new process needed to be developed to produce such a mirror shell, which is based on initial slumping [7], and subsequently fine polishing to achieve the required surface form accuracy and roughness.

The mirror shell will be bonded to the actuators via struts that are stiff in the vertical direction and compliant in all other degreed of freedom. A crucial aspect during the bonding of these actuators is that the shape error of the mirror surface after the bonding this well within the positioning range of the actuators. While the maximum displacement range of the actuators are around 40µm PV, it is targeted to keep the initial shape errors within 10µm PV. To enable this an accurate assembly rig is developed that is shown in Figure 4-2. This assembly rig holds the mirror shell accurately in place during this bonding procedure. A dry run of this assembly sequence has been performed over the summer of 2023 to verify this procedure and to gain experience before the final integration of the UH2.2 ASM will take place.

ASM Specification	
Item	Value
diameter	Ø630 mm
number of actuators	210
actuator spacing	39 mm
facesheet thickness	3,5 mm

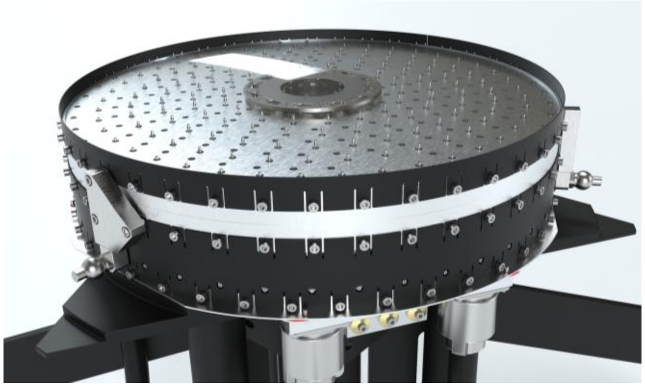

Figure 4-1: UH2.2 ASM specifications and CAD rendering.

Figure 4-2: Integration test trail for the UH2.2 ASM.

OUTLOOK

After integration of the IRTF and the UH2.2 ASM, a test campaign will start with initial lab test to verify the nominal functionality and performances, and subsequently the ASM's will be integrated to the telescope to shows actual AO performance in a telescope environment. Besides AO performances, also the operational aspects such as initial flattening, long term stability and controller tuning will be tested. In parallel, the design of the ASM for the larger observatories will be ongoing among which the ASM for the KECK telescope, and lessons learned with the manufacturing, integration and testing of the IRFT and UH2.2 ASM will be adopted.

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