LBT PROJECT

2 X 8,4m OPTICAL TELESCOPE

LBT672 On-axis Wavefront sensor #2

Lab Acceptance Test Report

	Signature	Date
Prepared	Joar Brynnel	30 Jan 2008
Reviewed	Simone Esposito, Andrea Tozzi	30 Jan 2008
Released	Joar Brynnel	30 Jan 2008

1. Revision History

Issue	Date	Changes	Responsible
A	30-Jan-09	Issue a	Joar Brynnel

2. Table Of Contents

3. About this document

3.1. Purpose

Subsystems manufactured for the Large Binocular Telescope (LBT) shall be subjected to acceptance testing before leaving suppliers premises. The test constitutes a major milestone, and based on the test result the LBT Director may grant “Lab Acceptance” after which the equipment may be shipped to Arizona.

Two “W” On-axis Pyramid wavefront sensors are developed and built by Arcetri under the contract AO103 “WLBT On-Axis Wavefront Sensing Units”.

This document describes test results from the Lab Acceptance Test of “W” unit #2, performed at Arcetri Observatory on Jan 27-29, 2009.

3.2. Scope

In this document test results are documented. Performance test cases are documented in [RD2]. Performance, operation, interfacing, and inspection results, an executive summary and resulting Action Items are contained in this document.

3.3. Reference Documents

[RD1] LBTO Contract AO103 WLBT On-Axis Wavefront Sensing Units
[RD2] 687f002 W unit laboratory acceptance test specifications, S. Esposito, A. Tozzi, A. Puglisi, E. Pinna
[RD3] 687f007 Tip-Tilt mirror test report
[RD4] 687f004 ADC Test Report
[RD5] 687f006 Optical de-rotator test report
[RD6] 680a020 AGW Units Technical Specification
[RD7] 562s002 Telescope Cooling System Installation
[RD8] 670s001 Instrument Rotator and Cable Chain technical specifications
[RD9] 687f005 Filter wheel #1 test report
[RD10] 687f003 W#2 Preliminary Acceptance test report

4. Executive Summary

The “W” pyramid wavefront sensors are key components for the LBT Adaptive Optics system. Overall system AO performance and reliability depends on how well the subsystems function. Therefore it is important that the “W” sensors are well characterized and debugged in advance of AO system tests in Arcetri and subsequent tests on the LBT.

It is a pleasure to report that the design and implementation of the W sensor #2 unit meet expectations in almost all areas. The revised internal cabling has brought significant improvements to build quality, and thermal performance has been improved from Unit #1. The Engineering SW is very robust and offers adequate control of all parameters. No showstoppers were identified; however some issues need further attention (see Action Item List in Section 6). In particular the following is noted:

- Complete unit must be balanced around the instrument rotator axis
- Component malfunctions and optical alignment issues at low temperatures must be addressed.
- CCD39 noise not fully meeting specification

It is expected to re-visit the status of action items very soon, and review the official outcome of the test at that time.

The PO would like to thank the “W” team in Arcetri for excellent cooperation during the acceptance test, and also acknowledge the outstanding work in bringing the “W” unit #2 to this state of completion and performance.

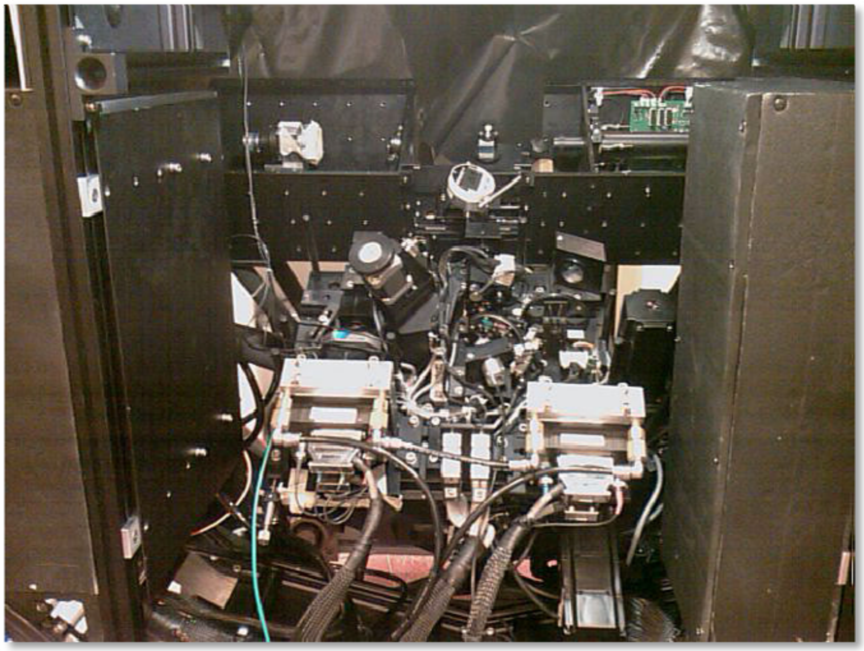

Figure 1: On-Axis wavefront sensor optical table

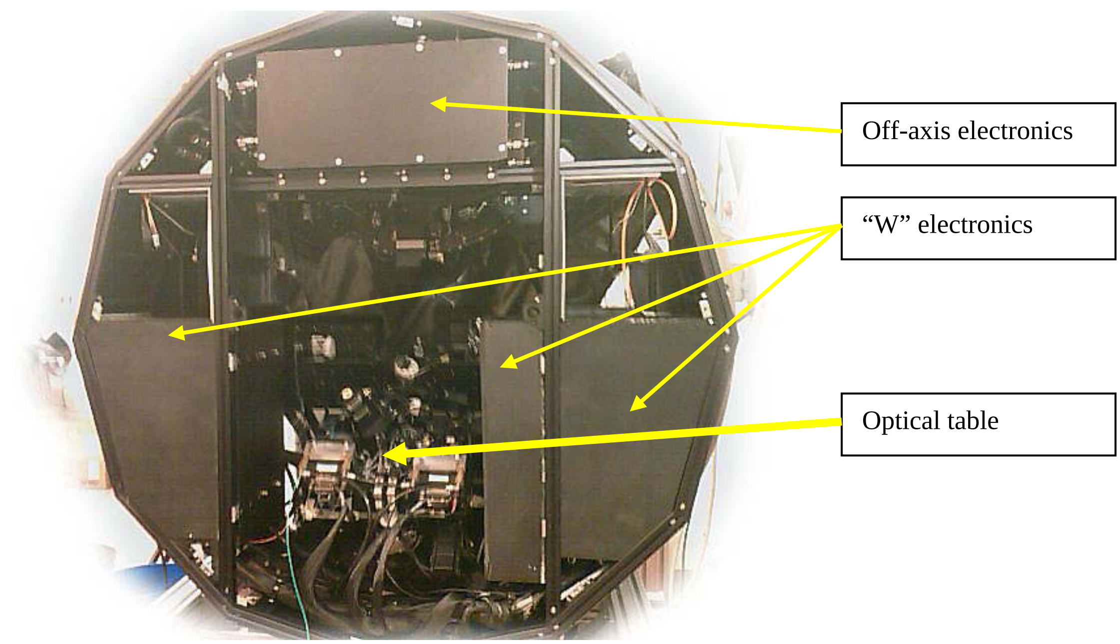

Figure 2: AGw front side

5. Test Results

5.1. Glycol cooling system inspection

The W unit will be connected to the LBT facility glycol cooling system. Cooling liquid is first split between the AGw unit and the on-axis system, and then further divided for cooling of the various electronics boxes and CCD units. The on-axis system internal coolant distribution appears appropriate for the application. For the test, the on-axis system was connected directly to the Arcetri facility coolant circuit because there was a leak in the AGw distribution couplings. This needs to be inspected by the Potsdam team.

AI: Potsdam to inspect and tighten glycol circuit couplings

A coolant hose to camera lens box was routed in a way that will create interference with Lucifer. The hose should be re-routed.

AI: Re-route camera lens coolant hose

5.2. Surface temperatures

To check for local hot spots and surface temperature distribution, IR images were acquired with the W sensor in full operation.

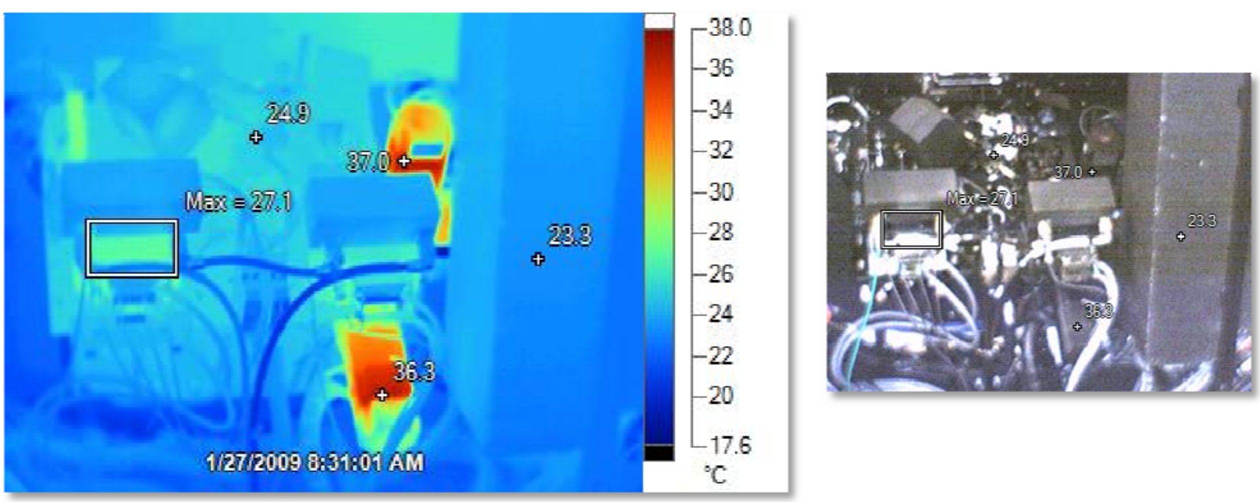

Figure 3: Thermal image of optical table

Figure 3 shows a thermal overview of the on-axis sensor optical table. For the test, the system was supplied with a glycol/water mixture with a temperature of approximately 21 degrees C. Ambient temperature was about 23.5C. The electronics box on the right side in Figure 3 is cooled by large cooling plates with extremely uniform surface temperatures of about 23 degrees. The two CCD heads in the center of Figure 3 are also supplied with coolant. While the top of the CCD's is cooled and insulated with styrofoam, the CCD lower part is not insulated, leading to elevated surface temperatures (see box in Figure 3). The optical table is at a temperature of 24.9 degrees generally slightly warmer than ambient with no obvious hotspots. The warm unit visible in the upper left corner of Figure 3 is an auxillary CCD camera used during the acceptance test. This CCD camera will be removed after the acceptance test.

Hotspots visible around the optical bench are the XYZ stage motors that have surface temperatures of around 37 degrees. This heat is generated by the motor itself and its encoder. The motors will require thermal insulation. It must be pointed out that with an insulated motor, the dissipated power will be sunk into the mechanical structure, with a possible further increase of optical table temperature.

AI: Improve CCD thermal insulation
AI: Thermally insulate XYZ stage motors and re-measure optical table temperature

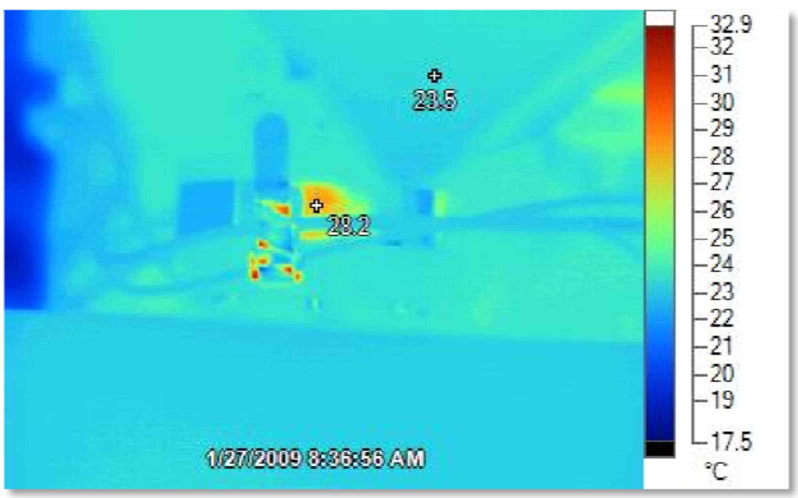

Figure 4: Tip-Tilt stage

Figure 4 shows a close-up of the tip-tilt stage actuator. Maximum surface temperature is 28.2 degrees. Since this is a small area, it was not deemed critical.

AI: Investigate reason for warm tip-tilt stage actuator.

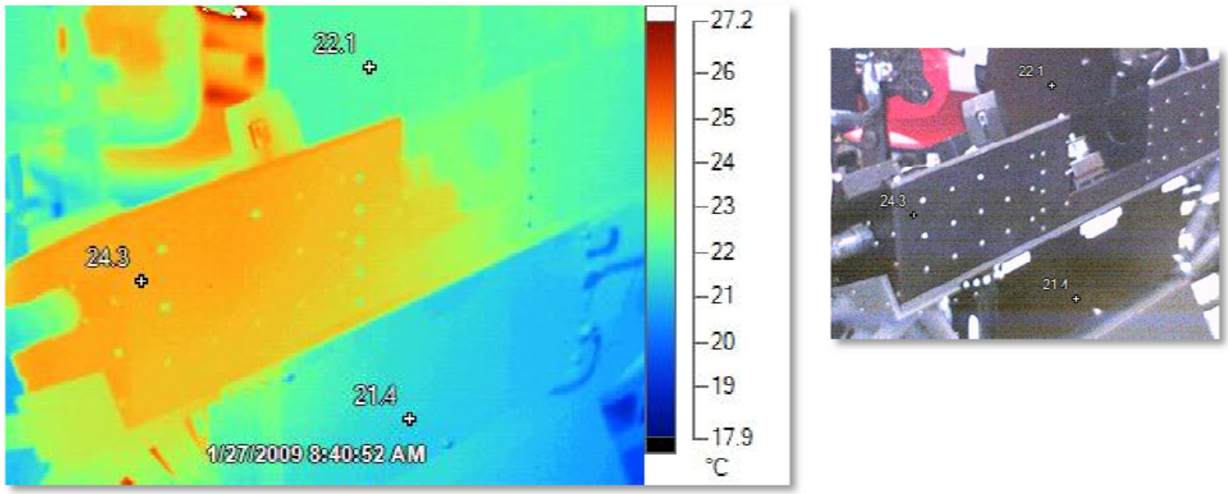

Figure 5: Thermal image of "Flower pot"

The flower pot contains calibration sources and electronics for the calibration unit. The box is not actively cooled. During normal operation, the calibration unit will be switched off. For the test, the calibration unit was intensively used and it was therefore warm.

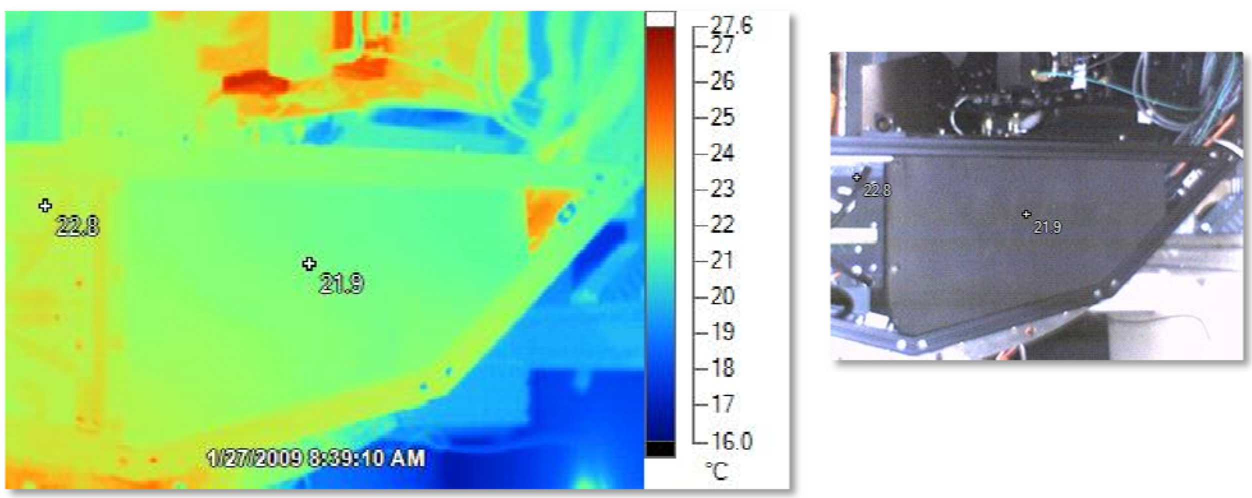

Figure 6: Thermal image of WFS Electronics box 1

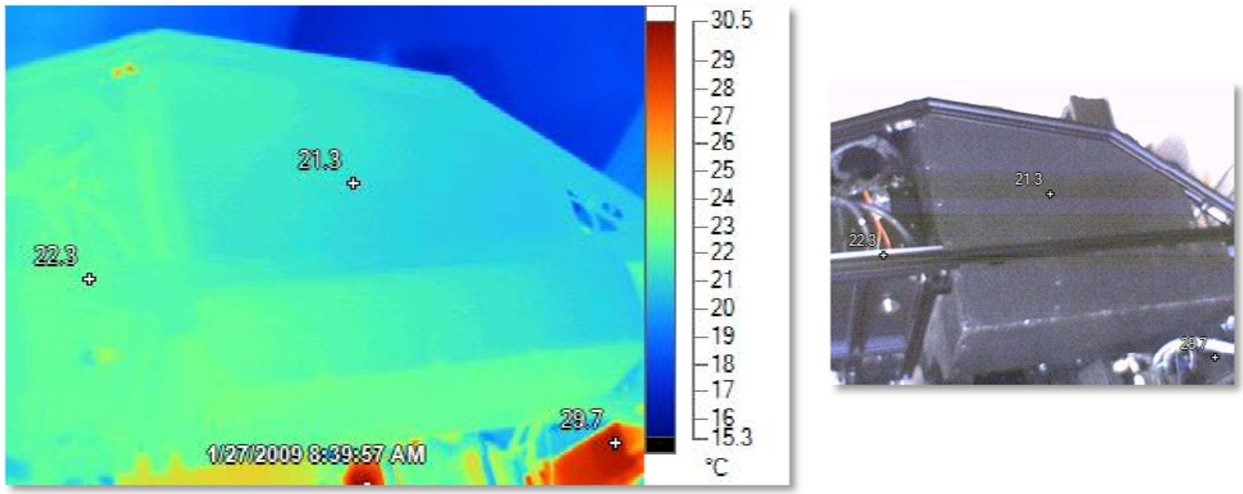

Figure 7: Thermal image of WFS Electronics box 2

The two main electronics enclosures (Box 1 and Box 2) are water cooled and thermally insulated. This is very efficient and no increased surface temperatures were observed. Note the warm stage motor in the lower right corner of Figure 7.

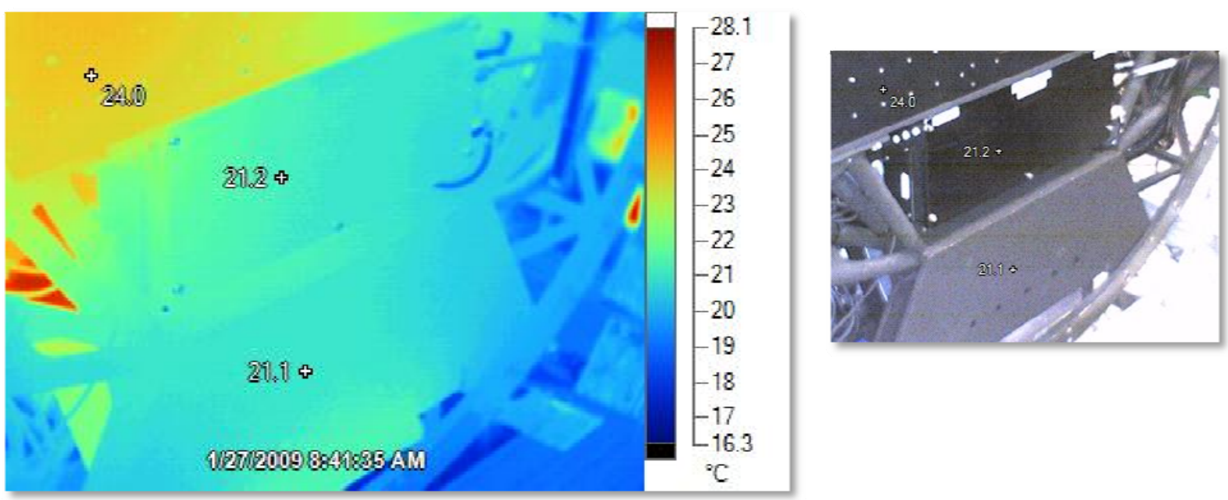

Figure 8: Thermal image of WFS Electronics box 4

The camera lens electronics were integrated into a new enclosure (Box 4, center of Figure 8). The box is water cooled and thermally insulated. The warm surface on the upper right is a part of the “flower pot”.

5.3. Glycol cooling system flow and pressure

During the test the W sensor was supplied with cooling liquid from a closed loop chiller. We measured the following flow and pressures. Note that this numbers are for the W sensor only, the off-axis cooling system was turned off.

Pressure in: 3.0 Bar
Pressure out: 1.2 Bar
Flow rate: 4.2 L/min

A pressure test of the W sensor cooling circuit was done using compressed air. The cooling system was pressure tested at 10 Bars, see report in [RD10].

5.4. Over-temperature protection

The coolant system flow was turned off, and the system was left in full operation. The over temperature sensor, located in one of the electronics enclosures was programmed for a switch-point of 26C. After approximately 12 minutes of operation the sensor triggered and the system shut down automatically.

5.5. Electrical power supply

The W unit uses one power supply connection 120VAC/60Hz. For the duration of this Lab Acceptance test a transformer-fed supply 110VAC/50Hz was used.

Test result:

All units on: 3.1A/105VAC/50Hz max current draw.
Standby: 0.15A/107VAC/50Hz current draw.

A surge protection and power filter is integrated on the power interface panel.

5.6. General inspection

The unit was inspected for completeness and workmanship. The following was noted.

- Not all filters installed in filter wheel.
- The new electronics enclosure "box 4" has a light leak at a cable feed through where light from LED's is visible from the outside.
- Some cable labels missing
- Extensive flexure testing has been has been done for Unit #1 in Potsdam, and will not be repeated for Unit #2. Some limited flexure testing of Unit #2 will be done in Arcetri.
- Fiber connectors for W sensor electronics on connection panel not labeled
- WFS optical table cover missing
- Filter Wheel 2 sometimes misses initialization due to ambiguous home switch signal. A SW fix for this problem has been developed, but this patch was not installed.

AI: Install complete filter set in filter wheel.
AI: Seal Electronics box 4 to prevent light leaks
AI: Add labels to all cables and cooling lines
AI: Add labels to fiber connectors on connection panel
AI: Install optical table cover
AI: Update control SW for correct filter wheel initialization

5.7. Performance

Performance was tested according to test procedure [RD2]. Individual subsystems have been tested prior to system integration and assembly:

- Tip-Tilt mirror [RD3]
- ADC [RD4]
- De-rotator [RD5]
- Filter wheel [RD9]

5.7.1. Pupil Images optical configuration

Measurement was performed according to Section 4 of [RD2], with the goal to verify pupil diameters to 30 +/-0.1 pixels on the WFS CCD, and pupil center distances to 36 +/-0.1 pixels.

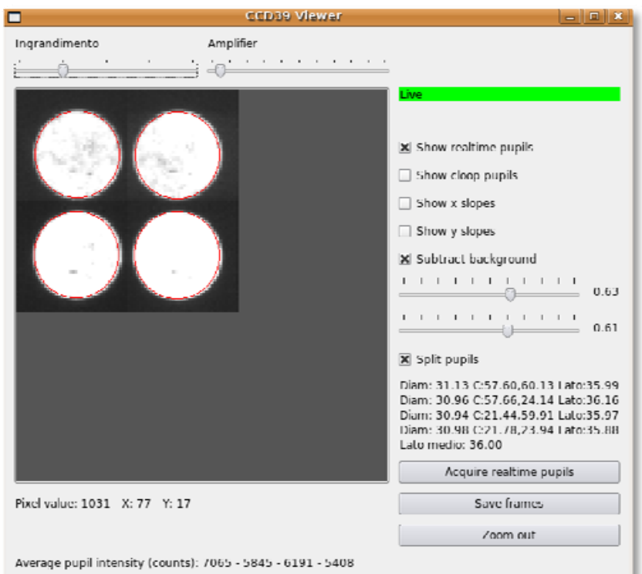

Figure 9: Pupil configuration

Conclusion: Pupil diameters (average) and center distances are marginally out of specification. Center distance can be adjusted independently from pupil diameter by adjusting focus of the WFS board.

AI: Adjust focus on WFS board to correct pupil image geometry

5.7.2. Pupil Re-rotator

The pupil re-rotator stage performance was verified.

Measurement	Requirement	Measured	Result
PSF total displacement	0.5 arcsec	0.19 arcsec	Pass
PSF displacement during integration	9 um (2.5 deg rotation)	10.9 um	***Fail***
Pupil image total center displacement	+/- 2 pix[1]	0.58 pix	Pass
Pupil image displacement during integration	0.1 pix (2.5 deg rotation)	90: 0.04 px 180: 0.05 px 270: 0.04 px 360: 0.09 px	Pass

AI: Pupil re-rotator not meeting spec for PSF displacement.

5.7.3. Fast Tip-Tilt mirror

Test of tip-tilt mirror unit performance: available amplitude vs. modulation frequency.

Modulation Freq	Requirement	Measured	Result
100 Hz	500 urad	8600 urad	Pass
200 Hz	420 urad	6300 urad	Pass
400 Hz	250 urad	5700 urad	Pass
600 Hz	170 urad	2900 urad	Pass
1000 Hz	90 urad	450 urad	Pass

[1] Requirement changed after addition of remote controlled camera lens

5.7.4. Camera lens translation

Measurement of available stroke in X and Y of the camera lens stages.

Direction	Requirement	Measured	Result
X	4 pix	4.4 pix	Pass
Y	4 pix	4.7 pix	Pass

Measurement of positioning accuracy and stability in X and Y of the camera lens stages.

Direction	Requirement	Measured	Result
X	0.1 pix	<0.05 pix	Pass
Y	0.1 pix	<0.05 pix	Pass

5.7.5. X stage absolute repeatability

The stage was homed, and moved to an absolute position. The final position was measured with an electronic dial gauge with a measurement resolution of 1 um. Requirement for X stage repeatability is 28 um.

Measurement #	Position	Result
1	1.820 mm	
2	1.819 mm	
3	1.820 mm	
4	1.819 mm	
5	1.819 mm	
X stage PtV	**1 um**	**Pass**

5.7.6. Y stage absolute repeatability

The stage was homed, and moved to an absolute position. The final position was measured with an electronic dial gauge with a measurement resolution of 1 um. Requirement for Y stage repeatability is 28 um.

Measurement #	Position	Result
1	1.941 mm	
2	1.943 mm	
3	1.942 mm	
4	1.943 mm	
5	1.944 mm	
Y stage PtV	**3 um**	**Pass**

5.7.7. Z stage absolute repeatability

The stage was homed, and moved to an absolute position. The final position was measured with an electronic dial gauge with a measurement resolution of 1 um. Requirement for Z stage repeatability is 100 um.

Measurement #	Position	Result
1	1.324 mm	
2	1.325 mm	
3	1.325 mm	
4	1.327 mm	
5	1.326 mm	
Z stage PtV	**3 um**	**Pass**

5.7.8. CCD39 Performance test

Readout noise of the CCD39 WFS camera was measured at various readout speeds and ambient temperatures (-20C, -10C and +20C). For W unit #1, a non-conformance report LBT-012 was issued and approved. It was noted that for W unit #2, noise performance is somewhat worse than Unit #1.

Pixel rate	RON -20C	RON -10C	RON +20C	*Req. RON*	Result
2500	18 e-	17.6 e-	14.6 e-	*8.4 e-*	***Fail***
890	13 e-	12.6 e-	10.5 e-	*5.8 e-*	***Fail***
400	10.9 e-	10 e-	8.5 e-	*4.5 e-*	***Fail***
150	8.1 e-	7.9 e-	6.6 e-	*3.5 e-*	***Fail***

AI: CCD39 detector readout noise not meeting specifications.

5.7.9. CCD47 Performance test

Readout noise of the CCD47 acquisition camera was measured at various readout speeds and detector temperature.

Pixel rate	RON -10C	RON +20C	*Req. RON*	Result
2500	10.5 e-	10.8 e-	*8.4 e-*	***Fail***
250	9.6 e-[2]	5.3 e-	*5.8 e-*	Pass

AI: CCD47 detector readout noise not meeting specifications.

5.7.10. Reference Star Acquisition

The accuracy of the automatic reference star acquisition was tested using an artificial reference source.

Measurement	Required accuracy	Measured accuracy	Result
Centering accuracy	40.2 um in focal plane	X,Y = 8,7 um in focal plane	Pass

[2] The increased RON at -10C and slow speed was attributed to straylight inside the cold chamber.

5.8. Interface verification

5.8.1. Mechanical Interface

Complete AGW unit (Off-axis + On-axis + AGW structure): 640Kg

According to [RD6] the AGW weight requirement is 600Kg.

Note: While this nominally violates the maximum weight requirement, it is not considered critical. Given the situation, the unit shall be weighed again after addressing the rotational balance problem (see section 5.8.2). If counterweights are added to balance the unit, this could push the AGw total weight into an unacceptable range.

AI: Weigh unit after balancing.

5.8.2. Rotational imbalance

Imbalance around the rotator axis was measured to 254 Nm with the off-axis CCD controllers installed. According to [RD8] the maximum compounded imbalance for AGw and instrument (here: Lucifer) is 200Nm.

AI: Reduce AGw imbalance to less than 50 Nm.

5.8.3. Optical Interface

XY stages travel ranges:

Direction	Measured range	Requirement	Pass/Fail
X positive	2.09 arcmin	2.2 arcmin	***Fail***
X negative	-1.05 arcmin	-1.05 arcmin	Pass
Y positive	+1.42 arcsec	+1.4 arcmin	Pass
Y negative	-0.98 arcsec	-1.03 arcmin	***Fail***

AI: Increase travel range in X and Y to meet FOV spec.

5.8.4. Electrical Interface

See section 5.5.

5.8.5. Software Interface

Since the W unit is a subsystem of the AOS (Adaptive Optics Supervisor) software, there is no direct software interface to the TCS.

5.8.6. Network Interface

Two optical fiber connections are required:

- Ethernet: Instrument control, CCD39 controller, CCD47 controller
- Fiber Fast Link to Adaptive Secondary

AI: Fast Fiber Link to Adaptive Secondary not installed

5.9. Software

During the test, the W engineering software version 3.0 was used to control the W unit, and to acquire measurement results. The engineering software worked flawlessly during the test and offers complete and adequate control of the W unit. The engineering GUI's appear complete and logically structured. V 3.0 can drive both W units although the hardware is slightly different between W unit #1 and #2.

5.10. Functional test at varying ambient temperature

The W sensor was tested for functionality at different ambient temperatures. Tests were carried out in a climate chamber in Arcetri. The W sensor was integrated in the AGw structure together with the complete off-axis unit.

Chamber temperature was set to 0, -10, and -20 degrees C. At each temperature the AGW was allowed to stabilize thermally (electronics turned off), then the W system was turned on and operated to verify functionality and performance.

Temperature	***Observations***
+10C	Full system test before test. System fully functional.
0C	• Functional test OK • Some vignetting visible on pupils (see Figure 10). Cube angle was re-adjusted by 0.4 degrees which removed the vignetting. • Re-rotator got stuck moving in negative direction. Fixed by reducing re-rotator rotation speed from 12 to 4 units.
-10	• Functional test OK • Some vignetting visible on pupils. Cube angle was re-adjusted by 0.7 degrees which removed the vignetting. • Re-rotator got stuck moving in negative direction. Fixed by reducing re-rotator rotation speed from 12 to 4 units. • Camera lens driver Y switched off unexpectedly (restarted) • BCU47 Ethernet shut down unexpectedly (restarted) • Misalignment 5 pixels visible on pupils. See Figure 11. • Camera lens range 98um (spec 100um)
-20C	• Functional test OK • Some vignetting visible on pupils. Cube angle was re-adjusted by 0.8 degrees which removed the vignetting. • Re-rotator got stuck moving in negative direction. Fixed by reducing re-rotator rotation speed from 12 to 4 units. • BCU47 Ethernet shut down unexpectedly (restarted) • BCU39 shut down unexpectedly (restarted) • Misalignment 5 pixels visible on pupils • Camera lens driver Y switched off unexpectedly.

AI: Investigate reason for unreliable function of camera lens driver at low temperatures
AI: Investigate reason for unreliable function of BCU39 and BCU47 at low temperatures
AI: Investigate reason for optical misalignment at low temperatures

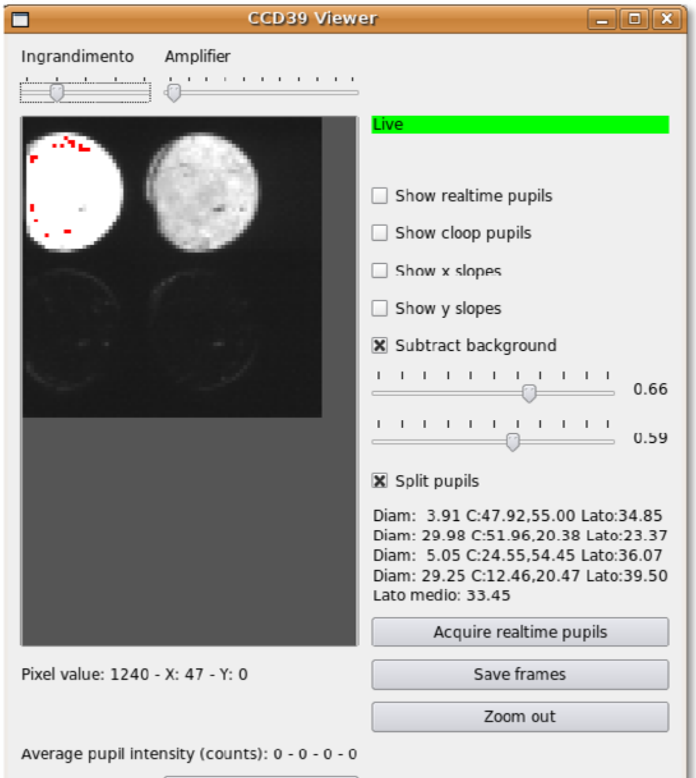

Figure 10: Vignetted pupils at 0C

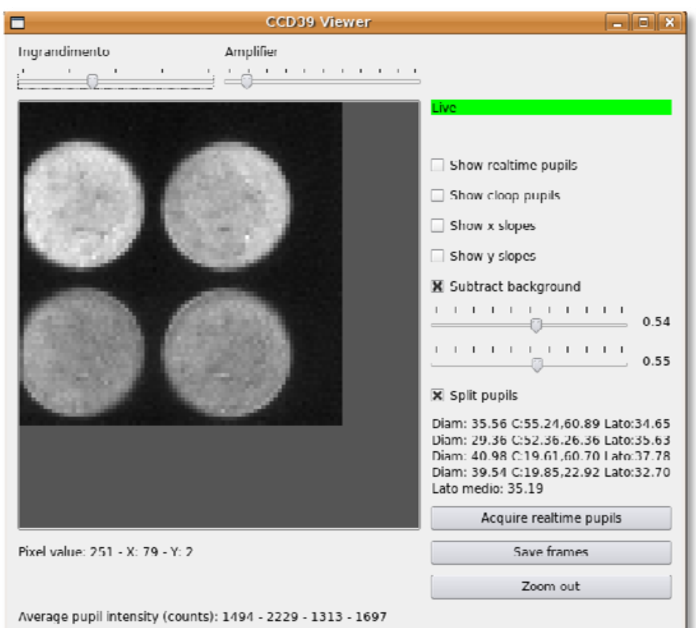

Figure 11: Misaligned pupils at -10 degrees C

6. Action Items Summary

Action Items are summarized, and completion date for individual action dates are assigned:

- AOINT: Action Item must be completed before AO system integration and test in the Test Tower
- MTN: Action Item must be completed before delivery to the mountain.

AI#	Ref	Issue	*Status*	Completion
1	5.1	**Potsdam to inspect and tighten glycol circuit couplings**	*Open*	AOINT
2	5.1	**Re-route camera lens coolant hose**	*Open*	AOINT
3	5.2	**Improve CCD thermal insulation**	*Open*	AOINT
4	5.2	**Thermally insulate XYZ stage motors and re-measure optical table temperature**	*Open*	AOINT
5	5.2	**Investigate reason for warm tip-tilt stage actuator.**	*Open*	AOINT
6	5.6	**Install complete filter set in filter wheel.**	*Open*	AOINT
7	5.6	**Seal electronics box 4 to prevent light leaks**	*Open*	AOINT
8	5.6	**Add labels to all cables and cooling lines**	*Open*	AOINT
9	5.6	**Add labels to fiber connectors on connection panel**	*Open*	AOINT
10	5.6	**Install optical table cover**	*Open*	AOINT
11	5.6	**Update control SW for correct filter wheel initialization**	*Open*	AOINT
12	5.7.1	**Adjust focus on WFS board to correct pupil image geometry**	*Open*	AOINT
13	5.7.2	**Pupil re-rotator not meeting spec for PSF displacement.**	*Open*	AOINT
14	5.7.8	**CCD39 detector readout noise not meeting specifications.**	*Open*	AOINT
15	5.7.9	**CCD47 detector readout noise not meeting specifications.**	*Open*	AOINT
16	5.8.1	**Weigh unit after balancing.**	*Open*	MTN
17	5.8.2	**Reduce AGw imbalance to less than 50 Nm.**	*Open*	MTN
18	5.8.3	**Increase travel range in X and Y to meet FOV spec.**	*Open*	AOINT
19	5.8.6	**Fast Fiber Link to Adaptive Secondary not installed**	*Open*	AOINT
20	5.10	**Investigate reason for unreliable function of camera lens driver at low temperatures**	*Open*	MTN
21	5.10	**Investigate reason for unreliable function of BCU39 and BCU47 at low temperatures**	*Open*	MTN
22	5.10	**Investigate reason for optical misalignment at low temperatures**	*Open*	MTN

7. Documentation

The following list of documentation was reviewed, including delivery dates for a draft version of the document.

Document	***Status***	**Due date**
Optics		
Optical design description	*Open*	~~1 Jan 07~~ ~~31-Jul-08~~ 1-Jul-09
Zemax files	*Done*	1 Aug 06
Mechanical		
Inventor file packed	*Draft done*	~~1 Jan 06~~ ~~31-Jul-08~~ 1-Jul-09
2D drawings	*Draft done*	~~1 Jan 06~~ ~~31-Jul-08~~ 1-Jul-09
Mechanics parts list	*Done*	1 Jan 06 31-Jul-08
Electrical		
Orcad design, wiring diagrams	*Draft done*	~~1 Jan 06~~ ~~1-Sep-08~~ 1-Jul-09
Block diagrams	*Draft done*	~~1 Jan 06~~ ~~1-Sep-08~~ 1-Jul-09
Data sheets for commercial components	*Open*	~~1 Jan 06~~ ~~1-Sep-08~~ 1-Jul-09
Software		
Documented source code	*Open*	~~31-Jul-08~~ 1-Jul-09
PIC controller source code	*Draft done*	~~31-Jul-08~~ 1-Jul-09
BCU and FPGA firmware (Microgate)	*Open*	~~31-Jul-08~~ 1-Jul-09
Interface description	*Done*	

General		
Handling and shipping plan	*Open*	~~1 Jan 06~~ ~~30-Sep-08~~ 1-Jul-09
Calibration plan (contained in [RD2])	*Done*	~~1 Jan 06~~ 30-Sep-08
Spare parts list	*Open*	~~1 Jan 06~~ ~~31-Jul-08~~ 1-Jul-09

--oOo--

Doc_info_start
Title: *LBT672 On-axis Wavefront Sensor #2 Lab Acceptance Test Report*
Document Type: *Report*
Source: *LBTO*
Issued by: *Joar Brynnel*
Date_of_Issue: *30-Jan-2009*
Revised by:
Date_of_Revision:
Checked by:
Date_of_Check:
Accepted by:
Date_of_Acceptance:
Released by:
Date_of_Release:
File Type: MS Word
Local Name: *LBT672 On-axis Wavefront Sensor #1Lab Acceptance Test Report*
Category: *600 Telescope Auxiliaries*
Sub-Category: *680 Acquisition & Guiding*
Assembly: *687 On-Axis Wavefront Sensing Unit*
Sub-Assembly:
Part Name:
CAN Designation: *687s002*
Revision: *a*
Doc_info_end