MATISSE: Warm Optics integration and performance in laboratory

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ABSTRACT

MATISSE (Multi AperTure mid-Infrared SpectroScopic Experiment) is the spectro-interferometer of the European Southern Observatory VLT operating in the spectral bands L, M and N, and, combining four beams from the unit or auxiliary telescopes.

The concept constitutes an evolution of the two-beam interferometric instrument MIDI operating on the VLTI. It will give access to the mapping and the distribution of the material, the gas and essentially the dust, in the circumstellar environments and will provide aperture synthesis images in the mid-infrared spectral regime.

The Warm OPtics (WOP) of the instrument provides the functions of spectral band separation, optical path equalization and modulation, pupil positioning, beam anamorphosis, beam positioning, and beam commutation. It also allows the alignment function of the beams with the Cold Optics contained in two separate cryostats. This sub-system is presently aligned and tested at the Observatoire de la Côte d'Azur in Nice, France, to validate accuracy and stability.

The present paper gives the results of the Warm OPtics laboratory tests.

Keywords: High Angular Resolution, Long-baseline stellar interferometry, Instrumentation

1. INTRODUCTION

MATISSE is a second generation instrument of the European Southern Observatory Very Large Telescope Interferometer (VLTI) designed to be a mid-infrared spectro-interferometric instrument combining the beams of up to four telescopes (Unit Telescopes or Auxiliary Telescopes). It offers two major breakthroughs[1], the opening of two new observing windows at the VLTI, the L and M bands (3.0 µm to 5.0 µm) in addition to the N band (8.0 µm to 13.0 µm), and the measurement of closure phase relations and capability for image reconstruction in the mid-infrared domain. The main astrophysical program is the study of the protoplanetary disks and the cores of Active Galaxies. Of course, the fields of astrophysical research which will benefit of MATISSE are much wider. Lopez et al, these proceedings[2], present a general overview of the scientific program, the expected performance[3] and the instrument.

The requirements imposed by the science cases have led to the definition of the desired spectral resolution, sensitivity and accuracy needed to answer a number of key astrophysical questions, and have driven the design study. The instrument will operate with two spectral resolutions in N band R≈30, R≈200, and four in L&M bands R≈30, R≈500, R≈1000 (L only), and R>3000 at 4.05 µm and 4.7 µm.

MATISSE is an instrument with a multi-axial global combination. Five images are formed on the detector, one interferometric image and four photometric channels for the photometry calibration. The interferogram pattern is composed of six fringe systems and is dispersed in the spectral direction. The beam configuration is non redundant in order to avoid the crosstalk between the fringe peaks in the Fourier space. The Fourier Transform (TF) of each spectral channel of the interferometric image is thus composed of the fringe peaks centered at six different spatial frequencies and of the low frequency peak that contains the object photometry and the thermal background. In order to measure the coherent fluxes with a good accuracy, the design of MATISSE is based on the use of spatial filters, including image and pupil stops[4]. In order to measure closure and differential phases with a good accuracy, a beam commutation allows to reduce the effect of the instrumental defects on the useful signal. To measure the coherent fluxes and the derived interferometric measures such as the differential visibility and phase and the closure phase, it is necessary to reduce the sensitivity of the fringe peaks to variations of the thermal background. This sensitivity is produced by crosstalk between the fringe peaks and the low frequency peak. Two methods are then combined: spatial modulation as used in the instrument VLTI/AMBER[5], combined with temporal modulation as used in VLTI/MIDI[6].

The project successfully passed the Final Design Review (FDR) in April 2012, resulting in the validation of the instrumental study, of the compliance of the estimated performance with the expected scientific requirements. Since then, the MATISSE consortium proceeds to the manufacturing, integration, and tests of the instrument in laboratory.
The aim of this paper is to give the results of the different tests performed this last year on one sub-system of the instrument, the Warm OPtics (WOP), presently under integration and alignment at the Observatoire de la Côte d'Azur, Nice. The philosophy is to verify the compliance with the specifications of every individual module before its integration with all the other WOP modules, and before it interfaces with the other sub-systems (the cold optics, the detectors assembled inside the cryostats, the electronics and the instrument software). The goal is to achieve the most stable and reliable instrument. In particular, care is taken to prevent any thermal variations and any beam positioning variations during the operation of the motorized components.

2. MATISSE CONCEPT AND OPTICAL LAYOUT

MATISSE instrument is composed of the Warm Optics (WOP) and two Cold Optics benches (COB), one for each spectral band, located in two cryostats. The optical references are shown on Figure 1.

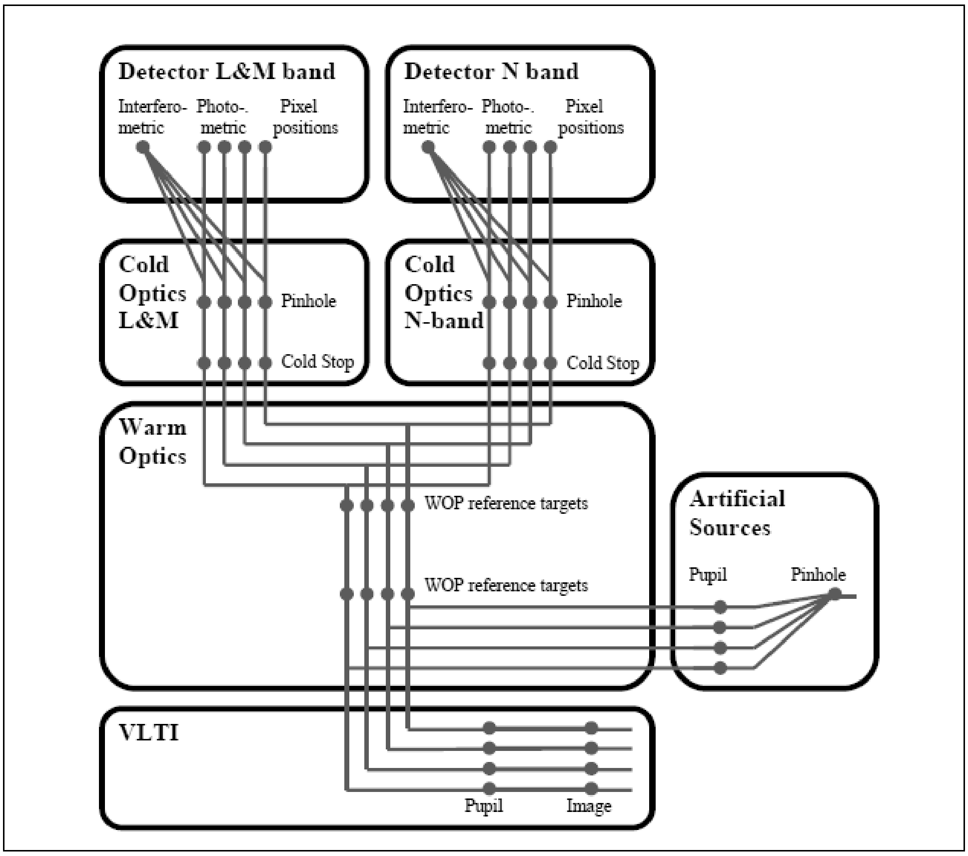


Figure 1. MATISSE optical references.

The warm optics (WOP) subsystem receives four beams coming from either the Unit Telescopes (UT) or the Auxiliary Telescopes (AT) of the VLT. The functions of the different modules are provided in Table 1. An overview of the WOP sub-system modules is provided on Figure 2.

Table 1. List of the WOP modules with their functions.

MODULE	FUNCTIONS
Artificial Sources (ARC)	Alignment, maintenance and calibration operations Four visible collimated beam delivery Four IR collimated beam delivery
Pupil Creator (PUC)	Creation of a pupil plane conjugated with the neutral point of the anamorphic system Four visible collimated beam delivery Four IR collimated beam delivery
Source Adjustment Device (SAD)	Positioning of the artificial beams Adjustment of the OPD
Source Selector (SOS)	Selection between the beams coming from the VLTI and those coming from the artificial sources
Beam Commuting Device (BCD)	Alignment, maintenance or calibration operations Minimization of the effect of the differential phase Beam commutation (1-2 and 3-4)
Photometry Anamorphic Optics (PAO)	Beam anamorphosis (factor 4)
Spectral Separator (SSM)	Spectral separation between L&M and N band
Co-Alignment Unit (CUN/CUL) Periscope in L&M and N bands	Co-alignment between warm and cold optics Beam lateral adjustment Beam inclination adjustment
OPD modulator in L&M and N bands (OMN/OMN)	Thermal background elimination
Co-Phasing Unit (CPL/CPN) Delay lines in L&M and N bands	Pupil transfer at the cold mask level in the cold optics OPD adjustment, OPD modulation Optional chromatic OPD adjustment between the L and N bands

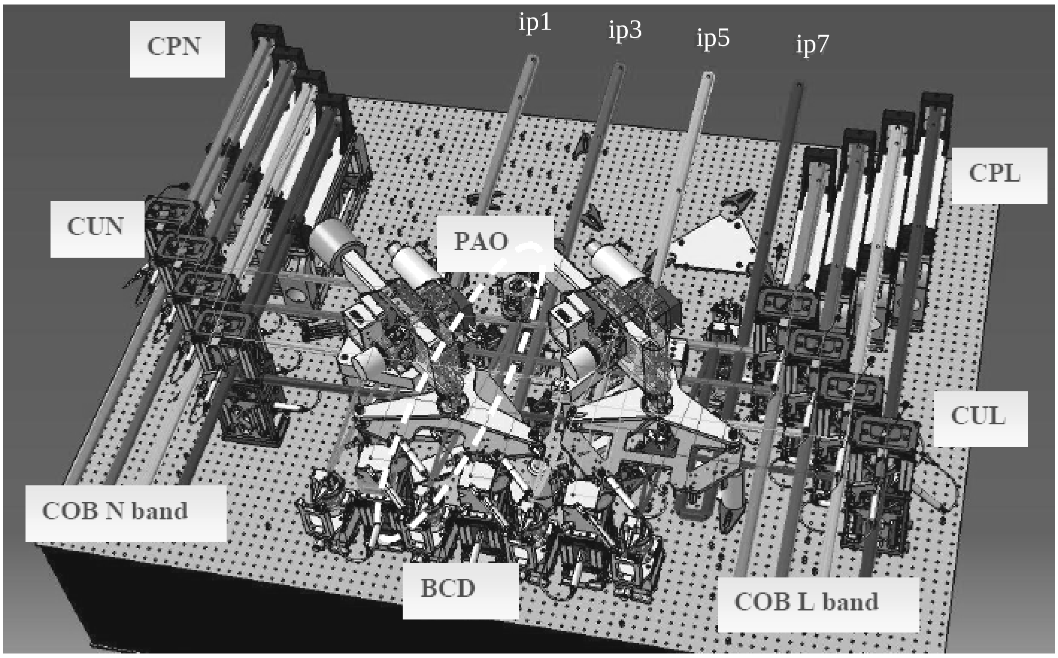


Figure 2. MATISSE warm optics (WOP) overview. The beams coming from the VLTI are noted ip1, ip3, ip5, ip7. BCD: Beam Commuting Device. PAO: Photometry Anamorphic Optics. CPN/CPL: Co-phasing units in N and L/M bands. CUN/CUL: Co-alignment Unit in N and in L/M band. COB: Cold Optics Bench.

The four beams enter first into the modules called Beam Commuting Devices (BCD). Then the beams undergo an anamorphosis with a ratio 1:4 thanks to the cylindrical optics of the Photometry Anamorphic Optics (PAO). The beams are then spectrally separated with dichroic optics in the Spectral Separator Module (SSM) in order to form the L&M band and the N band beams. Before entering into the Cold Optics benches each beam passes through two sets of modules:

- The periscopes Co-Alignment Unit in N and L/M bands (CUN/CUL) which are used for the co-alignment (image and pupil) between the warm optics and the cold optics.
- The delay lines Co-Phasing Unit (CPN/CPL) which deliver the pupil plane at the correct position into the cold optics, equalize the optical paths between the beams and the differential optical paths between the L&M band and the N band.

A temporal modulation of the interference fringes like in the instrument VLT/MIDI is ensured by the OPD Modulation device (OMN/OML). This modulation allows the calibration of the coherent flux and the derived interferometric measures.

In addition, internal optical sources (one visible for alignment and one IR for calibration purpose) are available from the module Artificial Sources (ARC). These optical sources deliver four identical beams (identical to the VLTI ones) and are injected into the instrument thanks to some plane mirrors of the Source Selector (SOS) module.

These modules are located onto the 2m x 1.5m warm optics.

Light enters the entrance windows of the cryostat with an anamorphic factor of 4, passing the cold stops and the off-axis optics and spatial filtering module (slit) of the re-imager unit until it reaches the beam-splitter. Here, light is split into the interferometric channels and the photometric channels. The anamorphosis of the interferometric channels is further increased by a factor 6 by anamorphic optics to produce a total of 24 taking into account the warm optics anamorphosis. Finally after passing the filter, polarizer and dispersion wheels light reaches the detector via the camera.

2.1 Characteristics of the tested modules of the warm optics

This section provides the main mechanical characteristics of the modules which have been tested.

2.1.1 Translation stages Co-Phasing units CPN/CPL, Beam Commuting Devices BCD, Co-Alignments Units CUN/CUL

In MATISSE instrument, translation stages with flexure beams are used in the following modules:

- Co-Phasing units CPN/CPL. The function is the OPD adjustment between the four beams in one spectral band, and between the two spectral bands.
- Static part of the Beam Commuting Device BCD. The functions are the OPD adjustment and the beam-axis co-adjustment between the instrument mode for which the beams are commuted and the mode for which they are not.
- Co-Alignments Units CUN/CUL. The function is the beam-axis co-adjustment at the interface between the warm optics and the cold optics.

The translation stage consists of two stages working in series: the first stage links the frame (reference frame) to the intermediate translation stage by the mean of flexure beams; the second stage is the translation stage itself and is linked to the intermediate stage by the mean of flexure beams. The flexure beams having the same length, the intermediate stage moves vertically and the vertical displacement of the translation stage is cancelled. The intermediate stage translates half from the translation stage. The actuator acts on the translation stage by the mean of a bracket. It is sketched on Figure 3.

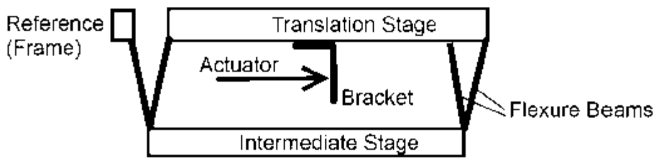


Figure 3. Sketch of the flexure beam translation stage.

For the three modules using translation stages it is important to measure the roll, pitch and yaw angles versus linear displacement. Results are presented in Sections 3.3 and 3.4. They have been reached after some mechanical modifications of the modules accordingly to the following observations:

- The positioning of the flexure beams (ensured by positioning pins) must ensure the good symmetry of the system.
- The thickness of the flexure beams must ensure a good rigidity (no buckling) of the system. It has been increased from 0.5 mm to 1 mm.
- For the CPN/CPL only, the two pillars holding the translation stages must ensure the good symmetry of the system.

2.1.2 Cranes: Source Selector units SOS and Beam Commuting Device BCD

Cranes moving up and down the optical stage are used in the following modules:

- Source Selector units SOS (Figure 4). The function is the artificial light injection towards the MATISSE optical axes.
- Mobile part of the Beam Commuting Device BCD. The function is the commutation between IP1 and IP3, and between IP5 and IP7.

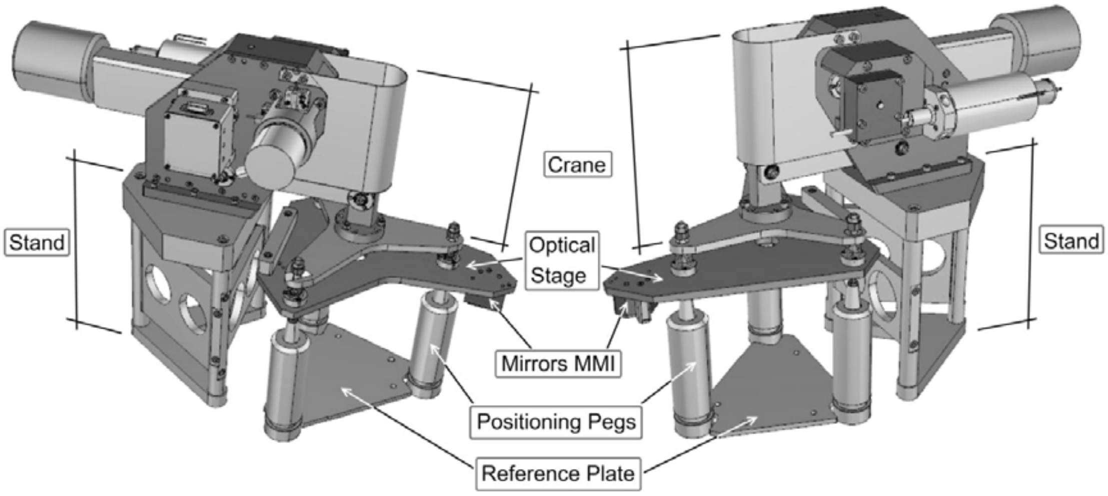


Figure 4. Overview of the SOS IP5-IP7.

When the module is in its active position (artificial beams injected in the science modules with the SOS, or commuted beams with the BCD) the optical stage is lowered. It rests on the 3 tungsten carbide spheres at the top of the pegs (isostatic positioning Sphere-Groove-Plane). The optical stage is pushed onto the pegs with the help of 3 springs pushed by a “pressure” plate linked to the vertical arm of the crane. The optical stage is then released from the crane (the shear force of the springs is almost zero). When the optical stage is lifted (VLTI beams injected in the science modules when the SOS is off, or uncommuted beams reflecting on the static part of the BCD), the optical stage is isostatically positioned and carried by the pressure plate. The stability and the repeatability of the position of the device is ensured by the force delivered by the springs. The optical stage is balanced to have its center of gravity at the geometrical center of the isostatic positioning (pegs tip), ensuring thus an equal gravity force on the pegs.

For the two modules using cranes it is important to measure the repeatability of the positioning. Results are presented in Section 3.2.

3. TEST RESULTS OF THE WARM OPTICS MODULES

Tests on individual modules have been conducted before their optical integration in order to ensure their performance in terms of:

- Thermal sensitivity: OMN/OML, SSM, CPN/CPL, PAO-CMO (Sect. 3.1).
- Positioning repeatability: BCD and SOS (Sect. 3.2).
- Roll, pitch, yaw versus linear displacement: CPN/CPL and BCD (Sect. 3.3 and 3.4).
- Displacement resolution and stage overall stroke – linear and angular: CPN/CPL and BCD (Sect. 3.3 and 3.4).
- Accuracy of the tip/tilt adjustment: BCD and CUL/CUN (Sect. 3.5).

The conclusion is that these modules presently comply with the requirements. Details are provided in the sections below.

3.1 Thermal sensitivity

3.1.1 Principle

The scope of these tests was to verify the angular stability of the different modules with respect to thermal variations.
At Paranal, the WOP sub-system instrument will work at a more or less constant temperature (16.3°C +0.5/-1°C) over a day, with thermal diurnal variations < 0.31°C PTV and seasonal variations <5.50°C PTV (from the ESO document: ICD between the VLTI and its instruments part I, VLT-ICD-ESO-15000-1826). It is then important to check if the beams stay within the specifications in terms of inclination, lateral position and optical path, during a day, and during periods of the order of a month during which no adjustment of the instrument is necessary. To minimize these effects several choices were made, including:

- The modules are fixed on the optical table independently to each other to avoid any deformation of long base plates which would carry several modules.
- Most of the mechanical components of the instrument were chosen to be made in stainless steel. The material is then homogeneous with the optical table, and its Coefficient of Thermal Expansion (CTE, value $10.10^{-6}\ K^{-1}$) is very close to the CTE of the material used for the optics. This reduces the differential CTE which could exist between the different components and between the modules and the optical table.

However, the thermal effects exist despite these precautions and have been quantified. The measurements are performed in a thermal enclosure VOTSCH VT3 7150. A triple beam plane mirror interferometer SIOS SP2000-TR series is used. The three beams supplied by a stabilized He-Ne laser allow three-axial measurement. They are reflected on a plane mirror attached on the module back to the interferometer where they merge with the original beams. Relative beam angles and displacements are then computed. One beam is used as the reference. The two other beams are used to measure the displacement of orthogonal points relatively to the reference point, thus the angular variation (trigonometric conversion).
The relevant axes to be checked are the horizontal rotation and the vertical rotation (Figure 5):

- The horizontal rotation corresponds to the vertical inclination (pitch) of the beam.
- The vertical rotation corresponds to the horizontal inclination (yaw) of the beam.

The set also comprises a temperature sensor.

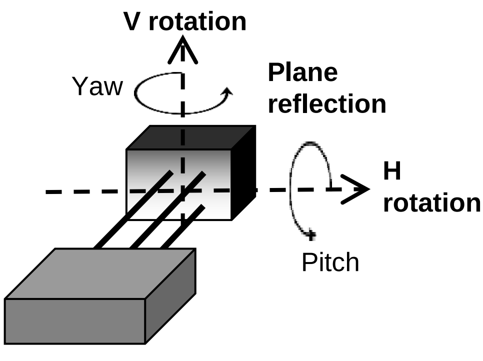


Figure 5. Measurement principle with the triple beam interferometer SIOS SP2000-TR: yaw (V rotation) and pitch (H rotation) angles of the beams reflected on a plane mirror attached on the module of MATISSE to be measured.

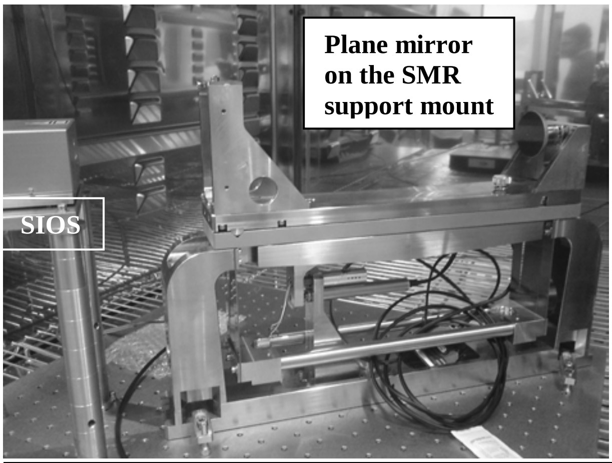
The sensitivity of the modules to the thermal variations was measured in two steps:

- A reference part was bridled onto the test bench inside the thermal enclosure and its deformations as a function of temperature were measured. This reference part is a massive stainless steel block with a plane mirror.
- The MATISSE module to be checked was bridled onto the test bench and its deformations were measured.

Assuming that the thermal behaviour of the test bench was the same in both cases, the deformations measured with the reference part were subtracted from the deformations measured for the MATISSE module. Since then, the thermal sensitivity of the SIOS itself has been estimated by a team of OCA, in the framework of a study on temporal stability in high contrast instruments[7].

3.1.2 Test results

The thermal sensitivity of the following modules was measured: OMN/OML, SSM, CPN/CPL, PAO-CMO. Figure 6 shows one CPN/CPL module and the steel reference block installed on the test bench inside the thermal enclosure.



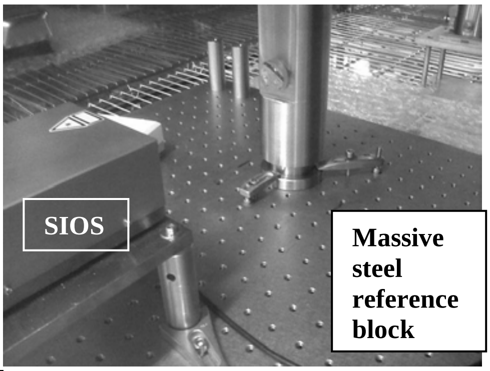


Figure 6. One module CPN/CPN and steel reference block installed on the test bench inside the thermal enclosure.

The measurement results are provided in Table 2 and compared to the requirements. The modules are conform to specifications. The mirror support of the OMN/OML module needed to be re-machined in order to minimize longitudinal and vertical dilatations. Contrary to the choice which was made for most of the other mechanical components of the instrument, this support is in aluminum to be light to be handled by the piezo-electric stage ensuring the OPD modulation. The aluminum CTE being twice that of the stainless steel, the support was very sensitive to temperature variations. The solution was to shorten this support and to remove a small bracket which were introducing a deformation in one direction.

Table 2. Results of the thermal tests performed on the MATISSE modules.

Module	**Requirements**	**Results**
OMN/OML	≤ 2 as PTV/°C	0.6 as PTV/°C
SSM	≤ 2 as PTV/°C	0.8 as PTV/°C
CPN/CPL	Beam vertical displacement (anamorphosis direction): 65 µm => horizontal rotation: 1.6 as/°C Beam horizontal displacement: 250 µm => vertical rotation: 6.4 as/°C	 0.7 as/°C 1.3 as/°C
PAO-CMO	Beam vertical displacement (anamorphosis direction): 65 µm => horizontal rotation: 1.6 as/°C Beam horizontal displacement: 250 µm => vertical rotation: 6.4 as/°C	 0.25 as/°C 0.2 as/°C

3.2 Positioning reproducibility of the BCD and SOS module

3.2.1 Principle

The goal of these tests was to measure the reproducibility of the SOS allowing the artificial source injection and of the BCD ensuring the beam commutation for calibration.

The same triple beam interferometer SIOS that was used for the thermal sensitivity allowed to perform the measurements. The plane mirror that was attached on the optical stage of the module was large enough to continuously reflect the 3 beams of the interferometer during the vertical translation of the BCD/SOS (Figure 7).

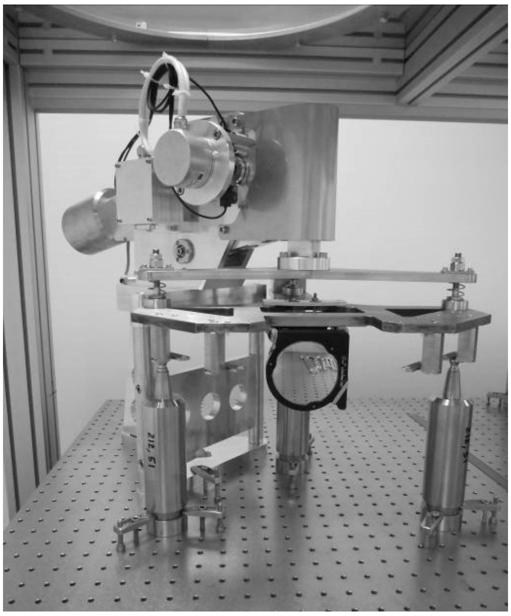


Figure 7. Plane mirror attached on one BCD module for the positioning test.

3.2.2 Test results

The measurements showed in Table 3 are averages and standard deviations resulting from different sequences of 11 to 12 data acquisitions taken after each operation of the module. The data are collected when the module is in the active position. The data are different from one sequence to another due to the instability of the interferometer (~0.5 as within 5 minutes) and of the environment, as the tests were performed in parallel to the motor parameterisation. However, the results show reproducibility well within the requirements of 5 as RMS.

Table 3. Results of the positioning reproducibility of the BCD/SOS modules. The requirements are 5 as RMS.

Sequence	Yaw angle (as) Vertical-axis	Pitch angle (as) Horizontal-axis
1	1.15±0.10	0.40±0.22
2	0.07±0.20	0.13±0.10
3	0.85±0.30	0.13±0.12
4	-0.03±0.07	0.70±0.40

3.3 Pitch, yaw versus linear displacement of the CPN/CPL – displacement resolution and stage overall stroke

3.3.1 Principle

The goal was here to measure the residual rotation (yaw angle along vertical axis and pitch angle along horizontal axis) and the vertical motion of the translation stage carrying the optical stage holding the 2 mirrors of the delay lines. The measurements were performed with the triple beam interferometer SIOS. The inclination of the optical beams was estimated after reflection on a plane mirror located on the translation stage of the delay line (Figure 8). The delay line motion is performed with a stepper motor TRA6PP S/N B134178.

The requirements are expressed in terms of optical beam displacement at the exit of the cat's eye configuration and translated in angles for the translation stage:

- Beam vertical displacement (anamorphosis direction): 65 µm => Pitch angle: 4 as on 1 mm travel (Goal: 4 as on 6 mm)
- Beam horizontal displacement: 250 µm => Yaw angle: 16 as on 1 mm travel (Goal: 16 as on 6 mm)

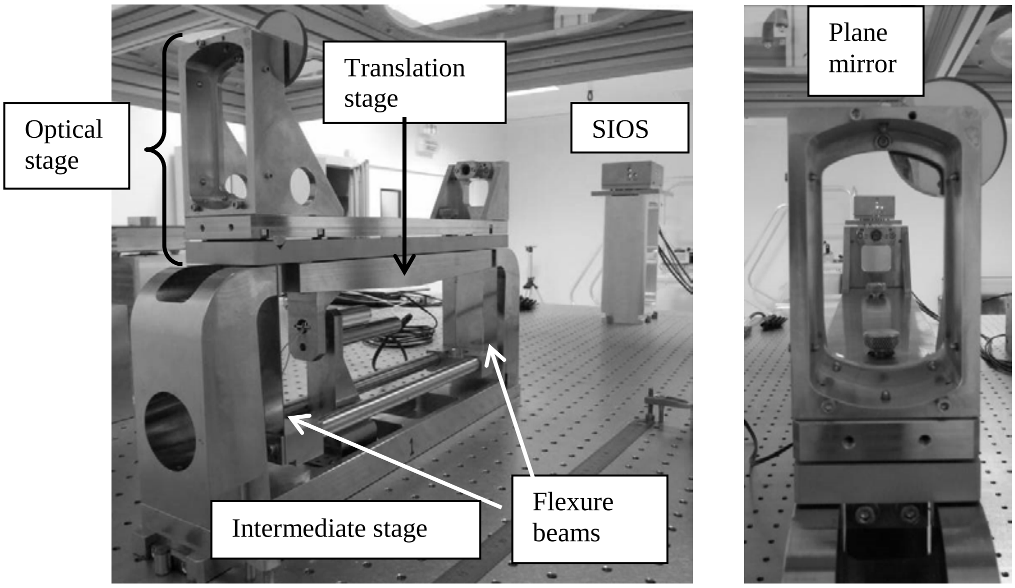


Figure 8. Measurements of the accuracy of the motion of one CPN/CPL module. Delay line located in front of the interferometer on the MATISSE optical table.

3.3.2 Test results

The final measurements are given in Table 4, for the forward and return paths with the total travel of 6 mm. The standard deviation of the pitch angle is noise. The standard deviation of the yaw angle is due to a modulation during the displacement. The yaw versus the travel of the delay line presents a sine variation with increasing amplitude up to 2 as at the end of the travel. When the motion is reversed, there is a shift of 1 as to 2 as. However, the maximum reached angles are within the specification, even the goal. To reach these results we mentioned in Section 2.1.1 that the thickness of the flexure beams were increased, from 0.5 mm to 1 mm. This allowed to improve the initial measures by a factor 3. Modifying the assembly of the module in order for its geometry to be the most symmetric as possible contributed further to the improvement of the yaw angle by a factor 3 and of the pitch angle by a factor 10.

Table 4. Results of the motion accuracy of the CPN/CPL modules.

Sequence	**Yaw angle (as)**		**Pitch angle (as)**	
	forward	**return**	**forward**	**return**
1	4.3 ± 1.0	5.1 ± 1.3	1.5 ± 0.3	1.5 ± 0.3
2	4.2 ± 1.0	5.0 ± 1.3	1.3 ± 0.2	1.4 ± 0.3
3	4.0 ± 1.0	5.0 ± 1.3	1.2 ± 0.2	3.2 ± 0.3

The vertical displacement was measured with marking gauges. It is 10 µm maximum on the entire travel. In addition, the displacement resolution of the actuator has been estimated <0.5 µm PTV, compared to the requirement of <7 µm PTV.

3.4 Pitch versus linear displacement of the static BCD - Displacement resolution and stage overall stroke

3.4.1 Principle

The goal was to measure the residual pitch angle (along horizontal x-axis) and vertical motion of the translation stage carrying the optical stage holding the 2 plane mirrors of the static part of the BCD. The principle is the same than for the CPN/CPL.

3.4.2 Test results

The pitch angle for 1 mm of the displacement of the module (2-mm OPD) has been measured for the four assemblies (Table 5 and Figure 9). The accuracy takes into account the difference between values for the forward path being from the 0-position to 4.5-mm, and for the return path. The measurement of the yaw angle is not relevant as it is null by design, the beam being reflected by two perpendicular plane mirrors with the intersection in the vertical direction. Nevertheless, this has been verified. These modules were modified accordingly to the test results on the CPN/CPL: the thickness of the flexure beams were increased by a factor 2 from its initial value and the positioning of the flexure beams was optimized to ensure a good symmetry of the assembly.
The resolution of the stepper motor is the same than for the CPN/CPL.

Table 5. Results of the motion accuracy of the BCD modules. The requirement is 1 arcmin on 4.5 mm travel.

BCD ip#	Pitch angle (as/mm)
1	4.6 ± 0.2
3	2.9 ± 0.3
5	0.5 ± 0.1
7	2.0 ± 0.1

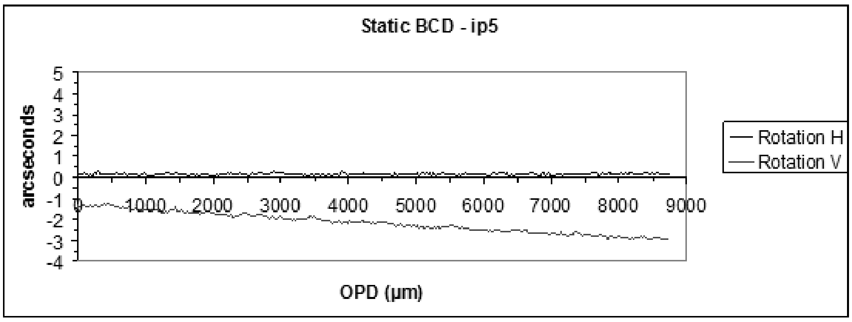


Figure 9. Measurements of the pitch (rotation V) and yaw (rotation H) angles as a function of the OPD for the static part of the BCD dedicated to the VLTI beam ip5.

3.5 Accuracy of the tip/tilt adjustment of the static BCD and CUN/CUL

3.5.1 Principle

The purpose was to quantify the effect of a beam angular adjustment on the opposite angular direction. The module is placed in front of an alignment telescope Moller-Wedel Elcomat Direct500, the incident beam being normal to the plane surface of the mirror to be tilted. Figure 10 shows one CUN/CUL module on the optical table.

The required accuracy of the adjustments is 5 as. In addition, the motions have to be linear, stable and reproducible.

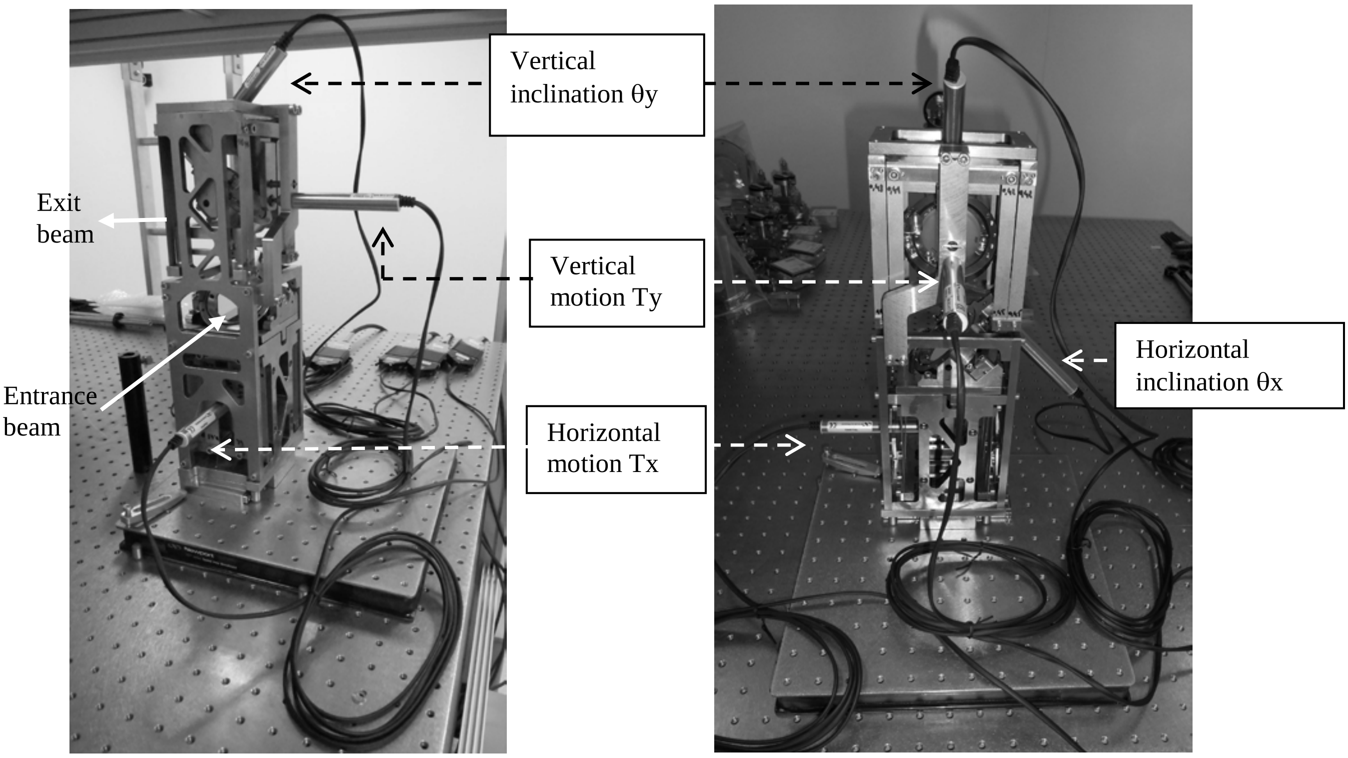


Figure 10. Measurements of the accuracy of the beam inclination adjustment of one module CUN/CUL dedicated to the VLTI beam ip1.

3.5.2 Test results

The inclination of the beam in the opposite direction of the beam adjustment has been measured for the four static BCD and one CUN/CUL. The slopes of the motion are provided in Table 6 and Figure 11.

The inclination induced by the vertical adjustment is at the limits of the requirements for the BCD. Nevertheless, as we won't adjust these modules during the operation of the instrument on sky, it is acceptable. The reproducibility and the linearity are less than 0.1 as/amin, which is extremely satisfactory. The motions are linear, stable and reproducible.

Table 6. Results of the motion accuracy of the static part of the BCD modules.

	Horizontal adjustment (as/amin)	**Vertical adjustment (as/amin)**
Static BCD ip1	0.43 ± 0.01	5.72 ± 0.01
Static BCD ip3	0.33 ± 0.02	5.65 ± 0.02
Static BCD ip5	0.25 ± 0.02	5.52 ± 0.1
Static BCD ip7	0.53 ± 0.005	5.81 ± 0.02
CUN/CUL	0.55 ± 0.5	1.27 ± 0.02

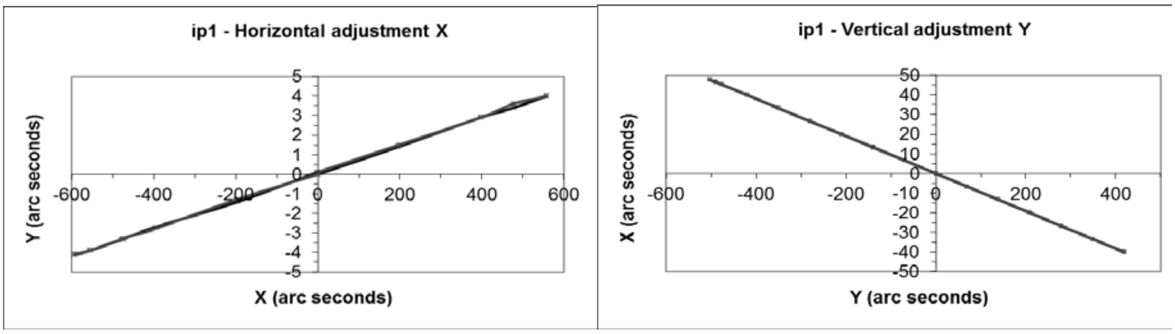


Figure 11. Measurements of the accuracy of the beam inclination adjustment of the static part of the BCD dedicated to the VLTI beam ip1.

4. PERSPECTIVES AND CONCLUSION

The tests of the individual modules of the warm optics sub-system of MATISSE proved their compliance with specifications mainly in terms of thermal sensitivity and beam positioning stability, accuracy and repeatability during the operation of motors. The modules have been initially manufactured by several factories: the workshops of Observatoire de Bordeaux, MPIfR, Köln Universitat, Observatoire de la Côte d'Azur, and two private companies, Torneria Cocconcelli Aldo in Parma, Italy, and CLAPPAZ SARL in Meylan, France. Then the workshop of Observatoire de la Côte d'Azur, S2M (Service Mécanique Mutualisé), carried out the accurate work and mechanical modifications necessary for these modules to reach the goals.

We are presently performing the visible alignment of the Warm OPtics. In parallel, a partial integration of the Cold Optics and detectors within the cryostats is conducted at MPIA, Heidelberg, Germany. This partial integration takes place after the alignment and test in warm conditions of the Cold Optics[8,9] from NOVA-ASTRON, Dwingeloo, Netherlands, and the delivery of the detectors by ESO Garching and MPIfR Bonn, Germany. The N-band assembly including cryostat, Cold Optics and detector will be transported in July to OCA, Nice to be interfaced with the Warm OPtics. It will be followed a few months later by the L-band assembly. The test of the whole instrument allowing to assess the expected performance will then take place in 2015 during almost one year. The end of this phase will be marked by the Preliminary Acceptance in Europe (PAE) before the delivery to ESO, Chile in 2016.

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