# LBT PROJECT
# 2 X 8,4m OPTICAL TELESCOPE

# LBT Adaptive Optics System

# LBT672a
# Opto-Mechanical Integration Test Report

ADS International Srl – via Roma, 87 - 23868 Valmadrera (LC) - ITALY

# TABLE OF CONTENTS

# 1 APPLICABLE DOCUMENTS

[AD1] 640s002, LBT Adaptive Optics System - AIT Management Plan, Issue B, dated 8-Sept.-05

[AD2] 640a003, General Assembly LBT672

[AD3] 640a010, Hub M2

## 2 SCOPE OF WORK

This document reports the results of measurements performed on June 13,14 2006 on the adaptive secondary Unit#1 integrated with its hexapod and hub. Tests were carried out at ADS premises at the presence of G. Brusa (LBTO).

The tests performed are in accordance with reference to Section 5.4 [AD1].

## 3 LIST OF ACRONYMS

HP Hexapod
DWG Autocad drawing file

# 4 TEST SETUP

## 4.1 Coordinate system

- The reference coordinates used in this report are the HP coordinates.
- The origin is placed at the secondary shell's vertex.
- The Z axis is the nominal optical axis, displacement from primary mirror toward secondary mirror are positive.
- The Y axis is oriented downward when the telescope is horizon pointing.
- The X axis is parallel to the elevation axis of the telescope.
- X, Y and Z form a right-hand coordinate system.
- Alpha, Beta and Gamma designates the rotation about the X, Y and Z axes respectively.

## 5 INTERFACE TO HUB

The adaptive secondary unit was integrated with hexapod and in the hub.
The mechanical interface of the secondary unit with its hexapod (ref. [AD2]) was successfully matched.
The interface between hexapod and hub (ref. drawing [AD3]) was also correctly matched.

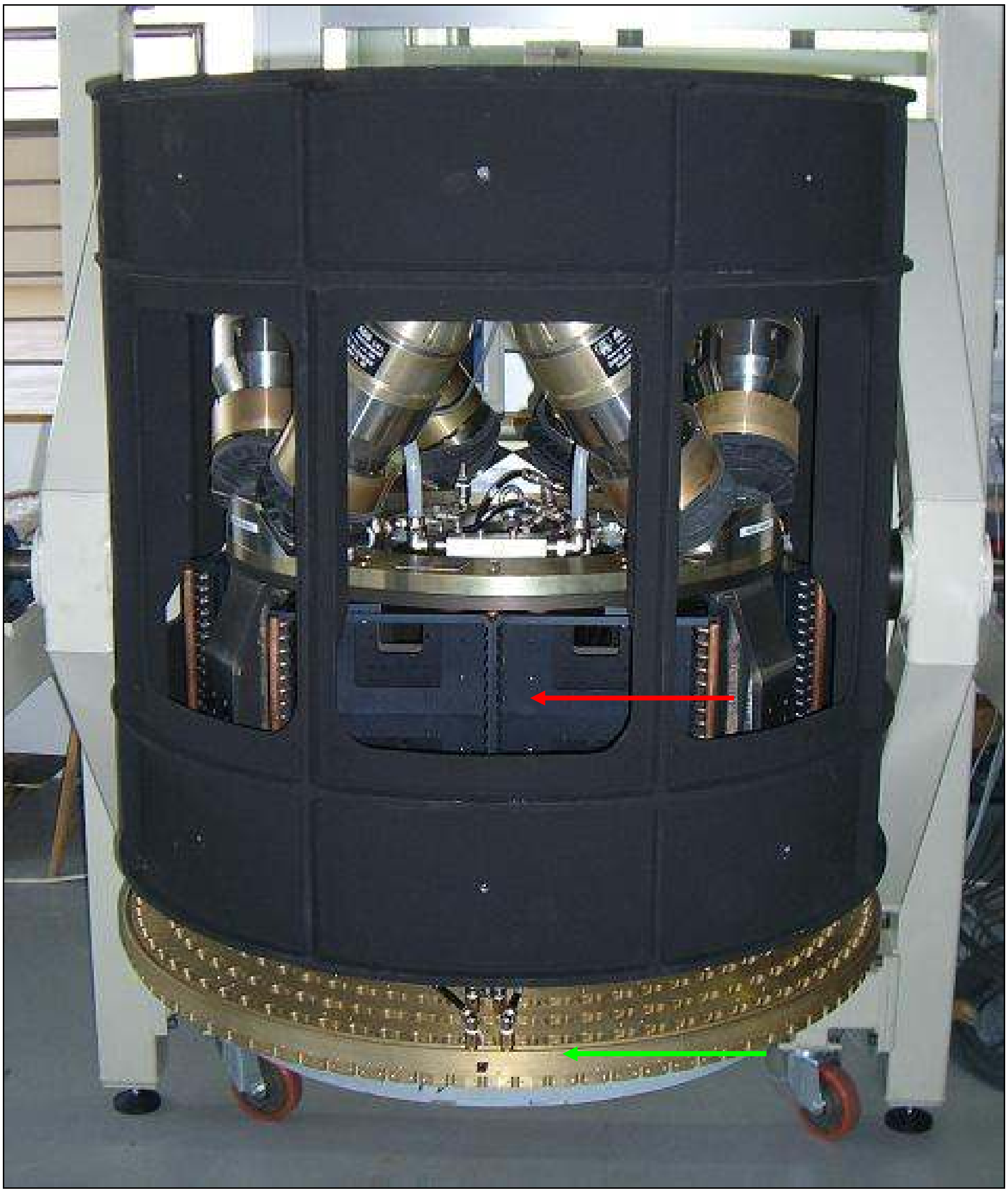

**Figure 1: the hub with the hexapod, the empty crates (red arrow) and the cold-plate (green arrow).**

# 6 HEXAPOD MOVEMENT RANGE IN HUB

The goal of this test was to verify the home position and the homing procedure. These tests were carried out by mounting a 110 Kg dummy mass on the coldplate to simulate backplate and actuators own mass.

## 6.1 Homing procedure

Command homing procedure to the hexapod. Check that during homing motion there is always clearance between adaptive secondary unit and hub.
Both short (with legs all contracted) and long (with legs all extended) home position where tested successfully.

## 6.2 Measures of home position

Check that the homed position corresponds to the nominal position of the adaptive secondary with respect to the hub (see [AD2]).

### 6.2.1 Distance top cold plate-hub

Test setup: a machined plate is screwed to the lower flange of the hub. The digital caliper is used to measure the distance between the upper plane of the plate (equal to the lower flange of the hub) and the first parallel plane on the cold plate.

**Figure 2: The integrated hub. The red arrow indicates the lower flange of the hub.**

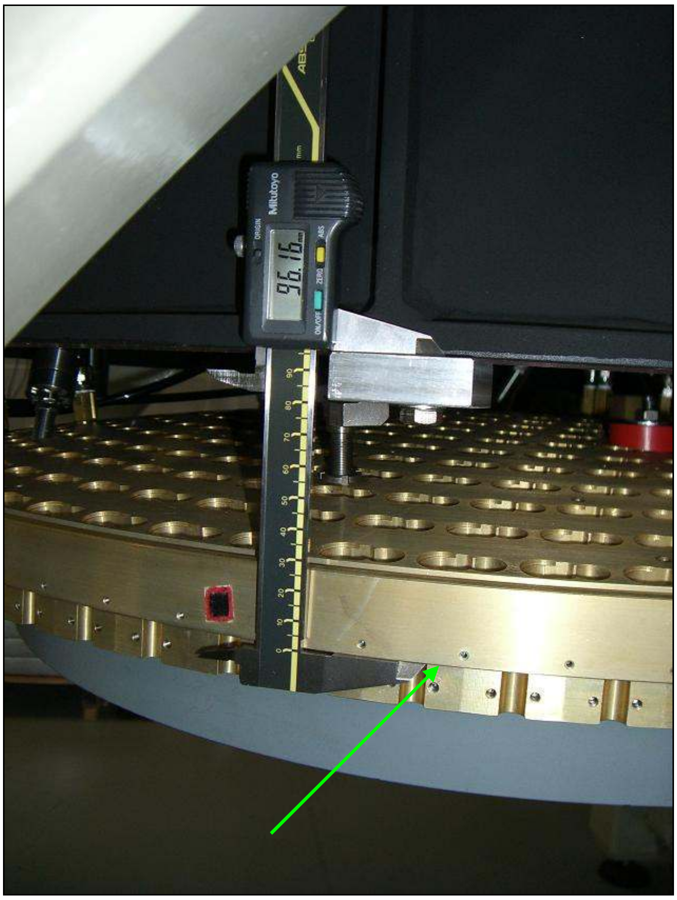


**Figure 3: Measurement of the coldplate to hub axial distance. The green arrow shows the reference ring in the coldplate.**

The measure was taken in 8 points, in correspondence of the 8 ribs of the hub. The position of these points is given in the Hexapod Coordinates (see section 4.1). As per [AD2] the nominal distance is 95.7mm.

| Position of measure point: degree in XY plane, starting from X axis going to Y axis | Measure [mm] |
|---|---|
| 22.5 | 96.60 |
| 67.5 | 96.70 |
| 112.5 | 96.19 |
| 157.5 | 96.15 |
| 202.5 | 96.22 |
| 247.5 | 96.17 |
| 292.5 | 96.03 |
| 337.5 | 96.37 |

**Table 1: coldplate nominal position measurement results.**

### 6.2.2 Centering

The cold plate has to be centered with respect to the hub.

The measures are taken in two different ways. In the first test the measure tells on the real grade of concentricity of the cold plate.
The second setup is used to test the real efficacy of the first one.

#### 6.2.2.1 Measure taken with the precision square

Setup: A precision square is placed between the lower flange of the hub and the external circumference of the cold plate. A digital caliper is used to measure the distance between the square and the external circumference of the lower flange of the hub. This measure is compensated for the thickness of the square.

The following table shows the radial distance (in the XY plane) between the external circumference of the lower flange of the hub and the external circumference of the cold plate.

| Degree, X to Y axis | Distance [mm] |
|---|---|
| 0 | -1.45 |
| 22.5 | -1.75 |
| 45 | -2.17 |
| 67.5 | -2.2 |
| 90 | -1.4 |
| 112.5 | -1.34 |
| 135 | -1.33 |
| 157.5 | -1.14 |
| 180 | -0.95 |
| 202.5 | -0.62 |
| 225 | -0.85 |
| 247.5 | -0.68 |
| 270 | -0.25 |
| 270, II measure | -0.20 |
| 292.5 | -0.65 |
| 315 | -1.00 |
| 337.5 | -1.35 |

**Table 2: concentricity coldplate to hub.**

As per [AD2] this measure is -1.5mm.

### 6.2.2.2 Verification of the concentricity

Setup: a precision square is installed on flat interfaces at the outer edge of the cold plate that are used for the installation of the outer ring of actuators [AD2].

**Figure 4: Measurement of the coldplate to hub radial distance.**

The plane that holds the precision square is not parallel to the secondary unit axis therefore this measurement can only be used to verify the centering of the cold plate with respect to the hub.

| Degree, X to Y axis | Measure [mm] |
|---|---|
| 0 | 3.90 |
| 22.5 | 3.60 |
| 45 | 3.25 |
| 67.5 | 3.30 |
| 90 | 3.50 |
| 112.5 | 3.90 |
| 135 | 3.85 |
| 157.5 | 4 |
| 180 | 4.30 |
| 202.5 | 4.48 |
| 225 | 4.62 |
| 247.5 | 4.62 |
| 270 | 4.87 |
| 270, II measure | 4.82 |
| 292.5 | 4.75 |
| 315 | 4.37 |
| 337.5 | 4.03 |

**Table 3: concentricity coldplate to hub (second method).**

This measure highlights that the cold plate is not perfectly centered. The cold plate is out-of-center with respect to the lower flange of the hub by 0.7 mm.
It was found that part of this decentering could be easily corrected by improving the centering between the secondary upper flange and the hexapod mobile.

The following table shows the new centering measurement:

| Degree X to Y axis | Measure [mm] |
|---|---|
| 0 | 4.12 |
| 22.5 | 4.06 |
| 67.5 | 3.56 |
| 90 | 3.98 |
| 112.5 | 4 |
| 157.5 | 3.94 |
| 180 | 4.15 |
| 202.5 | 4.26 |
| 247.5 | 4.26 |
| 270 | 4.50 |
| 292.5 | 4.54 |
| 337.5 | 4.12 |

**Table 4: concentricity coldplate to hub – repeated after alignment.**

The cold plate is now de-centered by 0.25 mm only. This is considered well within HP lateral stroke and thus it is kept as final alignment. In this positions radial pins were placed between mobile flange of the HP and secondary unit upper flange.

## 6.3 Hexapod full stroke

The goal of this measurement was to check that when the hexapod is commanded to move to its full stroke no mechanical interference with the hub is found. The envelope of the hexapod motion is defined by three shifts (±5mm) and two tilts (±0.25 deg).

The point of maximum interference between the secondary unit and the hub is when the values of the HP coordinates are:
X = +5mm, Y= +5mm, Z = +5mm, alpha = -0.25deg, beta = +0.25 deg.

The minimum distance was found to occur between one of the cooling fittings and one of the ribs of the hub. This distance was found to be 15 mm.

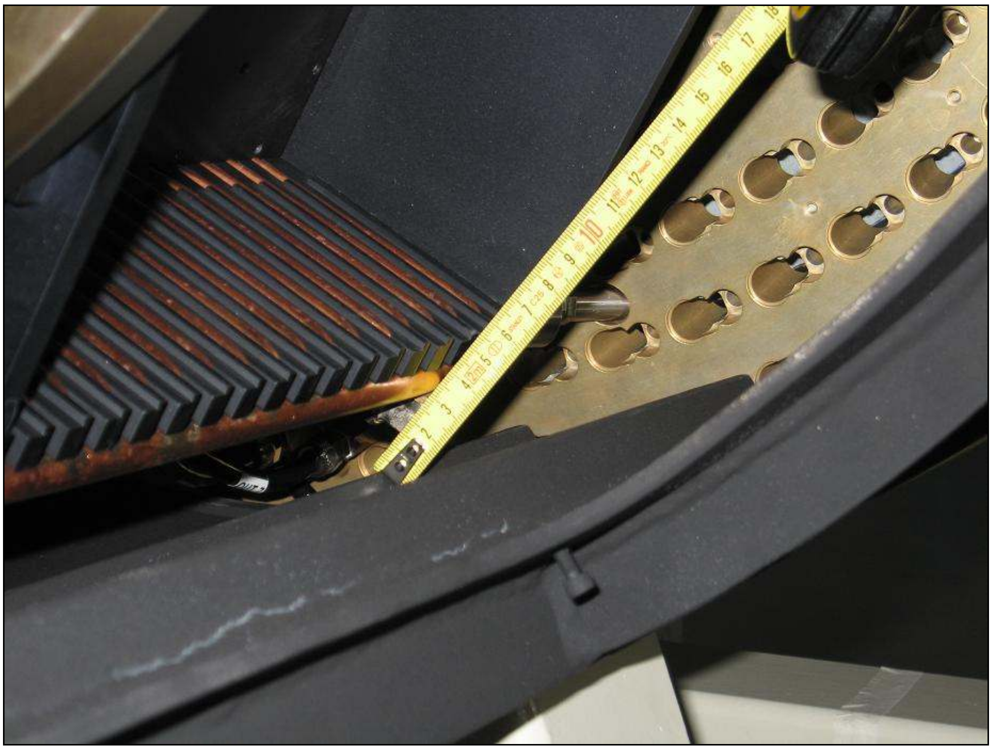

**Figure 5: the point of maximum interference**

To complete the test, three other attitude of the hexapod were used:

| X | Y | Z | Alpha | Beta | Status |
|---|---|---|---|---|---|
| 5 | 5 | 5 | -0.25 | +0.25 | OK |
| 5 | 5 | 5 | +0.25 | +0.25 | OK |
| 5 | 5 | -5 | +0.25 | +0.25 | OK |
| 5 | -5 | -5 | +0.25 | +0.25 | OK |

**Table 5: pointing attitude of the HP used to check the free space in the hub**

## 6.4 Hexapod homing procedure from full stroke

The homing procedure was repeated toward the extended position starting from the last attitude of the table 2.

# 7 INTERFACE TO SWING ARM

## 7.1 Measure the angle of the four hub to spider interface

Checked: [TBD]

## 7.2 Check the position of the four hub to the spider interface

Checked: [TBD]

## 7.3 Check the bolts holes positions on each interface plate

Checked: [TBD]

NOTE: sections 1, 2 and 3 will be performed at a later stage because the spider interface is not accessible. A measure of the relative position of the interface with respect to the hub lower flange will be performed to check these points.

## 7.4 Inspection of cable guiding and cable routing from the hub to the swing arm including cooling hoses

*(This is important for Joar to prepare the swing arms).*
Checked also the harness interface for the HP.

## 7.5 Verification of thin shell nominal position in XYZ w.r.t. the swing arm interface

Only the verification of the cold plate position with respect to the hub lower flange was performed.

The check with respect to the spider interface will be performed at a later stage (see above) and the check between cold plate and shell could not be performed because the backplate was not installed in this phase. Again a check between the cold plate and the reference plate will be performed after it has been installed.

## 8 INSPECTION OF DUST PROTECTION

[TBD]

NOTE: this activity will be performed on Unit#2 because to save time on schedule it was agreed to postpone it and to move Unit#1 to Microgate without installing the dust protection. On the other hand, such protection is not consistent with the initial debugging activity planned on the electronics as well.

## 9 WEIGHT

The unit is not yet fully integrated (crates are empty, actuators and backplate and shell are missing, astatic levers not installed) and therefore this test cannot be performed.

The current plan is to compute this weight with the weights of the various subsystems. These will have to be measured separately.

## 10 FLEXURE TESTING

With respect to the proposed test plan, only the section A was performed because it provides a reliable and more direct measurements.

### 10.1 Decentering of the cold plate

Setup: the displacement is measured with an Heidenhain MT2581 linear encoder, with a resolution of 0.02 μm. The encoder is held by a magnetic base.
The magnetic base is mounted on the beam that holds the hub at the lower interface to the spider. The encoder is measuring the displacement along Y axis of the lowest point of the cold plate when the telescope is horizon pointing. This point is the intersection point between the Y axis (gravity) and the external circumference of the cold plate.

This measure is performed at several elevation angles; 0 deg corresponds to telescope pointing to horizon; 90 deg corresponds to telescope pointing to zenith.

The following table shows the results of the measurements:

| *Elevations angle [deg]* | *Y displacement [μm]* |
|---|---|
| 90 | 0 |
| 80 | 130 |
| 70 | 270 |
| 60 | 380 |
| 50 | 480 |
| 40 | 530 |
| 30 | 575 |
| 20 | 590 |
| 10 | 575 |
| 0 | 537 |
| 10 | 580 |
| 20 | 590 |
| 30 | 570 |
| 40 | 535 |
| 50 | 470 |
| 60 | 375 |
| 70 | 250 |
| 80 | 110 |
| 90 | -5 |

**Table 6: flexure test results.**

The PtV de-centering results about 600 μm, which is anyway well within hexapod lateral correction capability.

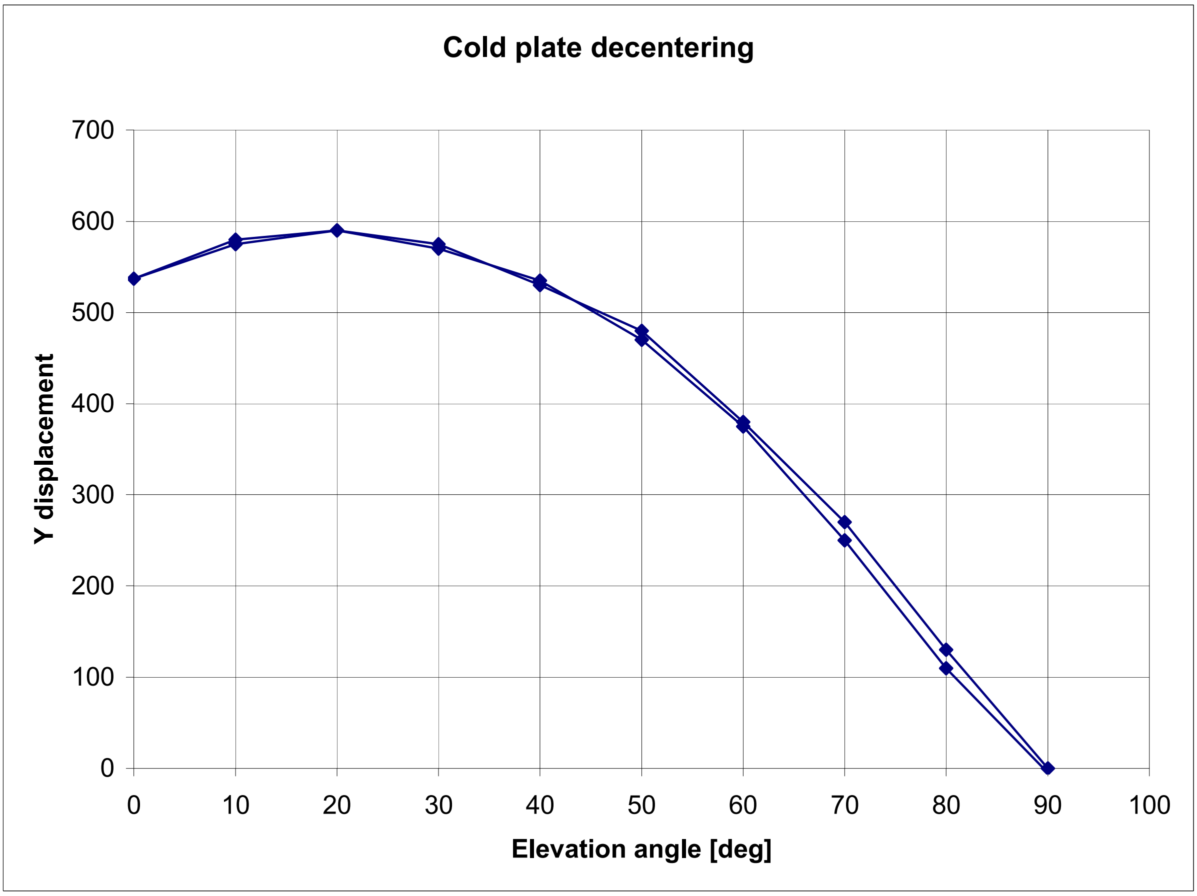


**Figure 6: flexure test results.**

## 10.2 Alpha axis rotations

Setup: three linear encoder are used to measure the alpha (TIP) rotation of the cold plate. The encoder are Heidenhain MT2581 with a resolution of 0.02 $\mu$m and are hold by three different magnetic base.

The magnetic base of the first encoder is mounted on the beam that holds the hub at the lower interface to the spider (Figure 7, the beam shown by green arrow). The encoder is measuring the displacement along the optical axis (Z axis) of the lowest point of the cold plate when the telescope is horizon pointing, that is the intersection point between the Y (gravity) axis and the external circumference of the cold plate. (angular position of the C mobile wedge).

The two other encoders are placed 120 degree away from the first one. The magnetic base is mounted on the hub above the lower interface and the probes are placed on the external circumference of the cold plate (see Figure 9), in correspondence of the angular position of A and B wedges of the mobile flange of the hexapod.

Next figure shows the points where the encoders measure the displacements of the cold plate. A, B and C are placed in the same angular positions of the wedges of the mobile flange of the hexapod.

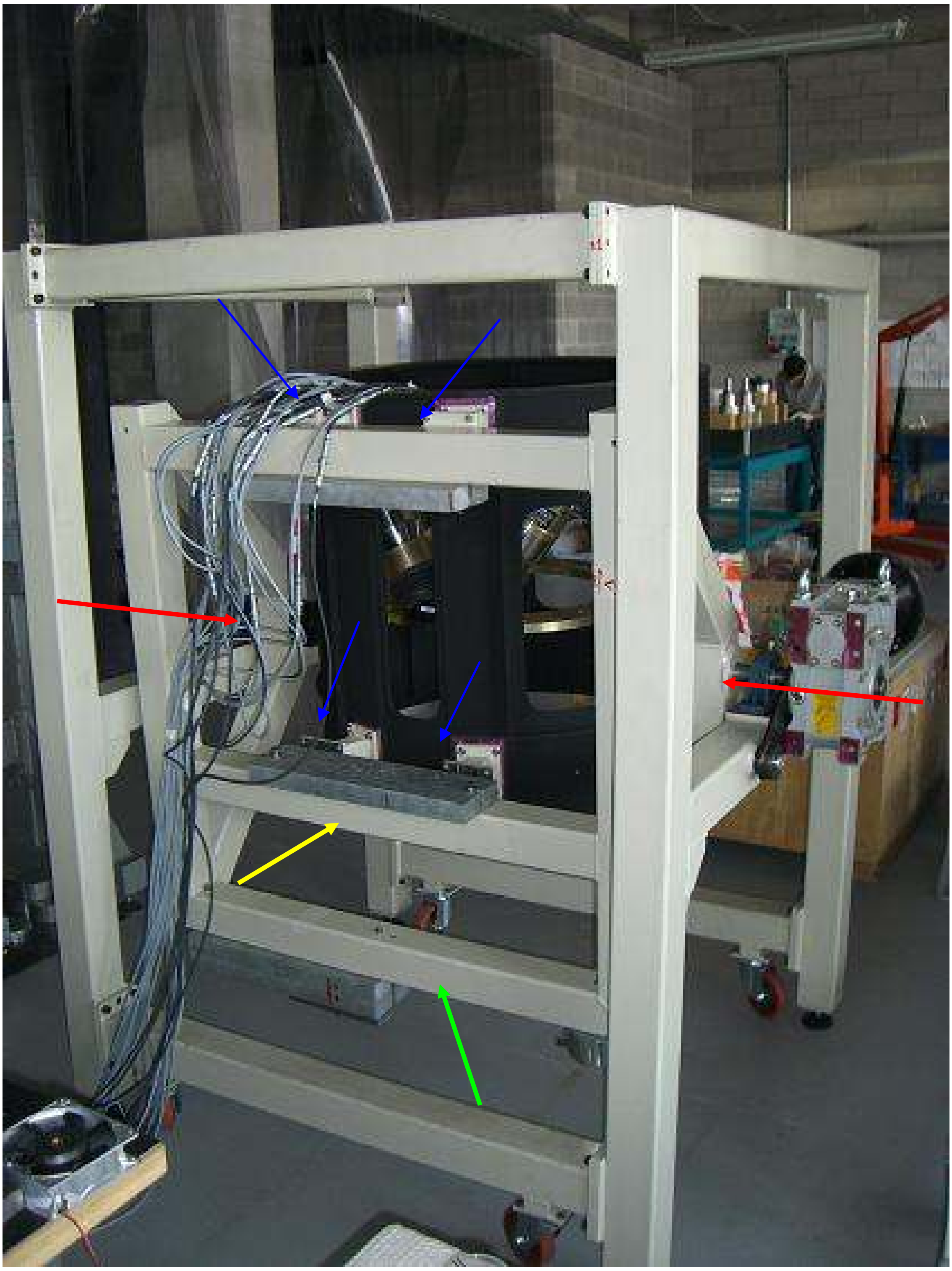

**Figure 7: trolley of the hub: the red arrows indicates the elevation axis of the trolley. The blue arrows indicates the four interface spider-to-hub. The yellow arrow indicates the beam that holds the lower interfaces spider to hub. The green arrow indicates the beam solidly connected to the elevation axis.**

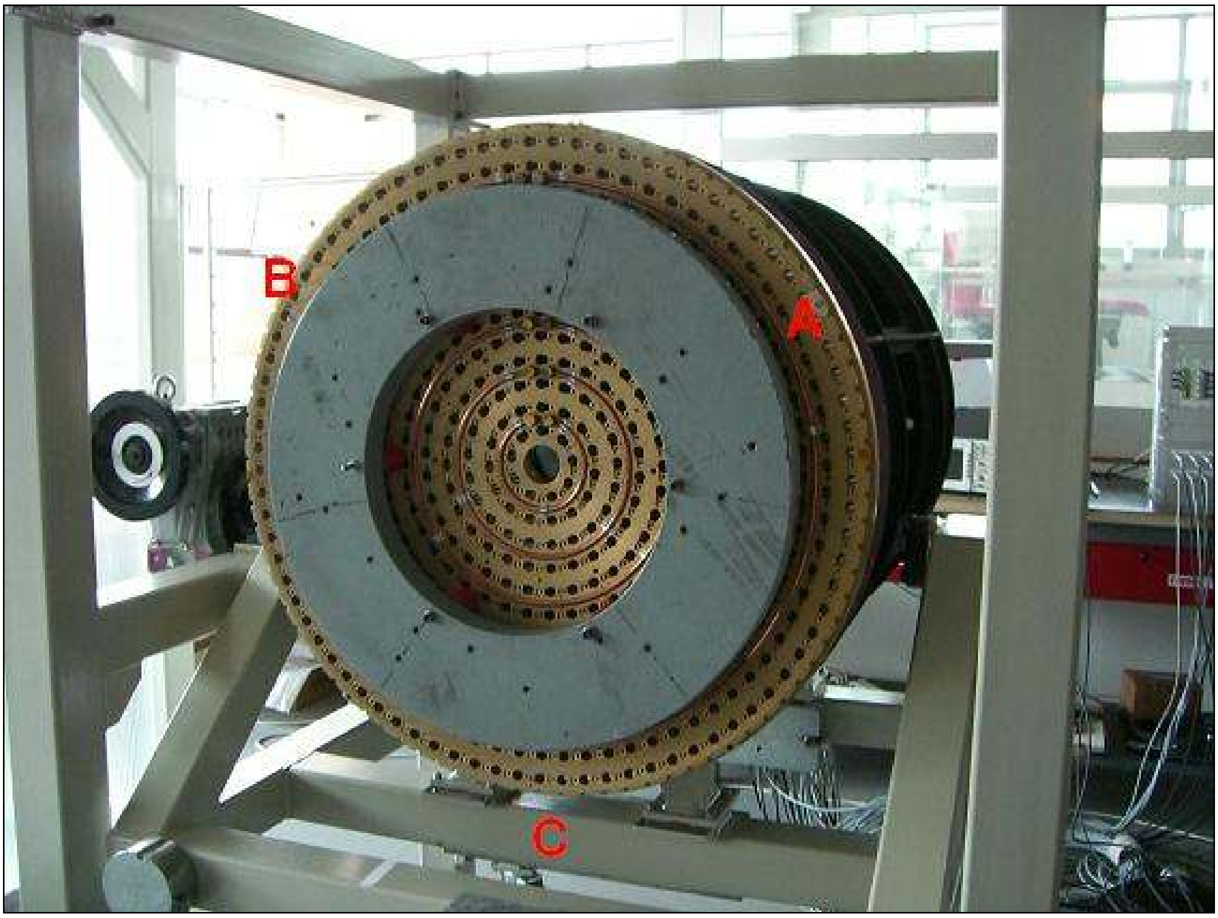


**Figure 8: the hub rotated in the horizon pointing position. A, B and C mark the locations on the cold plate where the encoders for the tip measurement were placed.**

**Figure 9: magnetic base mounted on the hub; the encoder is sensing the B point of the cold plate**

The following table shows the displacement in Z direction.

| *Elevations angle [deg]* | *A wedge [μm]* | *B wedge [μm]* | *C wedge [μm]* |
|---|---|---|---|
| 90 | 0 | 0 | 0 |
| 80 | -29 | -24 | 34 |
| 70 | -61 | -46 | 74 |
| 60 | -89 | -63 | 118 |
| 50 | -110 | -76 | 153 |
| 40 | -130 | -87 | 185 |
| 30 | -146 | -96 | 209 |
| 20 | -155 | -100 | 226 |
| 10 | -160 | -100 | 233 |
| 0 | -160 | -96 | 232 |
| 10 | -170 | -100 | 233 |
| 20 | -170 | -102 | 223 |
| 30 | -163 | -99 | 208 |
| 40 | -154 | -93 | 183 |
| 50 | -136 | -80 | 147 |
| 60 | -118 | -68 | 115 |
| 70 | -85 | -47 | 65 |
| 80 | -58 | -29 | 34 |
| 90 | -30 | -13 | 3 |

**Table 7: tilt text as function of EL angle, A B C points Z displacements measures.**

The measures located at A and B wedges need to be compensated to take into account various other flexures. In fact, while the measure in correspondence of wedge C is referred to the spider interface, the measures on A and B wedges are referred to the hub that is deforming following its own stiffness.

The displacement of the two points where the magnetic base is mounted is monitored with the following tests.
The magnetic base is placed on the elevation axis of the trolley that carries the entire structure and the encoder is measuring the displacement of the lower flange of the hub (see Figure 10)

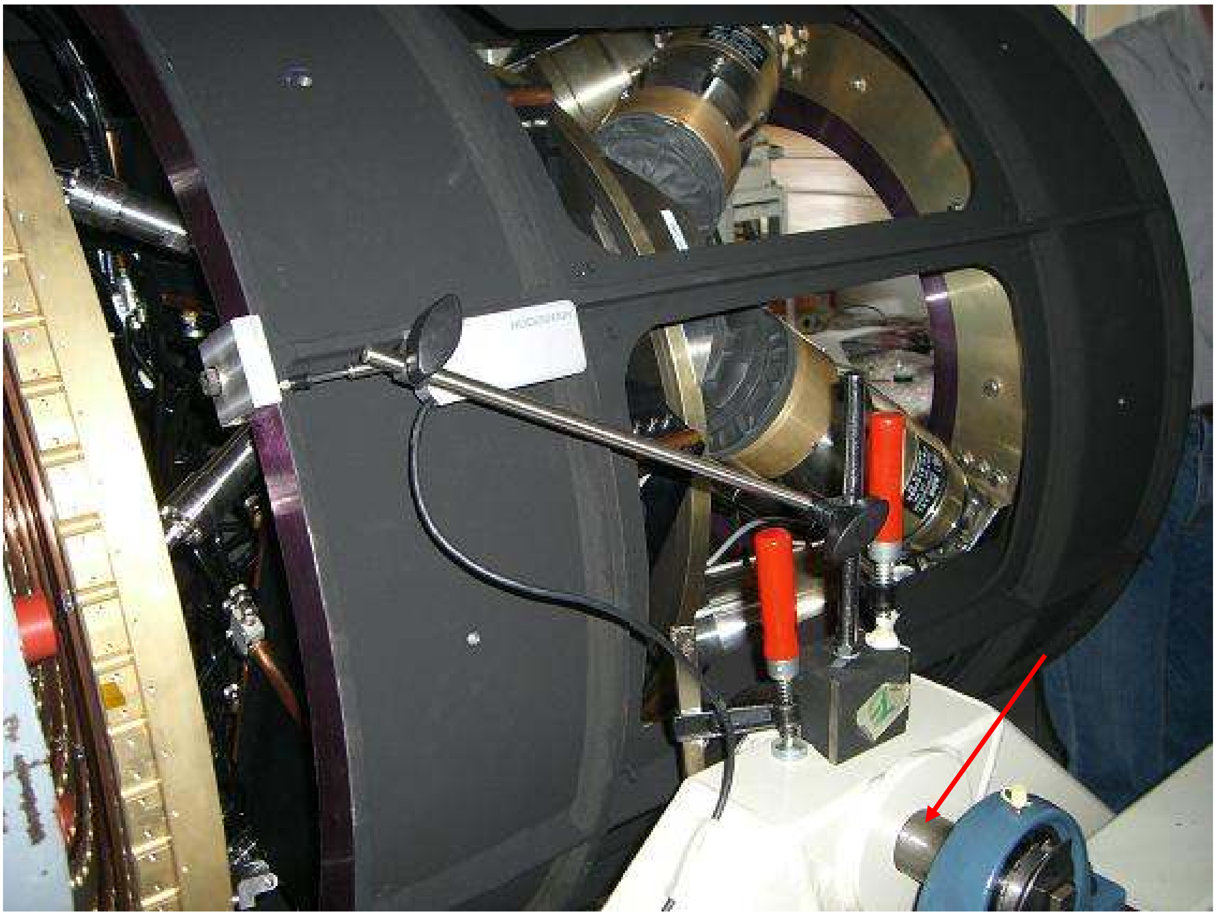

**Figure 10: measure of the displacement of the lower flange of the hub. The red arrow indicates the elevation axis of the trolley.**

The following table shows the displacement of the point in correspondence of wedges A and B of the mobile flange of the HP. This measurement was performed for the 0 and 90 deg elevation angles only.

| *Elevations angle [deg]* | *A wedge [$\mu m$]* | *B wedge [$\mu m$]* |
|---|---|---|
| 90 | 0 | 0 |
| 0 | +160 | +100 |

**Table 8: A and B points displacement due to the deformation of the hub.**

In addition, in order to have the three measures of Table 7 referred to the same reference system, the measurements need to be corrected for the displacement of the elevation axis with respect to the spider interface.
This measure is performed with the same Heidenhain encoder of the previous tests, placing the magnetic base on the beam that holds the lower interface flange of the spider and measuring the displacement of the beam that is solidly connected to the elevation axis of the trolley of the previous point. Referring to Figure 7, this is the measure from the beam with the yellow arrow to the beam with the green arrow.

The following table shows this displacement. This measurement was performed for the 0 and 90 deg elevation angles only.

| *Elevations angle [deg]* | *Beam displacement [$\mu m$]* |
|---|---|
| 90 | 0 |
| 0 | +150 |

**Table 9: displacement due to the deformation of the hub**

After correction for these effects **the flexure of the cold plate with respect to the spider interface along the X axis (angle alpha) is computed to be 112 arcsec.**

## 11 FINAL REMARKS

A mechanical interface test session was performed mounting the adaptive secondary unit #1 inside the hub.

Interfaces inside the hub were successfully tested as well as minimum clearance requirements all around hexapod pointing envelope.

Structural deflection tests as function of changing EL was measured and it resulted within the correction capability of the hexapod.

For schedule reasons, some interfaces measurements and functional tests were not performed on this first unit, but they have been postponed to be carried out on the second unit.

Doc_info_start
Title: Opto-Mechanical Integration
Document Type: Test Report
Source: ADS International Srl
Issued by: Fumi
Date_of_Issue:06/20/2006
Revised by:
Date_of_Revision:
Checked by: Gallieni
Date_of_Check: 01/09/2007
Accepted by:
Date_of_Acceptance:
Released by: Fumi
Date_of_Release: 06/20/2006
File Type: MS-WORD 7
Local Name:
Category:Telescope Auxiliaries
Sub-Category:M2 F/15
Assembly:M2 F/15 General
Sub-Assembly: Opto-Mechanical Integration
Part Name: Test report
CAN designation:640a014
Revision:A
Doc_info_end