Status Report

to the

Gordon and Betty Moore Foundation

on the

Laboratory for Adaptive Optics

at

UC Santa Cruz

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Status Report: Laboratory for Adaptive Optics
UC Santa Cruz

The Laboratory for Adaptive Optics (LAO) has begun a six-year program to develop adaptive optics technology, concepts, and instruments for astronomy. The Laboratory was funded in August 2002 with a generous award from the Gordon and Betty Moore Foundation. From August 2002 to June 2003, we have been staffing the Laboratory, preparing laboratory facilities, and developing project plans for the planned multi-conjugate adaptive optics (MCAO) testbed and extreme adaptive optics (ExAO) instrument construction.

Executive Summary

The Laboratory for Adaptive Optics has achieved excellent progress toward its goals. We have been able to attract outstanding staff, and are well along in the process of preparing the permanent laboratory facility for the LAO. Interim lab space will allow us to begin our initial experiments over the next few months.

As of July 1, 2003, we have hired a significant portion (~two-thirds) of the staff for the LAO, with active recruitment for the remaining staff in progress. The laboratory facility space has been allocated, renovation plans completed, and refurbishment of the space as a low-vibration precision optics laboratory is under way.

Project plans for multi-conjugate adaptive optics (MCAO) and extreme adaptive optics (ExAO) experiments are drawn up and we are purchasing major equipment. Our developing MCAO experiments mesh nicely with astronomers' plans for extremely large (30-meter diameter) astronomical telescopes. Adaptive optics will be critical to observational astronomy of this magnitude. To detect planets around nearby stars, the ExAO instrument development plan will deploy a high-precision adaptive optics system on an existing (8-10-meter) large telescope in the 2007 time frame.

Our progress is due in large part to the mutually beneficial partnerships that we have with the University of California Observatories and the Center for Adaptive Optics. Our partners have provided intellectual as well as functional support, permitting us to accomplish much in this first year without "reinventing the wheel."

Staffing

During the Laboratory's first year, LAO staffing plans were defined and most of the positions have been filled. A few key positions remain unfilled; the university is actively recruiting for these positions.

In addition to the Principal Investigator (Claire Max) and two Co-Investigators (Jerry Nelson and Joseph Miller), the LAO has allocations for three Academic Research Astronomers, the senior of which is the designated Laboratory Director. Dr. Donald Gavel accepted this appointment and started as Director in June 2003. Dr. Gavel has more than ten years of experience at Lawrence Livermore National Laboratory in the

Adaptive Optics Group, fielding systems for astronomy, medical vision, and other applications.

Three additional researchers from LLNL have accepted multi-location assignments (a benefit of LLNL management by the University of California). The researchers, who will spend approximately half of their time at LAO, are:

- Dr. Bruce Macintosh, astronomer, who will be chief scientist for the Extreme Adaptive Optics Planet Imager (XAOPI) instrument project,
- Dr. Gary Sommargren, an expert in ultra-precise metrology who will also be working on the XAOPI project, and
- Mr. Brian Bauman, an optical engineer experienced in adaptive optics, will lead the engineering efforts for both the XAOPI and Multi-Conjugate Adaptive Optics (MCAO) projects.

The LAO has an allocation for two postdoctoral researchers in physics or astronomy and for two graduate student researchers. We are currently recruiting for the postdoctoral positions. Our first graduate student (Mark Ammons) is starting his graduate program at UC Santa Cruz in the LAO this summer. While still an undergraduate, Mr. Ammons built his own adaptive optics system. In fact, he came to UC Santa Cruz specifically to work in the Center for Adaptive Optics and at the LAO.

In addition to the academic appointments, the LAO budget included engineers, technicians, and a programmer. A laser-electro-optics assistant engineer recruitment is under way. This position attracted a great many qualified applicants, and we plan to complete the selection process by August 2003. A senior electronics technician and a mechanical technician have been identified and assigned to LAO from the UCO/Lick Technical Shops. A senior programmer recruitment will be posted later this month. The programmer will join the UCO/Lick software group, but will be assigned full-time to support the LAO. An administrative assistant for the LAO Director has been hired. The UCO/Lick Business Office is providing support in the areas of financial analysis, purchasing, personnel, payroll, and facilities coordination. Using this experienced business office to support the LAO has resulted in efficiencies for our operation.

In summary, the LAO has filled its three senior academic positions. We have also filled three out of five technical positions, and plan to have the remaining two hired by this fall. We expect to have two postdoctoral students by the fall of 2003, and we have filled one of our two planned graduate student positions. Our administrative and business operations support is also in place.

Facility Preparation

After much evaluation of available on-campus space, we selected a 1,900 square-foot area on the first floor of the Kenneth Thimann Laboratories as the site for the Laboratory for Adaptive Optics. This location (rooms 185 and 191) has the advantage of being in close proximity to both UCO/Lick and the Center for Adaptive Optics (CfAO). Its position on the ground floor makes it suitable for maintaining the kind of temperature and vibration control necessary for performing precise optical measurements.

We selected an architect, Glass Associates of Oakland, to support the design and construction phases. Glass Associates has retained an experienced laboratory facilities consultant (Thomas Mistretta, Research Facilities Design) to assist in the detailed laboratory planning. We brought in a vibrations/acoustics consultant (Michael Gendreau, Colin Gordon and Associates) to measure and analyze the environment, and to recommend necessary building modifications to achieve the stringent low-vibration requirements for adaptive optics.

Most of the floor space in the new Laboratory became available for our use in May 2003 (once the space was no longer conscripted by ongoing classes and other activities). A portion (408 sq. ft.) of the floor space will remain occupied by an astronomy research project until June 2004. The LAO space will be reconfigured as optics laboratories in three phases over the next ~18 months to accommodate the change in space use next year, and to make space available to LAO for experiments at the earliest possible time.

Phase 1 will consist of a quick renovation of the floor and walls in room 191 and the addition of two double doors (see Figure 1). This space will be ready for laboratory experiments in September 2003 with two optics benches to accommodate the first extreme adaptive optics (ExAO) and multi-conjugate adaptive optics (MCAO) experiments.

Phase 2 will consist of converting room 185 from a classroom to an optics laboratory. This room requires reconfiguration of the ventilation ducts and dampening of the supply fans in the plenum across the hallway in order to meet vibration and noise suppression requirements. Room 185 will be ready in early 2004.

Phase 3 will consist of completing the renovation of room 191 when the remaining space (in 191b and 191c) becomes available for LAO use in the fall of 2004. Experiments in 191 will be moved to room 185 during this time. When the renovation of room 191 is complete (early 2005), the ExAO experiment will be located in room 191 and the MCAO experiment will remain in room 185.

Phase 1 Phase 2 Phase 3

Figure 1. Laboratory for Adaptive Optics Facility plan. Phase 1 will be ready in September 2003, Phase 2 in early 2004, and Phase 3 in early 2005.

Interim Plans for the LAO Facility

In order to begin experiments immediately, we are setting up an interim facility in the high bay of the UCO/Lick Instrument Shop. This will be available to us until the Thimann Phase 1 renovation allows us to occupy that space in September 2003.

The ExAO experiment layout is shown in the diagram in Figure 2. The goal of this initial experiment is to verify that the phase-shifting diffraction interferometer, designed and implemented by Gary Sommargren, is capable of reaching the metrology goal of 1 nm.[1] This level of precision is currently achieved in Dr. Sommargren's laboratory at LLNL, shown in the photograph in Figure 3.

Once the interferometer has been calibrated, the next step will be to add a micro-deformable mirror (MEMS device) to the setup in place of the flat fold mirror, and to verify that the MEMS device can actively control the wavefront to the required 1/1000th wave precision.

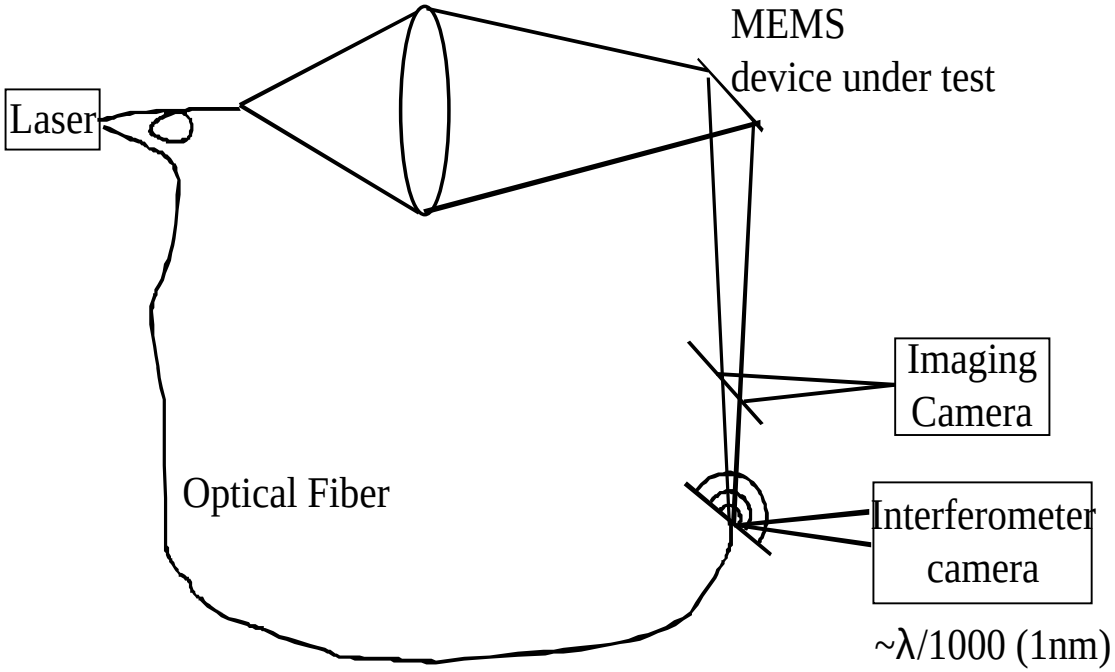

Figure 2. Layout of the initial ExAO experiment. A point diffraction interferometer capable of measuring 1 nm will test the control accuracy of a micro-deformable mirror.

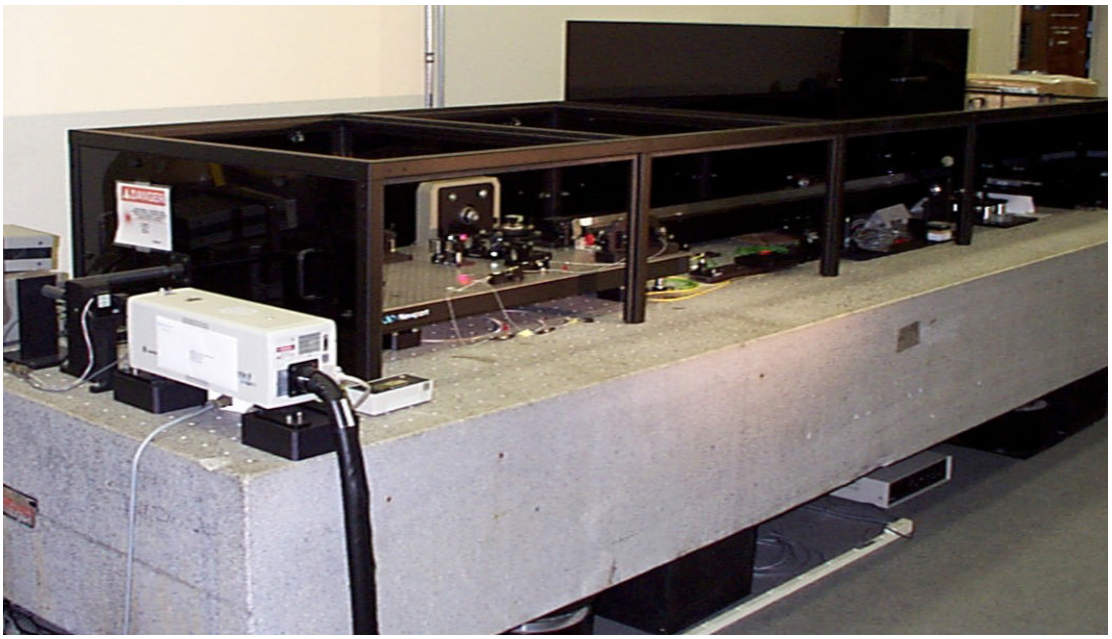

Figure 3. Gary Sommargren's phase-shifting diffraction interferometer at Lawrence Livermore National Laboratory. The layout at the LAO will be very close to the one in this figure.

Figure 4. Interim facility for ExAO experiments, in preparation at the UCO/Lick Instrument Shop at UCSC

ExAO Progress

We have refined the science case for the XAOPI instrument during the past year to account for the expected number of stars that might have young Jupiter-mass planets that would be detectable by the instrument.[2]

We initiated discussions with the staff at two observatories (the W. M. Keck Observatory and Gemini) concerning plans for XAOPI. Both observatories have adaptive optics upgrades as part of their strategic plans and are excited about the prospect of commissioning a planet-finder instrument.

A preliminary project plan for the construction of XAOPI involving LAO, UCO/Lick, and LLNL personnel is in progress. In late June, we submitted a proposal to NASA's Terrestrial Planet Finder Technology and Development Program to help support the complementary effort of the XAOPI instrument integration and initial science at its host observatory. We expect news of the agency's determination of this award as early as next month (August 2003).

MCAO Progress

Multi-conjugate adaptive optics (MCAO) is intended to provide wide field-of-view adaptive optics correction for the 30-m telescopes of the future. To perform laboratory experiments relevant to MCAO on a 30-m telescope, one must scale 60 km of turbulent atmosphere and a 30-meter diameter telescope to fit on a room-size optical bench, while still retaining the proper diffractive behavior of the optical system. This scaling issue has driven the optical design of the testbed. The scaling issues and their resolution are summarized in a report to the LAO/CfAO community.[3] The testbed optical design is nearly complete and we have specified the main components for purchasing. The first MCAO testbed experiments will be on the optics table in room 191 by September.

In order to mimic a turbulent atmosphere in the Laboratory, a means of creating optical aberrations similar to those of the Earth's atmosphere is needed. Under the guidance of the LAO, the microfabrication facility at LLNL is conducting research in the fabrication of glass plates to simulate atmospheric aberrations. The challenge is to achieve a high dynamic range of optical path difference in order to simulate the atmosphere over a 30-meter telescope aperture with a total of about 20 microns of optical path variation, to on the order of 100 nanometers precision, which is the adaptive optics correction accuracy goal for MCAO on a 30-m telescope. This project is progressing quite well and the first set of plates is due shortly. Once the process has been established, we plan to commission LLNL to fabricate a "library" of phase plates for the LAO's MCAO testbed, to emulate the atmospheric turbulent layers at various altitudes and a variety of strengths.

References

1. Sommargren, G. E., Phillion, D. W., Johnson, M. A., Nguyen, N. Q., Barty, A., Snell, F. J., Dillon, D. R., Bradsher, L. S., "100-Picometer Interferometry for EUVL," *Proc. SPIE*, Vol. 4688, July 2002, pp. 316-328.

2. Olivier, S., "Extreme Adaptive Optics," Center for Adaptive Optics, Spring Retreat, San Jose, CA, March 21-23, 2003. On the web at http://cfao.ucolick.org/presentations/springretreat2003/SR03_Olivier_ExAO.pdf

3. Gavel, D., "Laboratory for Adaptive Optics at UC Santa Cruz," Center for Adaptive Optics, Spring Retreat, San Jose, CA, May 21-23, 2003. On the web at http://cfao.ucolick.org/presentations/springretreat2003/SR03_Gavel_LAO.pdf

Financial Report

While we made good progress scientifically this year, two pivotal events in the creation of the LAO took considerably more time than we had originally planned. These were the appointment of our new Director and the preliminary design phase for the new laboratory facility. We commenced the new Director appointment process in November 2002 with the offer being extended in June 2003. This process took longer than expected because it was a very complex, senior appointment, but we believe we found the ideal candidate.

Our facility planning efforts began in August 2002 with a review of the proposed site in the Jack Baskin Engineering Building. It turned out to be unsuitable because of vibration issues. Given the limited space on campus, we evaluated several other options and came up with a new solution in Thimann Laboratories by augmenting an existing UCO/Lick laboratory with space belonging to the Physical and Biological Sciences Division. This entailed relocating an extensive and fragile sky survey plate archives to Lick Observatory on Mt. Hamilton. We are very excited about the new space as it is well situated on campus. Our plan to phase the renovations will allow the research to continue while permitting an ongoing astrometric project to sunset.

Because of these delays, we spent much less money in the startup year than expected. Now that we have most of our staffing in place, we expect our expense trajectory to rise considerably in the coming year. Additionally, we have begun the procurement process for some of the specialized lab equipment. Finally, the total estimate for our lab renovation is about $1 million. A small part of that was expended this year and a significant portion of that will be spent or committed during Year Two.

The Moore Foundation grant funds have accrued simple interest (at ~6%) during the first year. Typically, the campus' central administration and the University Relations Division share interest income earned on unspent grant funds. Because this project is so important to the campus, the administration has made a special provision for the disbursement of the interest income funds, which total approximately $91,000. The LAO project will retain one-third ($30,395) of the interest income as is indicated on the project financial report. The Physical and Biological Sciences Division and University Relations will equally share the remaining two-thirds. The LAO will use the funds most immediately towards renovation expenses. The Physical and Biological Sciences Division intends to use the funds to prepare a comprehensive brochure for the division that will market the attributes and achievements of the division to a wider funding audience. University Relations will use the funds to provide much-needed support for development operations, focusing on increasing private support to the campus from individuals, foundations, and corporations.

Summary

The Laboratory for Adaptive Optics is progressing well toward its goals. We have been able to attract outstanding staff, and we are well along in the process of preparing the permanent laboratory facility for the LAO. Over the next few months, interim lab space will allow us to begin our initial experiments. Our two initial experiments will test multi-conjugate adaptive optics concepts to enlarge the corrected field of view for 30-m telescopes, and “extreme” adaptive optics concepts to detect Jupiter-mass planets around nearby stars.

We are grateful to the Gordon and Betty Moore Foundation for providing the funds to launch this exciting endeavor, which has the potential to have a major impact on astronomical science and technology for years to come.