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TECHNICAL REPORT

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LBT672 Unit Laboratory Optical Acceptance Test Specifications

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ABSTRACT

This document reports the specifications for the lab testing activity of the LBT672a/b units in terms of thermal and optical performances required for the acceptance of the unit before the optical coupling with the other parts of the AO system in lab. The document covers the description of the AIT Management Plan (640s002) tests following the *"Adsec Unit ReadyReady for Optical Test"* milestone to the *"Flattened secondary shell, ready for AO test"* milestone.

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Abbreviations, acronyms and symbols

Symbol	Description
ADS	ADS International srl
AIT	Assembly, Integration and Test
AO	Adaptive Optics
ASM	Adaptive Secondary Mirror
ATT	Arcetri Test Tower
INAF	Istituto Nazionale di Astrofisica
LBT	Large Binocular Telesecope
LBT672	LBT 672-actuator Adaptive Secondary Mirror Unit
LBTO	LBT Observatory
MG	Microgate srl
MMT336	MMT 336-actuator Adaptive Secondary Mirror Unit
OAA	Osservatorio Astrofisico di Arcetri
P45	LBT 45-actuator Adaptive Secondary Mirror Prototype
PtV	Peak-to-valley
resp.	Responsible parties
rms	root mean square
SL	Seeing Limited
TS1	Thin Shell 1 (telescope shell)
TS2	Thin Shell 2 (reduced size shell for electro-mechanical tests)
W	Wave-front sensing unit for First Light LBT AO System
WFE	Wave-Front Error

Contents

1 Introduction

The present document reports the technical specifications to be test at the end of the Phase 6 for the laboratory optical acceptance of the LBT672 unit. The compliance of the test results with specifications constitutes the *"Flattened secondary shell, ready for AO test"* milestone related to the LBTO Contract AO104. See Ref. [1] for a general description of phases and milestones.

2 Requirements for starting Phase 6 (aka Secondary unit tests)

- LBT672 milestone *"Adsec Unit ReadyReady for Optical Test"* has to be successfully reached (i.e. related electro-mechanical, control and software tests passed, Ref. XXX) (resp.: MG+OAA)
- W milestone *"W sensor ready for System test"* has to be successfully reached (i.e. related electro-mechanical, control and software test passed, Ref. [2]). W unit is installed in AGW frame including the interferometer (resp.: OAA)
- Successful transport to Arcetri (phase 5, Ref [1]) of LBT672 unit together with (Resp: MG+ADS):
  - TS1, TS2. Optical side protected by OptiCoat film.
  - Test/Transportation Trolley (aka "test bench-assembly", 642a149a.dgw)
  - Test Tower installation support (aka "support for roof", 642a154a.dgw)
  - Swing arm (Ref [3], Sec. 13) rack with complete set of telescope cabling
- Hexapod complete of controller and telescope cabling (resp.: ADS)
- debugged TCS software for hexapod management with the following services (resp.: LBTO):
  - absolute positioning of shell vertex to x, y, z, θ_x and θ_y
  - relative positioning of shell vertex with Δx, Δy, Δz
  - relative rotation of shell of angles $\Delta\theta_x$ and $\Delta\theta_y$ around an arbitrary on-axis point at distance D from the shell vertex
  - relative rotation of shell of an angle $\Delta\theta_z$
- Arcetri Test Tower (ATT) fully working and performing (resp.: OAA):
  - thermal control of tower with drift ≤0.1°C/15min (λ/10 stability of focus in 15 min).Goal: drift ≤0.1°C/1hour (λ/10 stability of focus in 1 hour).
  - max vertical temperature difference of 2°C (warmer on the top to avoid convection). Goal:1°C.
  - min working temperature -5°C (goal -10°C, depending on test season)
  - remote control of cooling flux
  - remote acquisition of thermal status
  - internal tube pressure 700hPa±10% stable for 6 hours (Mt. Graham atmospheric pressure)
- Procedure of mounting LBT672 unit in the ATT successfully tested with a dummy unit
- Retro-reflecting optics assembled, tested and calibrated for interferometric measurement of LBT672 shell (resp.: OAA). Double-pass WFE λ/3 PtV (λ/10 PtV removing 11 Noll-Zernikes).Goal: λ/10.
- Retro-reflecting optics holder to be mounted at fixed flange of LBT672 hexapod (resp.: ADS)
- Silvering spray tests successfully ended and shell silvering procedure consolidated (resp.: OAA).

3 Preliminary operations before thermal acceptance tests

Preliminary operations to start the acceptance tests are needed. The details of the operations are reported in the AIT document of Phase 6 (LBT672 Laboratory Optical Test, writing in progress). We summarize here these operations for a more clear reading.

3.1 Re-assembly and functionality checks

The LBT672 is unpacked and reassembled in the Arcetri clean-room. Same communication and electro-mechanical tests, performed in MG for Phase 4 acceptance, are repeated for functionality checks using TS2 shell and, in case of success, using TS1.

3.2 Installation in ATT

The unit is moved from clean room to ATT lab room using the assembly bench (it is provided of weels). Using the winches installed at ceil of the lab the unit is installed on the "support for roof" stand. The stand is lifted and moved lifted on the test facility platform below the test bench entrance. The unit is lifted using the main crane up to the test bench and bolted on the top flange. The bottom flange is installed on the bench to assure no air exchange between the internal bench volume and the ambient.

3.3 Air drying inside ATT

Air inside ATT is pumped out to leave P_{ATT} = 100 hPa (0.1 atm) in the tube. Dry air is fluxed inside ATT to restore ambient pressure (~1000 hPa). The relative humidity (typically <70% at 20 C in lab) is decreased by a factor 10 allowing no dew or frost inside ATT with any temperature above -10 C (lower then any foreseen temperature for LBT672 tests).

4 Thermal functionality acceptance test (electrical, no optical feedback)

The thermal functionality test is aimed to check the electro-mechanical and control performances with respect to working temperature. The measurements for the present test are performed using just capacitive sensor reading. No optical feedback is used at this time because of the fast time scale of the measurements (es. step responses) and the low operating temperature of the ATT (down to -5°C/-10°C) that produce a dangerous environment for the AGW unit structure and optical/electronic components due to dew and frost.

The test and the corresponding specification to meet for acceptance are the following:

1. Set P_{ATT} = 700 hPa (~ mountain atmospheric pressure)
2. Set T_{ATT} = ambient, $T_{ASM} = T_{ATT}$-3°C, cooling flux 11 l/min (see Ref. [4])
3. Set the mirror at the nominal AO gap (~70μm) with suitable configuration for this environment. and wait for thermalization
4. Check the following electro-mechanical specifications (see Ref [5], Sec. 3.2):
   - Actuator position sensor noise < 10nm RMS (goal 3nm RMS)
   - settling time (single actuator and modal, for each controllable mode) < 1.5ms (goal 0.7ms), 0.1N max delta-force
   - tracking of a turbulent actuator command history generated with median seeing r_0(500nm) = 16 cm and wind speed 20 m/s (Taylor frozen turbulence hypothesis). The command history is compared with the corresponding capacitive sensor readings (actual position when command is sent). The specification on the turbulence tracking error is: 50 nm rms WFE (goal: 28 nm rms), with full-speed and full-mode correction.
   - Actuator position sensor long term stability < 20nm RMS over 8 hours
5. Set the mirror at nominal chopping gap (~100μm) with suitable configuration for this environment.
6. Check the following electro-mechanical specifications:
   - minimal chopping requirements (scaled from MMT336, Ref. [6]): ±4 arcsec (on-sky equivalent from capacitive sensor reading) at 5 Hz with 90% duty cycle. Goal (scaling from P45, Ref. [7]): ±7 arcsec, 5 Hz, 90% duty cycle
   - on-source tilt reproducibility: 10 mas rms (λ/10 at 5 μm) on-sky equivalent from capacitive sensor reading. Goal: 3 mas rms (<λ/10 at K=2.2 μm)
7. Set T_{ATT} = 10°C ($T_{ASM} = T_{ATT}$-3°C) with no more than 1°C/hour ramp (~10 hours expected)
8. Regulate P_{ATT} = 700 hPa inflating dry air. Wait for thermalization.
9. Repeat steps 3-6 (excluding the 8-hour stability test)
10. Set T_{ATT} = 0°C and $T_{ASM} = T_{ATT}$-3°C with no more than 1°C/hour ramp (~10 hours expected)
11. Repeat steps 8, 3-6 (excluding the 8-hour stability test)
12. Set T_{ATT} = -5°C (goal: -10°C) and $T_{ASM} = T_{ATT}$-3°C with no more than 1°C/hour ramp (~10 hours expected)
13. Repeat steps 8, 3-6
14. Reverse the ordering of the tests (warming the ATT) and repeat the tests to check for thermal hysteresis of performances with temperature

15. LBT672 is un-mounted from ATT and brought in clean room. The unit is inspected to check no damages due to low temperature tests.

Expected total time for acceptance test: 5 days.

5 Preliminary operations before optical acceptance tests

5.1 Shell silvering and unit installation with retro-reflector

TS1 shell is silvered and the LBT672 unit is mounted in the ATT together with the optical retro-reflector holder. Mechanical alignment of the retro-reflector is refined if needed. Cooling and power are connected. Communication and electro-mechanical functionality is checked again.

5.2 Unit optical alignment with interferometer and retro-reflector

AGW frame is installed on ATT and mechanically aligned with the retro-reflector/secondary unit. The LBT672 unit is aligned, using the hexapod, with respect to the axis joining the foci of the Interferometer and the retro-reflector. The Interferometer optics relay the LBT672 pupil on its detector with a 450x450 pixel sampling. The shell provides at least 6 fiducial points (x/y decenter, rotation, x/y magnification, x/y distortion) to allow the mapping of the actuator and capacitive sensor armature locations on the Interferometer detector.

5.3 Mirror flattening procedure tuning

The procedure obtains a set of actuator position commands producing the minimal WFE seen from the interferometer.

The flattening procedure is summarized here. The temperature of the ATT is set to a given value T. The shell is set to nominal average gap. The shell is preliminary flattened removing the low order spatial components (excluding piston and focus) of the shell-to-reference-plate gap as sensed by the capacitive sensors. That allows an alignment refinement using the hexapod. The surface error is measured using the interferometer. The error is projected on capacitive sensor areas, filtered removing highest order modal components and removed using the capacitive sensor signals. The procedure is iterated, filtering out less and less high-order modal components, until no further improvement is obtained in surface quality or forces larger then 0.2 N are reached. The set of positions recorded by the capacitive sensors are stored. This set defines the so called “flattening commands”.

At this preliminary phase the procedure is debugged, tuned and calibrated (es. capacitive sensor mapping) to provide an automatic flattening procedure for the following acceptance test.

6 Mirror flattening specifications for optical acceptance test

The flattening test is aimed to check the optical flattening level and stability both for SL, AO and chopping purposes.

The test and the corresponding specification to meet for acceptance are the following:

1. Set T_{ATT} = ambient (=temperature when magnets have been glued), $T_{ASM} = T_{ATT}$-3°C, cooling flux 11 l/min
2. Set the mirror at the nominal AO gap (~70µm) with suitable configuration for this environment. and wait for thermalization
3. Execute the flattening procedure. Record the flattening WFE residual using the interferometer and the flattening commands from capacitive sensor reading.
4. Reset the mirror, apply the flattening commands and check the following AO flattening specifications:
    - minimal requirement: WFE 65 nm rms (piston, tip-tilt and focus removed) with peak force <0.2 N
    - Goal requirement: WFE 30 nm rms (piston, tip-tilt and focus removed) with peak force <0.07 N
5. Set the mirror at the nominal AO gap (~100µm) with suitable configuration for this environment. and wait for thermalization
6. tilt the shell of an angle θ around its vertex using the hexapod. The angle θ is defined by the result of the chopping acceptance test of Sec. 4.
7. Execute the flattening procedure. Record the flattening WFE residual using the interferometer and the flattening command from capacitive sensor reading.
8. Reset the mirror, apply the flattening commands and check the following Chopping flattening specifications:

  - minimal requirement: WFE 200 nm rms (<1/3 turbulence WFE rms, i.e. 1/10 variance, in *serendipity* seeing conditions: r_0 = 45 cm at 500 nm and L_0 = 20 m)
  - goal requirement: WFE 100 nm rms
9. Chop to -θ position using the mirror actuators and go back to previous flattening position at +θ (one complete chopping cycle). The specification on the flattening (WFE <200 nm rms) has to be maintained including tip-tilt error.
10. Repeat sequence 6-9 starting from the –θ hexapod position to simulate the chopping after a nodding
11. Set T_{ATT} = ambient+10°C, T_{ASM} = T_{ATT}-3°C, cooling flux 11 l/min
12. Repeat steps 2-10
13. Set T_{ATT} = ambient-10°C, T_{ASM} = T_{ATT}-3°C, cooling flux 11 l/min
14. Repeat steps 2-10

The minimal WFE requirement on AO flattening is stated by the flattening results of MMT aspheric shell (masking the three edge defects, see [6]). It has to be noted that the 65 nm rms flattening WFE residual is also lower then the bight-end (i.e. best performing) AO residual WFE (80 nm rms) in median seeing conditions (see. Ref. [8]). The goal requirement is based on the flattening results of the P45 shell (Ref. [9]), i.e. the only shell produced with the new *"front-first"* procedure that has been tested after thinning.

The test with ±10°C, with respect to the temperature used to glue the magnets on the shell, is used to check the optical flattening stability with the temperature and to separate the component of flattening error due to the actuators from the intrinsic figuring error due to shell manufacturing. The test cannot be performed at temperature lower then 10°C below ambient for dew problems on the AGW unit.

Expected acceptance test duration: 2 days

7 Static fitting error specification for fitting error acceptance test

The static fitting error test is aimed to check optically the ability of the LBT672 unit to match the turbulence WFE in median seeing conditions (r0 = 16 cm at 500 nm).

The test and the corresponding specification to match for acceptance are the following:

1. apply the flattening commands
2. introduce the phase screen (provided by Steward Obs., the same used for MMT test)
3. run the flattening procedure
4. record the WFE flattening residual using the interferometer and compute the rms
5. iterate for minimum 10 (goal 100) different positions over the phase screen and compute fitting error as the average rms (in quadrature). The specification on the resulting fitting error is:
  - <95 nm WFE rms (70nm rms pure fitting, 65nm rms pure flattening)
  - goal spec.: <75 nm WFE rms (70 nm rms pure fitting, 30nm rms pure flattening)

8 Conclusion of Phase 6

In case the LBT672 unit will pass the "thermal functionality", the "mirror optical flattening" and the "static fitting error" acceptance tests, the milestone *"Flattened secondary shell, ready for AO test"* is reached.

9 References

[1] Brynnel, J., "LBT Adaptive Optics System AIT Management Plan," 640s002, Issue B, 08 Sep 2005
[2] Esposito, S., "W unit laboratory acceptance test specifications"
[3] Biasi, R. "Adaptive secondary control system," 640a006, Issue B, 18 Dec 2003
[4] Gallieni, D. "LBT adaptive secondary, mechanics construction status report" LBT AO progress meeting 21-24 Feb 2005 (http://lbtwww.arcetri.astro.it/adopt/lbtao/review-feb-2005/daniele_gallieni-lbt_adaptive_secondary_mechanics.ppt)
[5] Gallieni, D. "F/15 Adaptive Secondary Mechanical Design," 640a005, Issue D, 17 Dec 2003
[6] G. Brusa, A. Riccardi, P. Salinari, F. P. Wildi, M. Lloyd-Hart, H. M. Martin, R. Allen, D. Fisher, D. L. Miller, R. Biasi, D. Gallieni, and F. Zocchi, ``***MMT adaptive secondary: performance evaluation and field testing***," in *Adaptive Optical System Technologies II. Edited by Wizinowich, Peter L.; Bonaccini, Domenico*, vol. 4839 of *Proc. SPIE*, pp. 691-702, Feb. 2003
[7] M.Xompero, D. Zanotti, and A. Riccardi, "P45 test results and beyond," LBT AO progress meeting 21-24 Feb 2005 (http://lbtwww.arcetri.astro.it/adopt/lbtao/review-feb-2005/marco_xompero-p45_test_results.ppt)
[8] Carbillet, M., Riccardi, A., and Esposito, S., "***Numerical simulation studies for the first-light adaptive optics system of the Large Binocular Telescope***", in *Advancements in Adaptive Optics. Edited by Domenico Bonaccini Calia, Brent L. Ellerbroek, Roberto Ragazzoni*, vol. 5490 of *Proc. SPIE*, pp. 721-732, 2004
[9] A. Riccardi, G. Brusa, P. Salinari, S. Busoni, O. Lardiere, P. Ranfagni, D. Gallieni, R. Biasi, M. Andrighettoni, S. Miller, and P. Mantegazza, ``***Adaptive secondary mirrors 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. 159-168, Dec. 2003.

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