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CURRENT STATUS OF THE INSTRUMENTS, INSTRUMENTATION AND OPEN USE OF OKAYAMA ASTROPHYSICAL OBSERVATORY

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ABSTRACT

Current instrumentation activities and the open user status of Okayama Astrophysical Observatory (OAO) are reviewed. There are two telescopes in operation and one telescope under reforming at OAO. The 188cm telescope is provided for open use for more than 200 nights in a year. The typical oversubscription rate of observation proposals for the 188cm telescope is $\sim 1.5 - 2$. The 50cm telescope is dedicated to γ-ray burst optical follow-up observation and is operated in collaboration with Tokyo Institute of Technology. The 91cm telescope will become a new very wide field near-infrared camera in two years. The high-dispersion echelle spectrograph (HIDES) is the current primary instrument for the open use of the 188cm telescope. Two new instruments, an infrared multi-purpose camera (ISLE) and an optical low-dispersion spectrograph (KOOLS), are now under development. They will be open as common use instruments in 2006.

Key words : astronomical observatory — instrumentation:optical — instrumentation:infrared — instrumentation:spectrograph

I. INTRODUCTION

Okayama Astrophysical Observatory (OAO) which was founded in 1960 is a branch of National Astronomical Observatory of Japan. Figure 1 shows a bird eye view of OAO viewed from south eastern direction. Four telescopes, the 188 cm telescope, the 91 cm telescope, the 50 cm telescope, and the 65 cm solar telescope, are there in OAO, and two of which (188 cm and 50 cm) are now under operation. OAO is the largest domestic facility for optical-infrared astronomical observation in Japan. It is operated on common-use base and more than 200 researchers visit at OAO in total in a year.

II. SITE CONDITION OF OAO

The OAO site (atop of Mt. Chikurin-ji in the west of Okayama prefecture) is one of the best astronomical observation sites in Japan. Photometric nights and spectroscopic nights at OAO are about 50 and 150 in a year, respectively. The direction of prevailing wind is north to north-east from fall to spring, south to south-west during summer. The average wind speed is $\sim 2 - 3$ m s^{-1}.

Seeing is good at OAO. Figure 2 shows the seeing statistics measured for three month (from November 2004 to January 2005) by an automatic DIMM (Differential Image Motion Monitor) installed in the OAO site. The uncertainty of the absolute values of the FWHMs in Figure 2 is estimated as $\approx 0''.2$. The mode of the FWHMs $\approx 1''.1$, and the seeing reaches down to subarcseconds for more than 30% of observation time. Note that this measurement was made in optical band. In the near-infrared K-band the seeing should be improved by a factor of 0.8, thus subarcseconds seeing will be gotten for more than half of observation time in K-band.

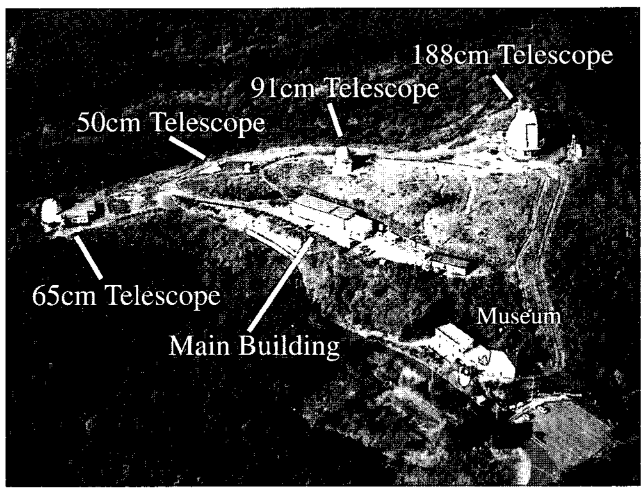

Fig. 1.— Bird eye view of OAO.

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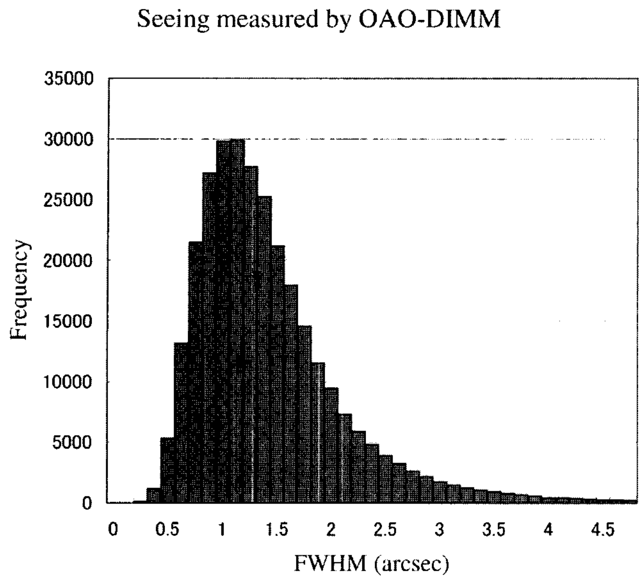

Fig. 2.— Seeing statistics of OAO for three months (from November 2004 to January 2005) measured by DIMM. The nominal FWHM values calculated from the DIMM data were corrected assuming typical measurement condition (the wind speed of turbulent layer = 20 m s^{-1}, exposure time of DIMM = 4 msec, DIMM aperture size = 5 cm).

III. TELESCOPES

(a) 188 cm Telescope

The 188 cm telescope is the primary open-use telescope of OAO. It was constructed by Grab Persons corporation in 1959. The control system of this telescope was renewed to a UNIX based network distributed system in 2000 (Yoshida et al. 2002). Currently, we are providing two instruments, a high-dispersion echelle spectrograph, HIDES (Izumiura 1999), and an optical low-dispersion spectro-polarimeter, HBS (Kawabata et al. 1999), for open-use of this telescope. Among these instruments, HBS is a so called "PI-type" instrument, which is managed and maintained by a user group including instrument development team. In addition, we are now developing two new instruments, ISLE and KOOLS, as next open-use instruments. Detailed description about these two instruments will be found in Section IV.

(b) 91 cm Telescope

The 91 cm telescope was constructed by NIKON corporation in 1959. This telescope was mainly used for optical photometry, low-dispersion spectroscopy, and polarimetry of bright point sources and nebulae until mid 2003. In order to reform this telescope to a very wide-field near infrared camera which is used for time variation monitoring of short period Mira variables (OAO-WFC project, Yanagisawa et al. 2002 and Yanagisawa in this issue), the open-use was shut down in October 2003. The main purpose of OAO-WFC project is to reveal Galactic structure by determining the distances of short period Mira variables embedded in the Galactic plane using the periodicity-luminosity relation which is well established for such type of Miras. The details of OAO-WFC project and its status are described in Yanagisawa in this issue.

(c) 50 cm Telescope

This telescope is dedicated to optical follow-up observation of γ ray bursts. This project is a collaborative work with Tokyo Institute of Technology. This is the newest telescope in OAO; it was constructed in 2003 by Chuo-Kogaku Inc. in 2003. An optical three-colors (V, R, and I-band) imager which consists of two dichroic mirrors and three 1K×1K CCD cameras (Apogee U6) is attached to the Cassegrain focus of the telescope. The field-of-view of this imager is $26' \times 26'$. The basic part of the telescope control system has been completed in mid 2004. The concept of the control system is the same as that of the 188 cm telescope (Yoshida et al. 2002). The optical afterglow of GRB041006 was successfully detected with this telescope (Kuroda, Yanagisawa and Kawai 2004).

IV. INSTRUMENTS AND INSTRUMENTATION

(a) High Dispersion Echelle Spectrograph – HIDES

HIDES (Izumiura 1999) is the main open-use instrument of OAO. It is installed at the coude focus of the 188cm telescope. Highest spectral resolving power R of HIDES is 110,000 when setting the slit width as $0''.4$. Simultaneous wavelength coverage around 6000 Å is $\approx$ 1000 Å. The detector is a 2K×4K back illuminated EUV CCD with a pixel size of 15 μm. The limiting magnitude of HIDES is ≈ 12 (S/N=10 at $\lambda = 6000$ Å with an exposure time of 1 hour). An image rotator and an I_2 cell (Sato 2002; Kambe 2002) are installed in front of the coude focus. Highly accurate radial velocity measurement can be made with the I_2 cell. The highest radial velocity resolution reaches up to $\simeq 4$ m s^{-1}.

Major targets of HIDES have been bright stars (e.g Takeda et al. 2002; Takada-Hidai et al. 2002) planetary nebulae (Otsuka et al. 2003), and solar system objects. Presently, the principal science project using HIDES is a Doppler survey of G-giant stars for searching extra-solar planets around intermediate mass stars. In the course of this project a giant planet was discovered around the G-giant star HD104985 (Sato et al. 2003). This is the first discovery of planets around G-giant stars. The details of the concept and recent results of this project are found in the paper of Sato et al. in this issue.

We plan to upgrade HIDES in order to make the limiting magnitude one magnitude deeper than the current value. The upgrade plan consists of three steps;

(1) CCD mosaicing which make the simultaneous wavelength coverage twice the present, (2) installing a fast guiding system to the telescope which stabilise the image motion on the slit, and (3) developing a image slicer with optical fiber feed system which make the aperture efficiency 1.5 - 2 times that of the current slit system. Currently, the step (1) is on-going and the basic design of the fast guiding system has been completed. The upgrade schedule is summarised in Table 2.

(b) Infrared Camera and Spectrograph – ISLE

ISLE (Infrared Spectrograph with a Low noise Efficient detector; Figure 3) is the upgrade version of the near-infrared camera and spectrograph, OASIS (Okumura 2000), which was an previous common-use instrument of OAO. The main grade-up points are follows: detector exchange (from 256×256 NICMOS-III to 1K×1K HAWAII array), optics renewal to fit the optical performance to the spatial sampling of the new detector (0″.25), and control system upgrade to enable remote observation. Specification of ISLE is shown in Table 1.

The new optical elements were installed into ISLE body in late 2004. The hardware of the control system of the mechanics of ISLE was also improved in 2004. The detailed design of the detector control system has been completed and the realization of the electronics and software is now in progress.

(c) Optical Low Dispersion Spectrograph – KOOLS

KOOLS (Kyoto Okayama Optical Low dispersion Spectrograph) is the renewal of the low dispersion spectrograph and camera called Kyoto-3DS I (Ohtani et al. 1998). Kyoto-3DS I was a three-dimensional spectrograph which has Fabry-Perot interferometry mode and integral field spectroscopy mode using a micro lens array. It was used for area spectroscopy of nearby active galaxies (e.g Hattori et al. 2004; Ishigaki et al. 2004).

TABLE 1.
SPECIFICATION OF ISLE

No. of pixels	1024×1024
Readout noise	<10 e$^-$
FOV	4′.2×4′.2
Pixel scale	0″.25/pix
Readout time	0.8 sec
Grating	300/mm, 75/mm
Slit length	40mm (4′)
Spectral Resolution (with 1″.0 slit)	≈2000 @ J+H ≈1200 @ K
Limiting mag. of imaging (S/N=10, exp=120sec)	17.3@J, 17@H, 16@K 21.5mag arcsec^{-2}@K
Limiting mag. of sp. (S/N=10, exp=600sec)	14.5@J, 13@H, 13@K

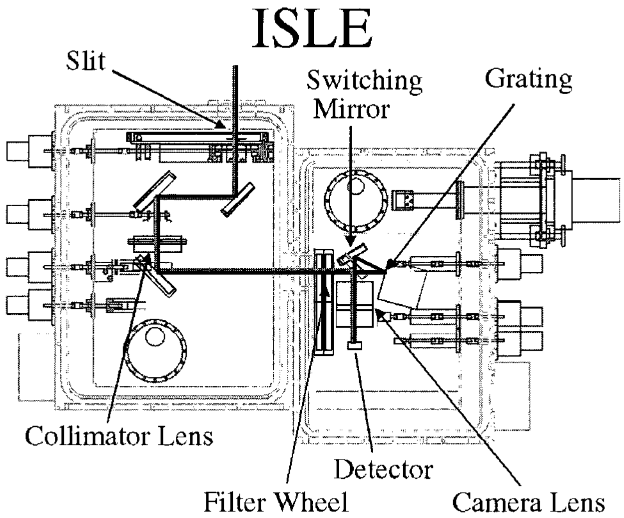

Fig. 3.— Internal structure of ISLE.

Both the micro lens array and the Fabry-Perot etalon was removed from the original Kyoto-3DS I in order to use them for the new 3D spectrograph for Subaru Telescope (Kyoto-3DS II, Sugai et al. 2004). We reformed the instrument as a simple optical spectrograph and camera with a high quality detector system.

We upgraded the detector system of Kyoto-3DS I from a 1K×1K TI CCD with Messia-II CCD control system to a SITe 2K×4K CCD with Messia-V system. Messia-V (Nakaya 2004) is the current standard detector control system of Subaru Telescope instruments. The readout noise (5e rms) and the quantum efficiency (≈ 85% at 6500 Å) of this new system are much better than those of the previous system (15e rms and 45% at 5500 Å, respectively). Thanks to this high quality detector system, the limiting magnitude (5σ detection for 1 hour exposure) of the imaging mode of KOOLS reaches down to ≈ 23 mag. at V-band, it is 1.5 magnitude deeper than that of Kyoto-3DS I. In the spectroscopy mode the 5σ detection limit of KOOLS is ≈ 19 mag. at V-band for point sources and a surface brightness of $\approx 1 \times 10^{-17}$ erg s^{-1} Å^{-1} arcsec^{-2} for extended sources at the spectral resolving power $R \approx 1000$ with 1″.5 width slit.

KOOLS is now in commissioning phase and has been attached to the 188cm telescope three times from late 2004 to early 2005. KOOLS exhibited a good performance on imaging and spectroscopy in those commissioning runs. Next step is to implement charge shuffling mode in the CCD control system.

(d) Instrumentation Schedule

Instrumentation schedule of OAO is summarised in Table 2.

TABLE 2
INSTRUMENTATION SCHEDULE OF OAO

Instrument		Schedule
HIDES	2005	CCD mosaicing
	late-2005	Fast guiding system installation
	2006	Image slicer and optical fiber-feed system installation
ISLE	2005	Detector system development and system quality evaluation
	late-2005	Attach to the telescope and start commissioning
	2006	Open use
KOOLS	early-2005	Charge shuffling mode implementation and testing
	mid-2005	Attach to the telescope and start commissioning for charge shuffling
	late-2005	Open use

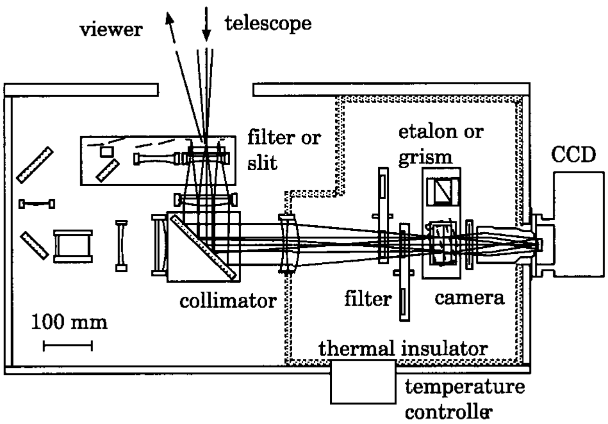

Fig. 4.— Optical layout of KOOLS. The optics left-side of the central folding mirror is for integral spectroscopy mode using a micro-lens array and is not used.

V. OPEN USE OF OAO

We provide ≈ 220 nights for open use observation in a year. The open use time is divided into two semesters, semester A (from January to June) and semester B (from July to December). Call for proposals is announced in April for semester B and in September for semester A. We invite applications to two observation program categories, long term observation category ("project category") and general observation category ("general category"). The "project category" was set up for time consuming, long term projects. The total nights and the maximum number of observation runs for "project category" per semester are 40 and 2, respectively. A "project category" program can be continued for 3 years at maximum. The maximum number of nights for each observation run of "general category" is 15. Usually, 6 or 7 nights are allocated to a "general category" program. All the observation proposals are judged by several anonymous referees from a point of view of scientific merit and technical feasibility. Typical over-subscription rate to the observation time of the 188cm telescope is 1.5 to 2. While most of the applicants are domestic researchers, proposals submitted by foreign astronomers of east Asian countries are gradually increasing in recent years. Domestic proposals and foreign proposals are refereed equally.

Details of the open use of OAO are found in the following URL:

http://www.oao.nao.ac.jp/e/index.html

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