WIYN's One Degree Imager: About a Year to the Start of Commissioning

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The One Degree Imager (ODI) is the future flagship instrument of the WIYN Observatory (see June and December 2006 issues of the *NOAO/NSO Newsletter* for previous updates on ODI). This innovative instrument will use an 8 × 8 array of Orthogonal Transfer Array (OTA) CCD detectors to sample a one-degree field of view with about one billion pixels. Additional electronic tip/tilt image motion correction is expected to improve the median image quality by 0.1 minute in the r' band (see accompanying box on OTA devices for details). ODI will be *the* wide-field, high-resolution imager in the US. The project has made substantial progress during the last few years. Installation of ODI at WIYN is scheduled for early 2010, with science commissioning following later in the year. ODI might be offered for shared-risk science operations as early as the end of semester 2010B. *(Disclaimer: Because all projects can suffer delays, do not base your entire career on dates presented in this article.)*

Figure 1: Instrument maker, Ron Harris, standing behind the aluminum Atmospheric Dispersion Compensator (ADC) housing. Three triangular shaped outrigger blocks will bolt to the housing to form the main structural component to which filter mechanisms and axles, ADC cells, and Dewar will mount. When completed, the housing will weigh 170 pounds with overall dimensions of 37 inches across the flats by 6.26 inches thick.

Status of ODI

The ODI project has made significant progress in all aspects of the instrument since the last *NOAO/NSO Newsletter* article two years ago. The design of the instrument is finalized, and all major system reviews have been successfully completed. (Separate design reviews were held for the Instrument Support Package, Dewar and focal plane assembly, and the software.) At NOAO, machinists and instrument builders have spent the past year working on ODI's backbone, the instrument support package (ISP) (see figure 1). All of the large aluminum and steel parts of the instrument have now been manufactured.

Almost all major component procurement items have been contracted: the optics are being manufactured by Société Europénne de Systèmes Optiques (SESO, France). ODI's optical system consists of a two-element field corrector (two Fused Silica lenses) and an atmospheric dispersion compensator (four wedges: two made from Fused Silica and two from flint glass PBL6Y) (figure 2). Parts of the optics are ready for shipment as of this writing. A California firm, Infinite Optics, will treat the optics with high-performance, broadband anti-reflection coatings.

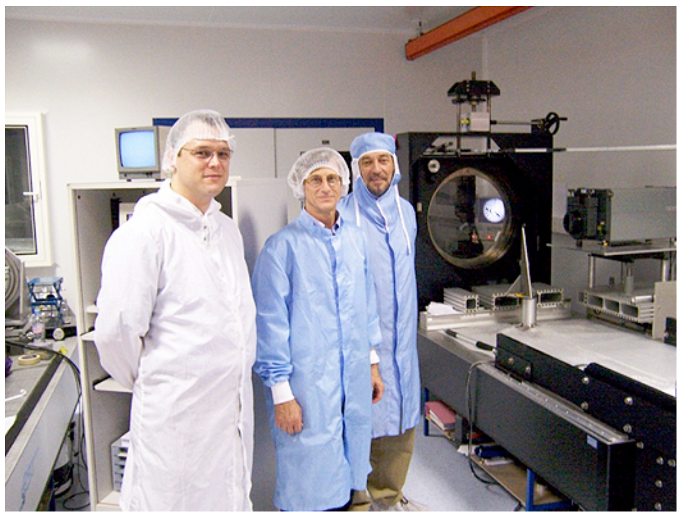

Figure 2: Dan Blanco, George Jacoby, and Daniel Harbeck (from right) visited the optical vendor SESO at Aix-en-Provence during the 2008 SPIE meeting. A wedge for the atmospheric dispersion compensator is mounted in an interferometer (right) to verify its flatness. All optics are anticipated to be delivered by March 2009.

Semiconductor Technology Associates finalized the design of the OTA CCD detectors, and production at the wafer level has been successful at DALSA Corporation. The detectors will be thinned and packaged by Imaging Technology Laboratory (ITL) at the University of Arizona. ITL will also fully characterize the detectors and mount them within the specified flatness requirement onto a custom-made Silicon Carbide focal base plate (Coorstek).

The detector array will be driven by a Stargrasp controller system, purchased from the Institute of Astronomy at University of Hawai'i. The Stargrasp CCD controller was developed to drive OTA detectors for the Panoramic Survey Telescope & Rapid Response System (Pan-STARRS) imagers, and has successfully demonstrated OTA-correction on sky

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with the PS1 camera. Substantial work towards the instrument control software design has been done at WIYN. The University of Bonn is under contract to deliver the large mechanical shutter for ODI.

The last major purchase for ODI, the filters, was started in December when we placed the order for SDSS g', r', and i' filters from Barr Associates. In the upcoming month, we will work on the specifications for the remaining four filters: z', U, H-alpha, and O [III].

We are now ramping up for assembly, integration, and testing of ODI during this year with an anticipated start of installation at the telescope in the first quarter of 2010. The next two major milestones in 2009 are the testing of the ODI instrument support package and optics *on the telescope* during the summer shutdown of operations, and the delivery in the fall of the focal plane plate with all detectors mounted.

The WIYN of Change

ODI will be by far the most complex and expensive instrument that WIYN has seen so far, and its integration at WIYN will certainly have an impact on operations. Most foreseeable, there will be a change in the port allocation. WIYN has two major ports in use, the two Nasmyth ports. Hydra, the multi-object spectrograph, currently occupies one of these ports. The other (named the "WIYN" port) hosts the Instrument Adaptor System (IAS) to which all other instruments are currently mounted (i.e., SparsePak, MiniMo, OPTIC, WHIRC, and visitor instruments). ODI will be permanently mounted at this "WIYN" port. The current Hydra port will then be shared between Hydra and the IAS in about two month-long time blocks. Whenever the IAS is mounted, sensitive parts of Hydra will ride on a cradle on the telescope fork. When Hydra is mounted, the IAS will be completely removed from the telescope.

ODI might lead WIYN to develop new, efficient observing modes. For example, we currently are investigating operating ODI in a queue mode, which would improve quality of data and calibration products, but could also *ensure* the success of the highest ranked projects (compared to betting on good weather). Similarly, diverse options are being explored to offer data reduction pipelines and support thereof to ODI users. The WIYN Board has authorized the hire of two dedicated scientists to support the study of the development of a data pipeline system and a queue observing mode for ODI.

What Are OTAs and How Can They Help Us?

Orthogonal Transfer Array CCD detectors (OTAs) were developed by Lincoln Labs and John Tonry in order to provide a detector that could assist in the process of maximizing the delivered image of every science exposure (e.g., Tonry et al. 2002, SPIE, 4836, 206). Each OTA device consists of an 8 × 8 array of CCD cells that can operate as an almost independent detector.

For ODI, each of these cells will cover approximately one square arcminute on the sky. The pixel structure in these CCD cells allows the charge to be moved up/down and left/right during integration, not just during the read-out of the array. Even better, the behavior of each cell can be controlled largely independently. While some cells of a detector might integrate light like a normal CCD, others can be repeatedly read out at video frequencies (about 20 Hertz). The basic proposed operating mode for OTA detectors is that cells with bright stars (about 12–14^{th} magnitude) are read out in video mode, and the image motion as sensed by these stars would be used to shift the charge in the integrating cells to compensate for that image degradation. Thus, OTA detectors are the electronic equivalent of a tip/tilt mirror system. The following operating modes are envisioned for ODI:

Static imaging: ODI is used as a conventional, large CCD imager. Guide stars can be used for telescope guiding.

Coherent correction: A single correction for unwanted image motion is determined for and applied over the entire field of view. This correction is derived from the correlated motion of guide stars in the corners, correcting for telescope guide errors and windshake. We expect this to be the workhorse mode of ODI for its low overhead needs.

A variation of this mode would shape the point-spread function into squares, allowing high-precision photometry. (See related article, "What are Orthogonal Transfer CCDs Good for Anyway?")

Local correction: Image motion is corrected locally based on the nearest guide star's motion signal. In addition to the correlated motion, effects of atmospheric turbulence could be corrected. This mode will provide the best possible image quality at the cost of increased data reduction efforts and observing overhead.

Shutterless photometry: Guide stars are science targets, and their video stream is used to derive shutterless photometry at rates from 0.1 to 20 Hertz.

Non-sidereal tracking: The guide stars are used to derive a telescope-tracking signal for non-sidereal guiding (solar system science).

If the concept of OTA detectors in a wide-field imager sounds familiar, you might be reminded of Pan-STARRS. Their cameras will utilize the same detector concept, and there is a close collaboration between the ODI team and the Pan-STARRS camera team in the detector and camera development effort (see *pan-starrs.ifa.hawaii.edu/public/* for more information on Pan-STARRS).

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ODI in the System

ODI will be a significant addition to the US System and will give us a unique wide-field imaging capability in the Northern Hemisphere. However, ODI will not be the only wide-field imager in the world. In fact, over the next ten years there is an entire ecosystem of optical, wide-field imaging capability developing (or already extant).

So where is ODI's niche in this highly competitive environment?

First, ODI offers open access to wide-field imaging for individual proposers: ODI is not dedicated for a single survey, but was conceived as an instrument supporting more numerous programs. Together, the Dark Energy Camera (DECam) and ODI will provide comprehensive wide-field imaging access in both hemispheres to the US community. ODI will be permanently mounted at one of the WIYN's Nasmyth ports. A paradigm in ODI's planning was not to compromise on image quality. The optical design, which includes an atmospheric dispersion compensator, and the use of OTA detectors underline this effort. ODI's key contribution to the US System will be wide-field, high-resolution optical imaging. The WIYN/ODI system should have good sensitivity in the blue optical bands (>45 percent in the U-band), which might fill a gap in available capabilities. WIYN's slow f/6.3 beam enables the use of narrowband filters, allowing programs not possible with many of the other wide-field imagers. ODI will hold up to nine filters simultaneously. Filter replacements will be possible on the timescale of a few hours. Filters for ODI will be very expensive, and, at least initially, the total number of available filters will be small and can be accommodated in the instrument.

From a national perspective, there is also a strategic value of ODI and DECam to pave the way toward efficient use of LSST. Valuable lessons will be learned about the acquisition, handling, and reduction of large data volumes. Even smaller programs done with Gigapixel cameras will most likely require data reduction strategies that rely on distributed computing; there is a need for a new generation of data reduction frameworks.

ODI is partly supported through NSF Telescope System Instrumentation Program (TSIP) funds. As a part of the TSIP agreement, Yale is planning survey projects that will involve the community—90 nights are already committed to these programs, and this total may increase. For further information, please contact Charles Bailyn (*charles.bailyn@yale.edu*).

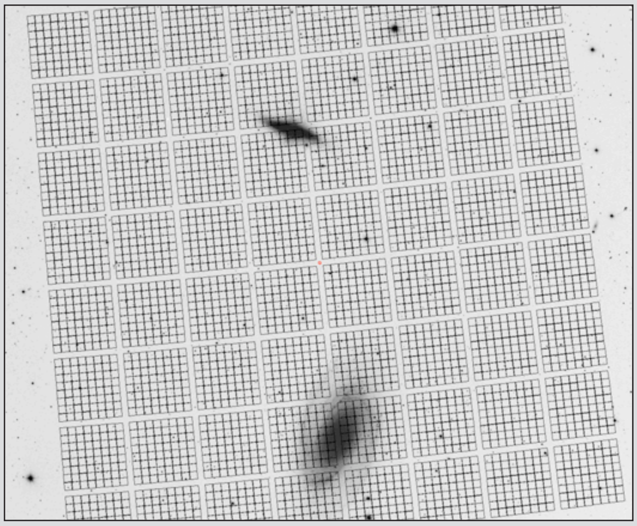

Figure 3: Predicted footprint of ODI illustrated at the M81/M82 group. Each of the 64 detectors is divided into a grid of 64 almost-independent CCD cells. The gaps between the cells are of order of 3 arcseconds, and the gaps between the detectors are about 45 arcseconds.