NSF SGER Grant
Annual Project Report for Award 0649261 (Sept 15, 2006 – Aug 31, 2007)

MEMS-AO / VILLAGES
MEMS in Astronomical Adaptive Optics Visible Light Laser Guidestar Experiments

Investigators
Donald T. Gavel (PI)
Scott A. Severson (Co-PI)

Research and Education Activities

The MEMS-AO/Villages project consists of building and fielding a series of on-sky experiments that will demonstrate two new key technologies for next generation adaptive optics on large telescopes: MEMS electrostatically-actuated deformable mirrors and pulsed lasers for efficient generation of laser guidestars with a minimum of laser power. Phase 1 of these experiments is to demonstrate a MEMS mirror adaptive optics system on the Lick 1 meter Nickel telescope using a bright natural star as the wavefront reference. In Phase 2, we will project a sodium beacon laser through the 1 meter and demonstrate that uplink adaptive optics correction provides significant reduction of spot size on the sodium layer. This SGER grant covers the work in Phase 1 and partial preparations for Phase 2.

To date we have completed the PDR and CDR phases of Phase 1 and are now mid-phase into laboratory integration and testing of the Villages instrument. In response to strong recommendations from the reviewers at the PDR in August 06, we extended the I&T portion of the project plan through the summer of 2007, with first light on the telescope scheduled for September 07. This represents a 3-month slip from our original plan as presented in the proposal. We are now on track with this revised plan.

Figure 1 shows the configuration of the optical layout and Figure 2 shows a CAD drawing of the instrument structure as it is to be mounted on the cassegrain focus of the Nickel telescope. The optical configuration allows both open and closed loop wavefront sensing by providing two paths, one to the wavefront sensor after reflecting off of the deformable mirror, and one that does not reflect off of the deformable mirror. Figures 3 and 4 are photographs of the assembled system in our laboratory. The initial alignment on the optical bench and check out of each of the active components is complete. The photo in Figure 4 shows a display of the wavefront sensor camera output when simulated starlight is fed to the system. Three beams are simultaneously recorded: Hartmann sensor open-loop, Hartmann sensor closed-loop, and tip/tilt.

We received the 140 actuator MEMS deformable mirror from Boston Micromachines in February 07. It was found to have an incorrect wedge angle on its front window and was replaced with one with the correct window in June. Both of these devices operated properly with 100% actuator yield. A photo of the device and a test measurement of actuator response taken with an interferometer are shown in Figures 5 and 6.

We received the wavefront sensor camera from SciMeasure also in February. The camera is now operating according to specifications after considerable interactions with the third party frame grabber supplier to get their software drivers working with RTLinux. RTLinux is the real-time operating system (OS) we are using for the AO control loops, chosen because we could then re-use large portions of the already developed AO control software from the 3-meter Shane AO system. There were considerable difficulties encountered in getting the latest version of RTLinux running with vendor-supplied hardware drivers, and this was complicated by the fact that the OS supplier's ownership changed hands recently so we were not able to receive the technical support we would have preferred. The OS and hardware drivers are now working satisfactorily.

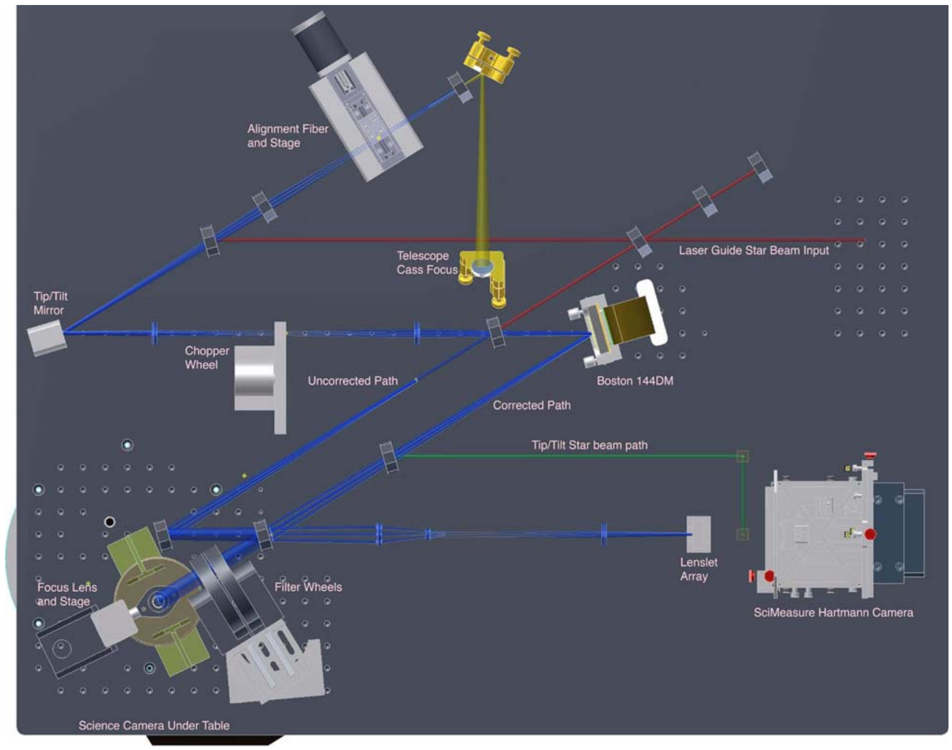

Figure 1. Layout of Villages optical bench (top view).

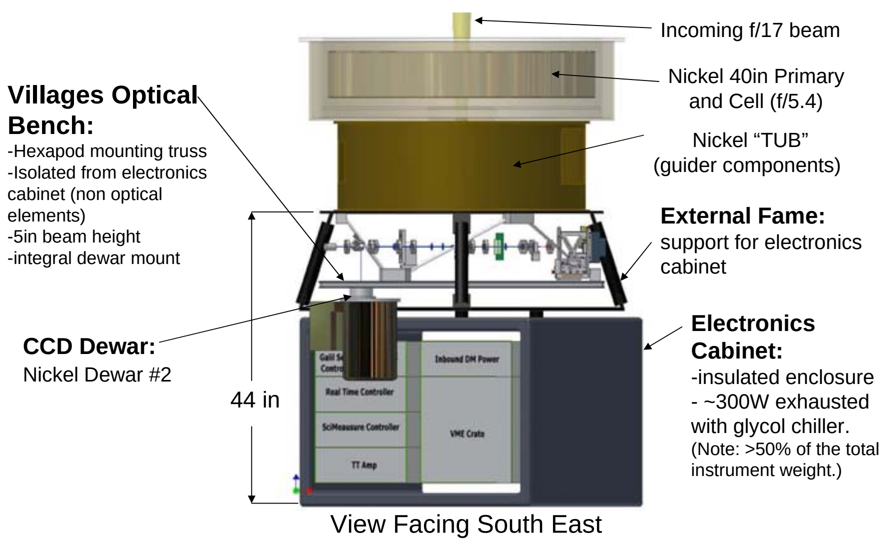

Figure 2. Side view of Villages instrument as mounted on the Nickel telescope.

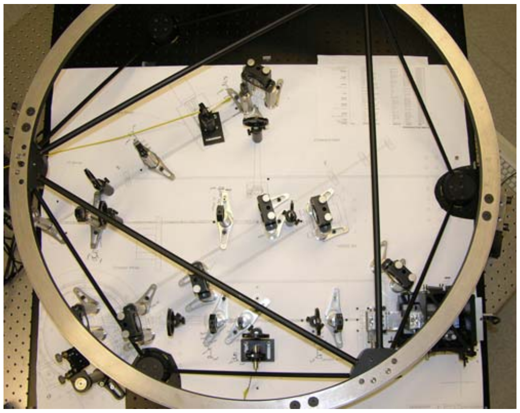

Figure 3. Top down view of Villages optical bench during laboratory I&T.

Figure 4. Optical assembly under test. A display of the Hartmann dots from a test beam shows on the monitor.

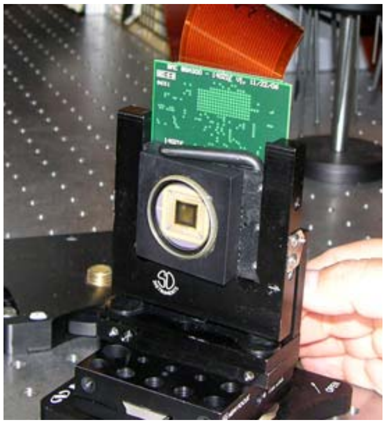

Figure 5. 144 actuator MEMS deformable mirror

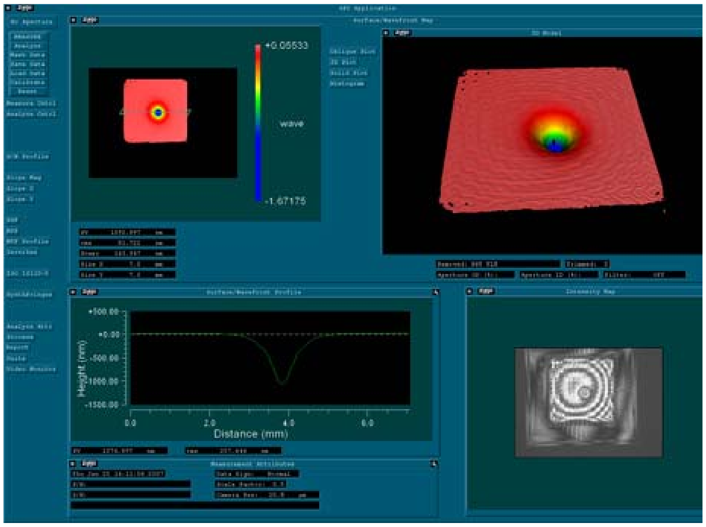

Figure 6. Surface measurement of the deflection of one actuator on the MEMS device. A movie of successive rows and columns actuation can be found on http://lao.ucolick.org/twiki/pub/LAOLibrary/ComponentEntry6/2007_02_27__140DM_Row_Col_test.wmv

In advance of experiments, we made a number of improvements to the 1-meter telescope dome to improve the dome seeing conditions. Minimizing dome seeing is important to optimize conditions for visible wavelength AO correction of the atmosphere above the dome. A small vestibule airlock between the dome entrance and the stairwell was constructed to prevent warm air from the main building from entering the dome and exiting the slit like a chimney. A set of fans were installed exhausting air out the side of the dome to provide a slight negative air pressure and bring air in from the slit. This helps equilibrate temperatures and keep the air in the dome relatively turbulence free. In September 06 we performed a Hartmann test of the Nickel telescope primary to check its figure in order to assure that the MEMS deformable mirror will have enough stroke to cover the static aberration of the telescope in addition to the atmosphere. The mirror figure was less than 1 micron of wavefront departure from ideal and is well within the capability of our DM.

Phase 2 of the Villages project involves fielding a sodium laser and projecting it, AO corrected, off of the 1 meter primary. The optics bench has been designed to split the laser into the beam path, chop the incoming beam to receive pulses from the sodium layer while blanking laser outgoing pulses, and provide a sample of the AO-precorrected outgoing beam into the Hartmann sensor. Under the auspices of the NSF Center for Adaptive Optics, the PI has hosted two workshops on Laser Technology and Systems for Astronomy where laser pulse format and spectral content are the hot topics (see the web site http://lao.ucolick.org/twiki/bin/view/CfAO/SodiumLaserGuidestars). Two lasers under development are potential candidates for fielding at Lick: the Lockheed-Martin Coherent Technologies solid state sum-frequency laser and the Lawrence Livermore National Laboratory sum-frequency fiber laser. Both laser development projects are funded separately by NSF sponsored programs (Adaptive Optics Development Program in both cases and partially by the Center for Adaptive Optics in the later case). We expect that the fiber laser will be fieldable by the end of this calendar year with experiments beginning next spring.