LBT-ADOPT
TECHNICAL REPORT

Doc.No : 687f002
Version : b
Date : 03 Nov 2005

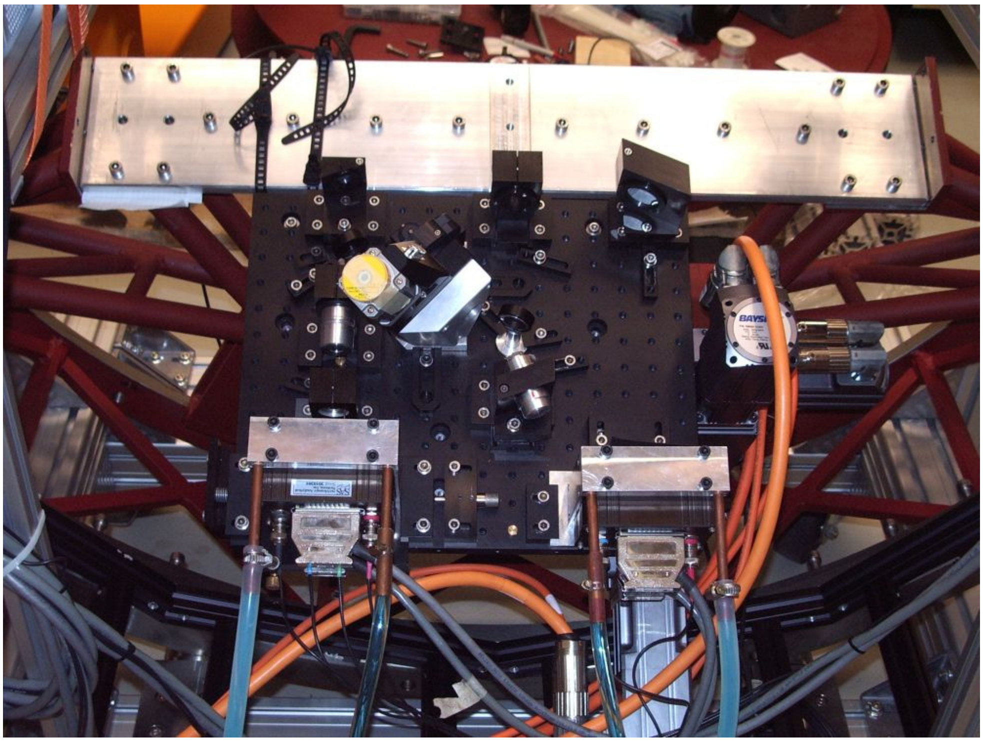
W unit laboratory acceptance test specifications

S. Esposito, A. Tozzi, A. Puglisi, E. Pinna

INAF – Osservatorio Astrofisico di Arcetri
Largo E. Fermi, 5 - 50133 Firenze - ITALY
http://www.arcetri.astro.it/adopt

ABSTRACT

The document gives a description of tests to be successfully completed during the laboratory acceptance of the W unit. The required HW subsystems and SW to perform the considered tests are listed too. Specifications for successful test completion are given. The list of the test has been defined in the AO review held in Florence in February 2005. The present discussion is following what stated in the meeting and listed in the document LBT Adaptive Optics System AIT management plan [1]. A picture of the W unit inside the AGW frame during the AIP flexure test is reported below.



Modification Record

Version	Date	Author	Section/Paragraph affected	Reason/Remarks
a	20 Feb 2005	S. Esposito		First release of the document after Feb progress meeting
b	3 Nov 2005	S. Esposito, A. Tozzi, A. Puglisi, E. Pinna	Reworking of all sections	10/11 Nov 2005 AO Review document release

Abbreviations, acronyms and symbols

Symbol	Description
LBT	Large Binocular Telescope
MMT	6.5m MMT telescope
LUCIFER	LBT NIR spectroscopic Utility with Camera and Integral- Field Unit for Extragalactic Research
AGW	Acquisition, Guiding and Wavefront sensing unit
AO	Adaptive Optics
W	On axis Wavefront sensing unit
LBT672a	First Adaptive secondary unit of LBT telescope
PSF	Point Spread Function
ARNICA	ARcetri Near Infrared CAmera
GUI	Graphical User Interface
TCS	Telescope Control System
ROI	Region Of Interest
FoV	Field of View
RTR	Real Time Reconstructor
RON	Read Out Noise
DM	Deformable mirror
SNR	Signal to Noise Ratio
WFS	WaveFront Sensor
SR	Strehl ratio
ADS	ADS International SRL
DL	Diffraction Limited
FWHM	Full Width at Half Max
AIP	Astrophysikalisches Institut Potsdam
BCU	Basic Computational Unit
HW	Hardware
SW	Software
ADC	Atmospheric Dispersion Corrector

Contents

1 Requirement before unit testing

The following items are needed in order to perform a full functional test on the W unit.

1. W control SW and engineering interface has to be installed and running on the control computer.
2. The W unit has to be mounted in the AGW frame. The main subsystems to be integrated are [2]:
   a. The three translation stages used for reference star acquisition together with their motors and encoders.
   b. The wavefront sensor board assembled with all the optomechanics has to be mounted on the focus stage.
   c. The three electronic boxes with their cabling have to be mounted and attached to the AGW chilling circuit. Electrical power has to be provided through the AGW socket.
   d. Auxiliary units has to be installed on the AGW frame auxiliary unit bench
2. The external reference source for flexure tests of the wavefront sensor has to be installed. It will contain a pupil projection system.

2 WFS board internal reference source

An internal reference source is part of the W unit and is placed in the auxiliary units bench. This source allows a first check of the optical alignment of the wavefront sensor board in terms of pupil positions and size. This reference source will be also available during telescope operation for on-line optical test. The source has to provide wavefront sensor illumination as an f/15 beam with a 1% accuracy. This specification will be checked in the optical laboratory with an ad-hoc optical set-up. The functionality test of this unit require to light the reference source and position the beam splitter cube in order to create four pupil images on the wavefront sensor CCD. The beam splitter is positioned using a translation and a rotator stage.

3 Translation Stages unit

The test of the translation stages that position the wavefront sensor board in the f/15 focal plane of LBT are summarized below.

3.1 Stages unit flexures

This test will use the external reference source to measure the displacement of sensor PSF and pupil images as a function of the rotation angle of the AGW frame (derotation angle) on the stand available in Arcetri. The specifications on the W unit flexure are given in terms of PSF and pupil displacements during operation. They are stated as:

1. PSF stability: 1/6 of the DL LUCIFER PSF FWHM at J band (30mas) for a single exposure of 10min. This corresponds to a SR attenuation of 1/e (Marechal approx.). This translates in a PSF average displacement rate less than 2.0 mas/deg when assuming 15deg/hour.
2. Pupil stability: 1/10 of a pixel in the 30x30 pixel sampling mode maximum displacement.

It has to be considered that the stated requirements do not take into account that PSF shift can be partially compensated using stages translation. This is possible because PSF displacement was found sinusoidal and repeatable in a previous flexure test at AIP Potsdam. Results for PSF and pupil displacements after mentioned test are showed in fig.1

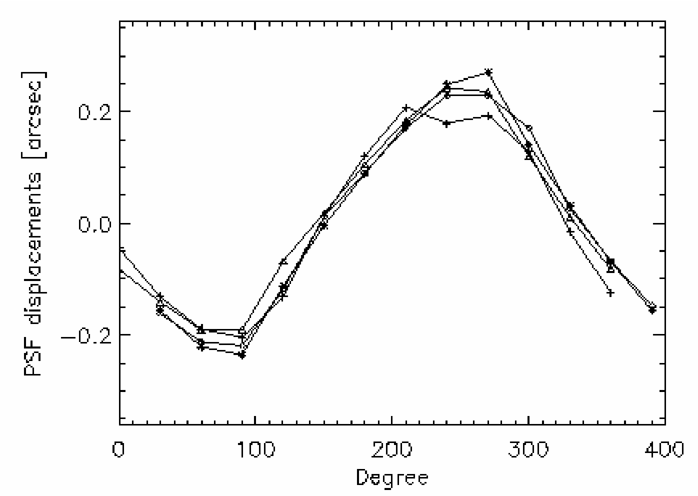


Figure 1 PSF displacement for various positions in the f/15 focal plane. The W unit was attached to the AIP telescope simulator. The W unit rotation axis is perpendicular to the optical axis and almost (6deg offset) parallel to the wavefront sensor board plane. Displacements are measured using the technical CCD of the wavefront sensor board.

Look up table to achieve sensor board counter displacement for telescope operation can be built so reducing the PSF displacement rate. LUCIFER internal tip-tilt detector will provide further reduction of PSF displacement.

3.2 Stages positioning operation

As already mentioned the sensor board is positioned in the LBT f/15 telecentric FoV using three linear stages [3] [4]. Two of them (X and Y stages) translate the board parallel to the LBT focal plane and provide star centering. The third stage (Z stage) translates the board perpendicularly to the LBT focal plane and provides star focusing. The three stages have to provide sensor homing command, positioning command and stage brake operation. The following commands will be tested:

1. Home command. Stages will be commanded on system reset to the home position waiting for next command. Homing has to be accurate to 60 micron corresponding to a 0.1 arcsec error. Homing repeatability will be measured using external position sensor with 1 micron resolution.
2. Positioning command. The stages are moved in order to place the sensor board in a particular position. The positioning error should be less then 40 micron for X and Y stages giving a maximum positioning error of approx. 60 microns. The positioning error for the Z stage should be less than 30 micron corresponding to a defocus rms of 10nm. The time required to complete a positioning command shall be less than 25s. Positioning commands accuracy will be measured using external position sensor with 1 micron resolution.
3. The stages will be stopped using their internal brake when the board requested position is reached. The brake backlash shall be less than 10 micron. The backlash will be tested using the stages optical encoder having a 0.1 micron resolution.

3.3 Stages limit switches

The stages have software limit switches and internal mechanical limit switch.

1. The software limit switches will be tested to show that the sensor board is stopped by the control software if it is moving outside the W unit FoV.
2. The mechanical limit switches will be tested to show that the WFS board is stopped by them before any mechanical interference between the board and the AGW frame.

.

4 Effective WFS FoV

The nominal FoV is specified as a rectangular region of sides [3.2, 2.3 arcmin]. The LBT optical axis is not centered in the FoV. The optical axis displacement is [0.55, 0.15 arcmin]. A sketch of the W unit FoV is reported in fig.2.

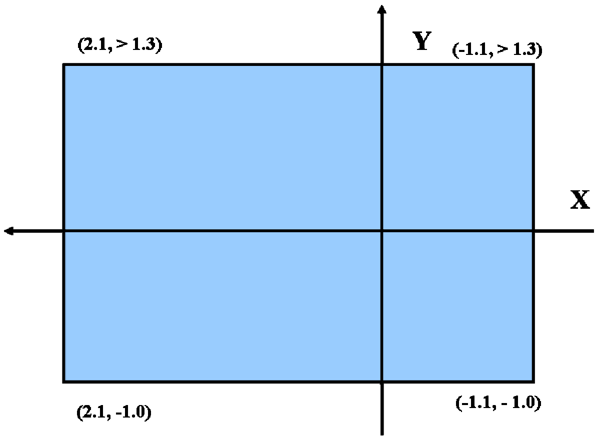


Figure 2. FoV of W unit in arcminutes. Linear dimension of this FoV at the f/15 focal plane are 115x83 mm.

The Effective FoV will have sides larger then 3.0, 2.0 arcmin. In particular the Y negative side of FoV should be reduced no more than 2arcsec corresponding to approx. 1mm. The achievable FoV will be measured doing a bi-dimensional scan of the stages travel range to check against mechanical interference between AGW frame and the WFS unit.

5 Wavefront sensor CCD RON performance test

The wavefront sensor CCD RON will be tested using the various pixel read out rates. Measured RON values should be lower than those reported in the following table

Pixel rate [kPixel/sec]	Read Out Noise [e^-]
2500	8.4
890	5.8
400	4.5
150	3.5

6 Electronic boxes test

6.1 HW and SW functionality checks

The successful power on and operation of all the control electronics inside the electronic boxes have to be checked. In order to do this low level SW has to be installed and running on the AO supervisor workstation. These commands will be available trough the engineering GUI. Control software has to provide feedback about the successful execution of issued commands (e.g. back-reading of encoder's value). The list of the modules to be tested is given below:

- Filter Wheel #1 and #2 stepper motors. Correct filter selection after SW commands has to be tested. No beam vignetting shall be present.
- Atmospheric Dispersion Corrector stepper motors.
- Pupil Re-Rotator stepper motor.

- Temperature probes operation. Measured temperature values from electronic boxes internal/external probes have to be acquired at 0.1 Hz rate.
- System rele operation. The correct power on state has to be checked when power on command is performed using a system rele. This is the case for the following devices: WFS CCD, Technical CCD, ADC, Pupil Re-Rotator, X, Y and Z Bayside stages, Filter Wheel 1&2, fast Tip Tilt mirror control electronic.
- Fast Tip-Tilt mirror control electronic. The control electronic driving signals should be checked against parameter settings. Three sinusoidal signal of the given amplitude with a phase delay of 0, 120 and 240 degrees have to be measured.
- WFS CCD control electronic and CCD frame-grabber (BCU39). CCD control electronic power on and CCD parameter setting via RS232 has to be checked. Correct frame acquisition through BCU39 has to be checked. In particular frame acquisition operation has to be checked for CCD binning mode 1x1, 2x2, 3x3, 4x4 and 5x5.
- Technical channel CCD control electronic and CCD frame-grabber (BCU47). CCD control electronic power on and CCD parameter setting via RS232 has to be checked. Correct frame acquisition through BCU47 has to be checked. In particular frame acquisition operation has to be checked for CCD binning mode 1x1, 2x2 and 16x16.
- BCU39 slope computation. Correct parameter settings like slopes null, dark frame, flat field and pixel position look up table have to be checked. Correct slopes computation has to be checked for all the WFS CCD binning modes

6.2 Thermal test

- Thermal uniformity. Thermal uniformity of the external surfaces of the electronic boxes has to be checked. Specification on the external surfaces temperature difference with respect to the external environment temperature is +/-1 degree. The test will be done measuring the temperature differences on the external walls of the boxes after allowing for thermal settling time. The cold plates of the electronic boxes will receive water at a temperature two degree less than the environment temperature. Water flow will be of 4.5liter/min. Test will be done with all the control electronics powered on and working.
- Electronic boxes internal temperature. The internal temperature of the electronic boxes has to be measured during full operation and have to be 5 degrees less than the maximum working temperature of the various components.

7 W unit hardware performance test

Some particular tests are done in order to check the correct optical performance of various subsystems of the W unit. These tests are listed below together with the required subsystem optical specifications.

7.1 Pupil Re-rotator

The pupil re-rotator stage is aimed to counter rotate the pupil images during AO operation keeping the correct registration between the actuator grid and the CCD pixel grid.
The optical performance of the pupil re-rotator has two specifications:

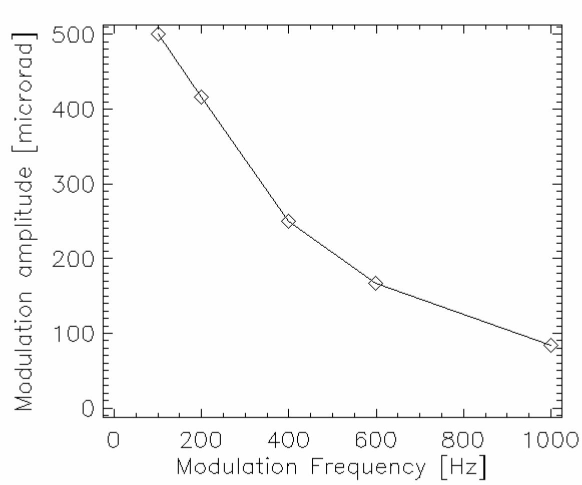
1) Pupil images center displacement has to be less than 1/10 of a CCD pixel for a counter rotation of ±2.5 deg. This rotation corresponds to about 20 min of Lucifer integration time assuming 15deg/h of rotation speed. This can be checked removing the pyramid and measuring the pupil center displacement during the Pupil Re-Rotator motion using the pupil images acquired on the wavefront sensor CCD.
2) The accuracy of the rotation provided by the PRR has to be checked. This accuracy has to be good enough to provide a pupil edge displacement error less then 1/10 of a CCD pixel. This translates in a rotation error of approx. 1 mrad. The accuracy test requires placing a custom pupil stop on the first filter wheel. This pupil stop is a non axial hole of about 2 mm that correspond approximately to ¼ of the pupil diameter. To verify the correct rotation angle value we move the PRR simulating the field rotation during an observation and computing the angular motion of the pupil patch. This is done using as input data the wavefront sensor CCD frames.

7.2 Atmospheric Dispersion Corrector

The PSF baricenter displacement due to residual or uncorrected atmospheric differential refraction has to be less than 1/10 of the LUCIFER PSF in the shortest imaging band (30mas @ J band). This correspond to approx 6 microns at the f/45 wavefront sensor focal plane. ADC test have to check that the PSF induced displacement is below the 6 microns limit stated above in the overall operation range of the ADC. The test will be done checking the wavelength dependent displacement at three different wavelengths sampling the wavefront sensors optical bandwidth (0.6-0.9) micron. For example using a HeNe laser (633 nm) we have to measure a PSF displacement on the f/45 technical viewer focal plane of 1.260 mm when the ADC is positioned for the maximum zenithal working angle (70 deg). To reach the considered accuracy in the PSF displacement measurement the technical viewer CCD will be replaced with a CCD camera having 7.4 micron pixel size.

7.3 Fast Tip-Tilt mirror unit performance

The fast steering mirror used in the sensor will be tested at different tilt modulation amplitude and temporal frequencies. The specification of the requested maximum modulation amplitude as a function of temporal frequency is given in the plot below.



To test the unit transfer function an ad-hoc set up will be built to basically have a collimated beam of approx 10mm in diameter reaching the tip-tilt mirror and then a focusing lens of 1m focal length. This will produce a plate scale of 1microrad/micron. A CCD test camera having 652x494 pixels with 7.4 micron pixel size will be used to check the unit modulation amplitude. The unit modulation amplitude will be determined fitting a circle to the frames acquired by the test camera. The rotation accuracy will be measured looking at the residual displacement of the PSF along the estimated best circle. The transfer function test will be performed when the unit is in the laboratory optical bench not yet assembled on the W board. This will make the test much easier. Tip tilt operating frequency has to be synchronized with the WFS CCD frame rate. Required accuracy is less than 0.2 %. An important feature of the unit is the maximum available stroke that could be used for fine centering of the PSF before loop closure. The maximum tip tilt amplitude will be tested with the same set up reducing the plate scale. Nominal maximum amplitude and accuracy values are 2.5 milliradians and 1 microradians respectively. The transfer function test will be done separately having the tip tilt unit in the lab optical bench.

8 Reference star acquisition sequence

The procedure for automatic reference star acquisition follows the steps listed below. A sequence of this test is

1. The reference source is placed off axis
2. The TCS or the supervisor SW send the macro command to acquire the r providing the coordinates defining the reference source position
3. The stages are positioned accordingly using the positioning command

4. The technical viewer is used to find the star photometric center. The star position is compared with the star nominal position needed for sensing operation.
5. A position command is applied to correct differences of positioning larger than 0.1 arcsecond. The residual error after two positioning commands (step 6 and 8) will be measured using the technical CCD.
6. Brake commands are applied to stop the stages in the acquired positions.
7. An image is taken with the sensor to evaluate the residual tilt. This residual tilt will be corrected internally to the sensor board using the fast tip tilt mirror unit. Successful execution of this step requires checking that the tip tilt signal measured by the wavefront sensor is less than TBD.

References

[1] Brynnel, J., "LBT Adaptive Optics System AIT Management Plan," 640s002, Issue B, 08 Sep 2005

[2] S. Esposito, A. Tozzi, A. Puglisi, P. Stefanini, E. Pinna, L. Fini, P. Salinari, and J. Storm, ``***Integration and test of the first flight AO system for LBT***,'' in *Advancements in adaptive optics. Edited by D. Bonaccini, B. Ellerbroek and R. Ragazzoni*, vol. 5490 of *Proc. SPIE*, pp. 228-235, 2004.

[3] S. Esposito, A. Tozzi, D. Ferruzzi, M. Carbillet, A. Riccardi, L. Fini, C. Vérinaud, M. Accardo, G. Brusa, D. Gallieni, R. Biasi, C. Baffa, V. Biliotti, I. Foppiani, A. Puglisi, R. Ragazzoni, P. Ranfagni, P. Stefanini, P. Salinari, W. Seifert, and J. Storm, ``***First Light Adaptive Optics System for Large Binocular Telescope***,'' in *Adaptive Optical System Technologies II. Edited by Wizinowich, Peter L.; Bonaccini, Domenico*, vol. 4839 of *Proc. SPIE*, pp. 164-173, Feb. 2003.

[4] S. Esposito, A. Tozzi, A. Puglisi, L. Fini, P. Stefanini, P. Salinari, D. Gallieni, and J. Storm, ``***Development of the first-light AO system for the large binocular telescope***,'' in *Astronomical Adaptive Optics Systems and Applications. Edited by Tyson, Robert K.; Lloyd-Hart, Michael.*, vol. 5169 of *Proc. SPIE*, pp. 149-158, Dec. 2003.