AODP Adaptive Optics Development Program

NOAO Annual Project Report

for

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Sub-Award No. C33002T: "Development of the Next Generation Optical Detectors for Wavefront Sensing," California Association for Research in Astronomy

The project was granted a further one-year no-cost extension of the period of performance to December 31, 2010. Phase 2, covering the design and prototyping of the polar coordinate detectors, is completed and is awaiting the availability of a wafer run for manufacturing.

As reported last year, the California Association for Research in Astronomy (CARA) formed a collaboration with the Starfire Optical Range (SOR) at Kirtland Air Force Base and with the Thirty Meter Telescope project (TMT) to share the cost of the wafer run. Because the wafer run is a collaborative effort, it will include a number of different device designs to serve the interests of all three partners. The designs to be fabricated follow:

- the 160 x 160 pixel, split-frame transfer format, incorporating all of the design improvements following prior runs;
- the 256 x 256 pixel, split-frame transfer format;
- the 1024 x 1024 imagers without the split-frame transfer format; and
- the Polar Coordinate detector prototype with 30 x 30 subapertures (724 active) and 32 video outputs.

CARA had planned to hold a design review in October 2009, but the review was postponed to allow time for complete analysis of problems found by SOR in field tests of the prior version of the 160 x 160 format device. These devices exhibited higher-than-expected clock feed-through in the video signal chain, as well as reduced quantum efficiency due to lost charge in the summing well of the readout register. SOR and CARA identified solutions for these problems and incorporated them into design revisions before committing to mask designs. Following a successful design review in mid-February 2010, drawing of lithography masks for the wafer run began in March 2010.

CARA now expects that Massachusetts Institute of Technology/Lincoln Labs, which is carrying out the wafer run, will have produced thinned devices in September 2010 and will deliver the first devices packaged for backside illumination in November 2010.

Sub-Award No. C33003T: "Pulsed Fiber Laser for Guide Stars," Lawrence Livermore National Laboratory

This contract was to develop and demonstrate a prototype 589-nm, 10-Watt average power pulsed laser system consisting of: (1) a 938-nm, 15 Watt average power pulsed fiber laser, (2) a 1583-nm, 10-Watt average power pulsed fiber laser, and (3) sum frequency mixing in a non-linear optics crystal to produce the required 589-nm laser output. All sub-award funds were expended before the reporting year, and work continued through the year on separate funding from the Center for Adaptive Optics (CfAO) at the University of California Santa Cruz.

Early in the reporting year Lawrence Livermore National Laboratory (LLNL) received from its vendor a replacement Nd-doped fiber for the 938-nm pulsed laser. The original fiber exhibited unacceptably poor efficiency that LLNL traced to residual OH absorption in the polymer that formed the pump cladding of the fiber. Following investigation and negotiation with the vendor, the vendor agreed to replace the fiber with one having a new, more efficient cladding. LLNL retrofitted the 938-nm fiber amplifiers with the new fiber and achieved 12 Watts of output from the 938-nm system while running 80 of the designed 100 Watts of input pump power. This level of efficiency and output was considered to be within the contract requirements.

LLNL also replaced the polarization-maintaining (PM) fiber on the 1538-nm laser system. The original 30-micron fiber core placed the amplifier in the LP01 polarization mode, which reduced the beam quality. The new fiber has a 20-micron core while allows operation in the LP00 mode, and beam quality has now improved. With this change, the 1538-nm system now produces 12 Watts of pulsed power.

With these improved inputs, LLNL achieved improved sum-frequency generation in the periodically-poled stoichiometric lithium tantalate (PPLST) crystal. With 11 Watts of input power from each of the 938-nm and 1538-nm systems, the complete system produced 10 Watts of power at 589 nm. A beam quality measurement verified that the 589-nm output light was diffraction limited. With these demonstration results, which were reached late in the reporting year, LLNL had met the contract requirement for 589-nm laser output power and beam quality. A final report had not been received as of 31 March 2010 but is expected shortly. As soon as it is received and accepted, the contract will be closed out.

Sub-Award No. C33005T: "Compact Modular Scalable Versatile LGS Architecture for 8–100-m Telescopes," Lockheed Martin Coherent Technologies

This contract was to develop a new, solid-state architecture for high-powered lasers operating at the 589-nm atomic resonance wavelength for Sodium. The goal was to demonstrate operation of a laser capable of emitting a total output power of 20 Watts per output beam with a highly versatile array of pulse formats that could meet several different operational needs for adaptive optics with laser guide stars, including range-gated Rayleigh backscatter correction at low altitudes and elongation-suppressed operation in the high-altitude Sodium layer. During the reporting year, this contract was to conclude its third and final phase with a full-power demonstration of the laser system.

As the reporting year began, Lockheed Martin Coherent Technologies (LMCT) was repackaging the system onto a single 4 x 6-foot optical breadboard from the two 4 x 6-foot tables on which it had previously been mounted. This repackaging was required by the contract as part of the requirement that the demonstration laser be sufficiently small that it could easily be transported and deployed at an observatory. To further accommodate the portability requirement, all of the electrical and thermal support equipment was consolidated into three standard, portable electronics racks.

The solid-state system generates the 589-nm output laser through sum-frequency generation (SFG) by mixing laser light from 1319-nm and 1064-nm input lasers in a solid crystal. During the prior contract phase, the conversion efficiency within the crystal was found to be substantially lower than predicted or required. The inefficiency was believed to be due to two sources: (1) beam jitter in the 1319-nm input laser caused by polarization jitter in the polarization-maintaining (PM) optical fiber that coupled the 1319-nm source to the pre-mixing optics; and (2) diffraction effects caused by interaction of the 1319-nm input beam with the sides of the waveguides in the pre-optics. It was anticipated that both problems could be solved by removing the PM fiber and running the 1319-nm system through free space, as was already done with the 1064-nm input. The 1319-nm laser oscillator had to be returned to the manufacturer for this modification.

After the modified 1319-nm laser oscillator was returned by the manufacturer, LMCT proceeded to complete the installation of the system on the single optical table. Each input stage was aligned and tested, and measurements were taken on each input side for the beam quality, beam profile and power. Based on the measured power from each input stage and the assumed efficiency of conversion, LMCT predicted that the final 589-nm output power would be about 33 Watts.

During final tune-up of the 1319-nm system prior to the full-power test, LMCT noticed a gradual but progressive degradation in both the beam quality and power. In the course of diagnosing this degradation, LMCT found that a small amount of energy was being reflected back into the modified 1319-nm laser oscillator, but LMCT believed that the oscillator had an internal isolator at the output aperture that would protect the oscillator from damage by this small amount of unintended feedback. However, the oscillator did appear to have suffered damage. LMCT contacted the vendor and learned for the first time that the isolator had been removed during the process of converting the oscillator from fiber to free-space operation; the vendor’s design calls for the isolator to be standard equipment only with the fiber-coupled version, but this fact was not known by LMCT until after the damage occurred. Because the 1319-nm oscillator was no longer usable, LMCT was unable to operate the system at all during the final review in September 2009, which was supposed to include a full-power demonstration.

During subsequent discussions with NOAO, LMCT maintained that the sub-award was a best-efforts contract, and, accordingly, LMCT refused to have the failed oscillator repaired or to take any other steps towards completing the full-power demonstration unless LMCT received additional funding to cover the costs of those steps. LMCT offered to repair the system and complete the demonstration for an additional payment of $47,121. LMCT further insisted that it be paid $2,198 per month for storage of the system while NOAO determined whether additional funding could be obtained to pay for the repairs. NOAO agreed to pay the monthly storage charges while it discussed the funding situation with the NSF.

Following discussions with the NSF, NOAO advised LMCT in early February 2010 that no additional funding would be available for repairs. NOAO at that time requested LMCT to prepare and submit its final report under the sub-award. LMCT submitted its initial draft of the final report by email on 26 February 2010. On March 2, NOAO responded noting four deficiencies in the report and requesting that the report be revised to address these deficiencies. As of 31 March 2010, NOAO was awaiting receipt of the revised final report from LMCT. As soon as the revised final is received and found satisfactory, NOAO will release the final payment to LMCT and close out this sub-award.