HARMONI SCAO PROTOTYPING

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Abstract: HARMONI, one of the first light ELT instruments, will reach ultimate performance thanks to the combination of the large telescope size and the use of adaptive optics (AO) to correct for atmospheric turbulence. Indeed, to fully exploit the image quality provided by the ELT (diffraction limited 39 m telescope), HARMONI will use two AO modes: the classical Single Conjugate AO mode (SCAO), offering high performance correction with limited sky coverage, and a Laser Tomography AO (LTAO) mode, with excellent performance covering almost the entire southern sky.

Two of the HARMONI systems are dedicated to wavefront error (WFE) sensing:

- The LGSS will sense high order WFE using laser guide stars (6 LGS modules) for LTAO operation.
- The NGSS will measure WFE (including position and focus) using natural guide stars (NGS). The NGSS includes several wavefront sensors (WFS) to cover the needs of the different HARMONI observing modes, LTAO, SCAO, High-Contrast. To limit thermal background in the science channel, the system is built in a cold environment, operating at 20° below ambient.

The work presented in this paper will mainly focus on three aspects:

Performance tests at room temperature: to fully characterize both the modulator and OSM behaviors at ambient (resolution, linearity, working frequency, mirrors gluing study, …)

Performance and tests at -20° C: to reproduce/measure same performance in a cold environment

Control/Command issues: to check for the compatibility with Beckoff standard control systems (ESO) using commercial Physik Instrumente devices.

HARMONI overview

❑ Instrument overview

LGSS

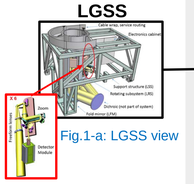

Fig.1-a: LGSS view

IFS

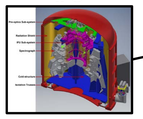

Fig.1-b: IFS view

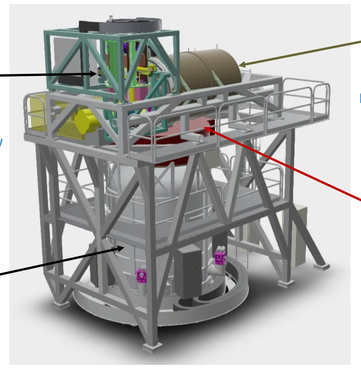

Fig.1: Instrument overview

FPRS

Fig.1-c: Relay System view

NGSS

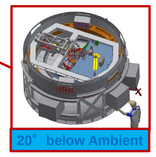

Fig.1-d: NGSS view

Fig.1-e: NGSS view

❑ Harmoni @ LAM

- ❖ Harmoni LGSS: 6 LGS benches)
- ❖ Harmoni NGSS: 3 sub-systems (SCAO/HC/LOWFS)
- ❖ Harmoni Top-End AIT: 3 parts (LGSS/NGSS/CARS)

HARMONI SCAO

❑ SCAO modules

❖ **Main modules**

- o Dichroic module,
- o Object Selection Module,
- o Low-Order Module,
- o Beam Correction Module
- o Pyramid Sensor Module

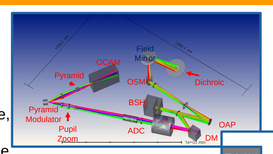

Fig.2: SCAO optical design

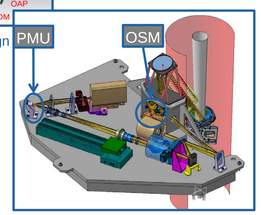

Fig.2: SCAO mechanical design

❖ **Prototyping need**

- o Critical components
  - ▪ Pyramid Modulator (PMU)
  - ▪ Object Selection Module (OSM)
- o Required performance
- o Cold operation (20° below ambient)

Even if Both devices are tip-tilt mirrors, they have very different specifications:

✓ PMU is expected to ensure a fast (500 to 1000Hz) tip-tilt of small amplitudes (milli-arcseconds on sky)

✓ OSM ensures a slow (duration of the observation) but large (+- 6 arcsec on sky) deviations.

Harmoni@ AO4ELT:

- **Fusco et al: [Talk, Session 9]**
- **Neichel et al: [Talk, Session 4]**
- **Sauvage et al: [Talk, Session 14]**
- **Caillat et al: [POSTER-WAV-SEN-207]**
- **Schwartz et al: [POSTER-WAV-SEN-208]**

SCAO PROTOTYPING

❑ OSM Specs & Design

❖ Mains specifications

- o Size : 2 inch mirror
- o TT accuracy: 1 arcsc
- o Deviation ranges: +/- 4.5°
- o Temperature : -20° C
- o Quasi static motions

➔ No COTS device

❖ LAM design

- o Gimbals stm with flexural pivots (Riverhawk)
- o 2 x Linear actuators (PI M-227.10)
- o Encoding : included in actuators
- o End stroke switches (To be added)
- o Reference (calibration sequences)

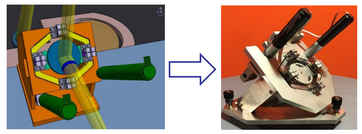

Fig.3: OSM from design to manufacturing

❑ Theoretical model

❖ Geometrical pivots principle

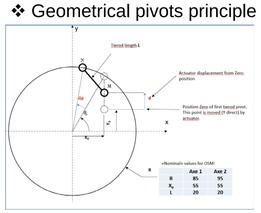

Fig.4: OSM deviation working principle

❖ Deviation model

- ✓ $Y_0 = sqrt(R^2 - X_0^2) - L$
- ✓ $\theta_0 = arctan((Y_0+L)/X_0)$
- ✓ *With* $\theta = \theta_0 + \Delta\theta$ ➔ **MN =L**

$$\theta = \theta_0 + \Delta\theta = acos\left[(R^2 + X_0^2 + Y_0^2 + d^2 + 2*Y_0*d - L^2)/2/R/sqrt(X_0^2+(Y_0+d)^2)\right] + atan((Y_0+d)/X_0)$$

❑ Characterization

❖ Different tools

- o Laser tracker
- o Electronic autocollimator
- o Theodilite
- o Interferometry

❖ Measurements

- o Linearity & Hysterisis
- o Deviation angle
- o Repeatibility
- o Resolution

- o ➔ **More amb tests needed**
  - o **Actuator test**
  - o **Repeatibility**
  - o **Heat dissipation**

❖ Cold test

- o ➔ Delayed after summer

❖ Control issues

- o ➔ Delayed after summer

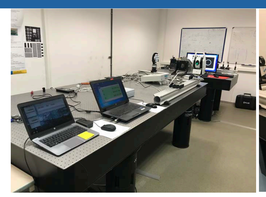

Fig.5-a: OSM bench (Laser Tracker)

Fig.5-b: OSM bench (Autocollimator)

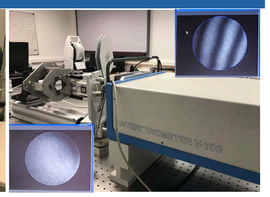

Fig.5-c: OSM bench (Interferometer)

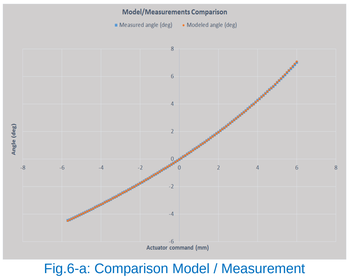

Fig.6-a: Comparison Model / Measurement

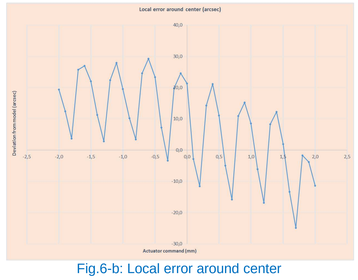

Fig.6-b: Local error around center

❑ PMU Specs & Design

❖ Mains specifications

- o Frq: 500 Hz & 1000 Hz
- o Deviation ampl.: 5-10-15 λ/D°
- o Temperature : -20° C

➔ COTS device (PI)

- ▪ TT: S-331.2SH (PI)
- ▪ Controller: E-727.3SDAP

❖ TT System

- o 10 cm mirror
- o Gluing process
  - o Test before/after
  - o No constraint

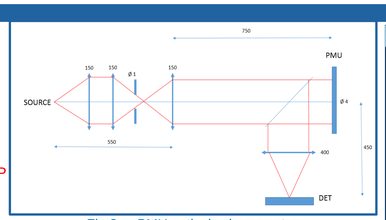

Fig.8-a: PMU optical scheme setup

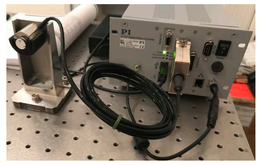

Fig.7: TT system assembled

Fig.8-b: PMU test bench

Fig.9: Modulation signal at 1000Hz, for 0 to 5 l/D

Fig.10: Modulation signal at 500Hz, for 0 to 15 l/D

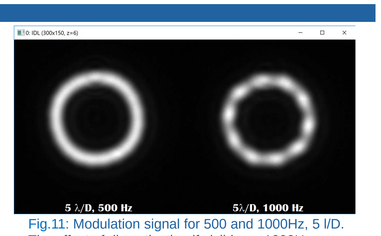

Fig.11: Modulation signal for 500 and 1000Hz, 5 l/D. The effect of discretization if visible on 1000Hz case

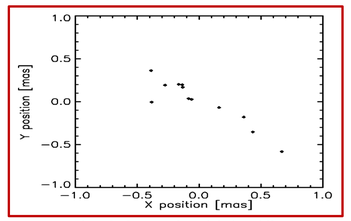

Fig. 12: Centre of modulation drift

Conclusion

- OSM : PI M-227.10 actuator presents required incremental resolution but its response is far from being linear. This induces a complexity in the calibration of the mechanism.
- PMU : all tests have shown performance compliance with specs for main SACO working configurations (500 &1000 Hz, 5-15 λ/D)
- Remaining tests: all the necessary investigations at ambient will be performed until a clear behavior is identified for each device (OSM nonlinearity, PMU center drift, …). Then the rest of the tests can be carried out as planned:
  - Cold tests , reproducing the same performance.
  - Control issues (Beckoff standard using PLC devices).

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