



NOAO Annual Management Report Adaptive Optics Development Program (AODP)

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PI Name: William S. Smith
AURA

Prepared by:
Dan Eklund, Project Manager
NOAO

Annual report for period April 1, 2007 to March 31, 2008

Management Activities and Findings

UC Berkeley:

"A Noiseless Imaging Detector for AO with KiloHertz Frame Rates"

The initial statement of work included producing a working vacuum imaging tube containing the GaAs photocathode and Medipix2 anodes. The project has succeeded in producing an image tube in-house with a Medipix2 anode and a multi-alkali (S-20) photocathode, allowing them to characterize its imaging performance. Response uniformity (flat field), spatial resolution and linearity, high frame rate (1 kHz) and electronic shutter (~1.5 microsec) have all been demonstrated to meet the specifications required of a wavefront sensor. Unfortunately, the quantum efficiency was a factor of 4 lower than expected due to a failure of the photocurrent sensing circuit during the photocathode deposition process.

The project had trouble interesting a major industrial partner in producing GaAs or GaAsP ("GenIII") photocathodes for these few development tubes, without a large order commitment for substantial resources. Recently, Photonis (including their recent acquisitions Burle Industries and DEP) have agreed to make some 25 mm tubes with S-25 cathodes on another NSF project on high time resolution imaging and any progress with this project can be directly applied to a Medipix ASIC readout tube design.

This work has also led to research with neutron sensitive MCPs read out with the Medipix (and the related Timepix ASIC) which allows high flux neutron radiography as well as high spatial resolution (< 30 micron FWHM) neutron imaging and a proposal has been submitted to the NSF to further support this effort. NASA has funded MCP readouts and a small amount of this funding will be used to develop space-qualified electronics for the Medipix/Timepix readout for UV sensitive MCP detectors. The group is also working with a small company (Epitaxial Technologies) to develop near infrared APD arrays mounted on the Medipix/Timepix readout and they plan a joint STTR proposal to NASA in September 2008. Over 10 papers on the work have been published both in conference proceedings and refereed journals.

Of the total award of 900,233, UC Berkeley has received the full amount.

CARA:

"Development of the Next Generation Optical Detectors for Wavefront Sensing"

CARA has been granted a further 1 year no-cost extension for the effort to end on 12/31/08. The process of "piggy backing" on other customer's wafers at MIT/LL, while cost effective, continues to be a primary schedule driver.

Two wafers carrying phase 1 devices (CCID-56b) were given to the project and processed through backside processing and AR coating. This avoids the masking problems encountered on the previous attempt, where masking for the AR coating resulted in problems that eventually made the parts in that previous attempt unusable.

A total of 12 parts with excellent cosmetics and functionality have resulted from the most recent processing. Four have been packaged and tested, with one on its way to SciMeasure for

testing with a low noise readout system. The parts also have very low dark current. Room-temperature dark currents are just under 0.5 nA/cm^2 , compared to typical values of 2-4 nA/cm^2 .

The project is expecting to be able to report definitive testing results for the phase 1 devices within the next few months.

The design of the phase 2 device is complete, and after finalization of various details, and checking, the layout will be ready for production on the next available wafer run. That is expected to take place in the fall of this year (2008).

The phase 2 device consists of 30×30 subapertures corresponding to one quadrant of a circle representing a full 60×60 subaperture device. There are 51,198 pixels on the prototype, with the full device having 204,792 pixels. The phase 2 device has 32 video outputs, each with an average of 1600 pixels from a number of subapertures via a long serial register. Readout time is $< 500 \text{ us}$, allowing a frame rate of up to 2,000 Hz. The inner imagers (nearest the laser projection point at the center of the telescope aperture) are 6×6 active pixels, and the outermost imagers are 6×15 pixels. These longer imager arrays will accommodate the expected size of the elongated image and a 20 km maximum mesospheric sodium layer thickness.

The device will be suitable for use with CW or pulsed lasers. There are 10 separate imager row clocks corresponding to 10 annular rings of subapertures, allowing a variable speed clock in each row to follow the apparent motion of a spot from a pulsed laser as it transits the mesospheric sodium layer. A test configuration for the device is being developed to permit simulation of the pulse tracking mode."

**Lawrence Livermore National Labs:
"Pulsed Fiber Laser for Guide Stars"**

LLNL received all parts for amplifier systems in late November, early December 2007. Due to late arrival of parts, a no-cost contract extension was approved through October 31, 2008. LLNL has now received the total award of 1.5 million. Construction of the laser system is now progressing rapidly. As of this writing two of three 938nm fiber amplifiers have been completed. The second stage amplifier output power is 3W meeting the design target for the second stage. Construction of the third stage has begun and will be completed by the end of June 2008. At that point a full 938nm system test will be performed including all targeted pulse formats. The 938nm amplifiers are rack mounted and are pumped by laser diodes contained in a separate rack mounted laser diode chassis.

The laser seed signals need to be phase modulated to guard against SBS in the fiber amplifiers. Dennman and Hillman (AFRL) have proposed that phase modulation frequencies need to be at least 180MHz apart in order to achieve maximum return from the sodium layer. LLNL has designed and constructed a phase modulation circuit that will permit nine equal power laser lines to be created from a single frequency input laser line with spacings of 180MHz. This will minimize SBS while maintaining a high sodium return. The RF circuit to accomplish this was not in the original project proposal, but was developed anyway to ensure maximum usefulness of the laser system.

It was determined that the commercial 1583nm fiber amplifier based upon Er/Yb simply will not perform as needed. A new amplifier design was developed based on core pumping of Er fiber without Yb. This design was tested at low power and worked well. A full 10W version of this

system will be constructed in July 08 using parts that were ordered in January and received in April. The sum frequency mixing breadboard has been designed and all parts for that system has been received. Sum frequency mixing experiments will be performed in August and September and the full system should be finished and tested by the end of September. Discussions with UCSC and Lick Observatory are continuing on the possibility of fielding the system on sky. However, doing so will require additional funding for moving the laser and installing it in the observatory.

Coherent Technology, Inc.

"Compact Modular Scalable Versatile LGS Architecture for 8-100 m Telescopes"

This past year has concentrated on power scaling the system. Progress has been steady with problems encountered leading to non-homogeneous profiles and preferred spatial gains. After modeling the pump lens design in Zemax those problems were solved. A second problem was the catastrophic failure of several diodes. This was determined to be from excessive heating of the diode driver connections. Older but more reliable models have been substituted and the manufacturer is working to resolve the problems with the newer drivers. Another problem that occurred was the loss of two 1064 nm waveguides due to excessive heating at the input face. This was determined to be from large absorption of the pump power very near the damage threshold. This has been corrected by adjusting the pumping wavelength dependent upon the doping of the waveguides.

After resolving these problems and the two IR systems stabilized, the two wavelengths were mixed in the PPSLT non-linear crystal. After using a polarization filter to clean up the polarization, the input to the first waveguide amplifier stage was reduced by about 20%. This led to 34W of 1064 and 28W of 1319 to produce 7.8W of 589 nm with a conversion efficiency of 12.4% which is 1/3 of the modeled performance and 2/3 of the expected performance. By using two more crystals and assuming 1/3 performance (current), a total of 38W of 589 nm power (CW) would be produced. This should also increase with improved conversion efficiency.

The current effort underway is testing the pulsed formats. Degraded diodes have been replaced and electro-optic modulators inserted into the IR legs beginning with the 1319 leg. The average power for the MCAO format in the 1319 leg is 40 W, 200 W peak power and the average power for the ELT format in the 1319 leg is 43 W, 860 W peak power. These are excellent results and is very encouraging for the SFG stage. The 1064 nm pulsed system is currently being set up with results expected by the end of June 08.

LMCT has received \$1,858,584 with the remaining \$1,375,669 having been encumbered for the total award of \$3,234,253.

Summary:

Under the current funded efforts for AODP, there will only be one effort still ongoing at the end of CY08, LMCT. Of the 4 ongoing efforts three are working on no-cost extensions which will expire by the end of the year. All three are identifying other funding sources to continue efforts with those projects.

Contributions

Contributions within Discipline

All of the AODP projects are contributing significantly to the astronomy community. The detector development is leading to better WFS for use on future larger telescopes. The laser development from both LLNL and LMCTI are leading to more compact LGS systems that will be safer than previous dye laser systems and coupled with the engineering research for fiber

development will significantly enable multi beam systems required for the larger telescope systems.

Contributions to Other Disciplines

The development of the more compact higher power fiber laser systems from LLNL is leading into investigations of using these to pump higher power lasers. NASA has expressed interest into the possibility of using the 938 micron laser to study water vapor absorption. The system from LMCTI using the waveguide amplifiers could be used for wind LIDAR systems and for atmospheric sensing. The on going detector development efforts at Berkeley are leading to using the same Medipix chip in photon limited IR applications as well as using it behind neutron sensitive micro-channel plates for high rate neutron tomography.