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THE FIZEAU SYSTEM INSTRUMENT AT ALBA OPTICS LABORATORY

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Abstract

The ALBA optics laboratory has recently acquired a new Zygo Verifire HD Fizeau interferometer. The instrument has been integrated into a positioning stage to allow stitching of long x-ray optical elements. The mechanical set up, with four axes, allows for automatic positioning and alignment of the interferometer aperture to the surface under test. The longitudinal movement allows for scan of X-ray mirrors up to 1500 m long. The positioning platform includes two angles, roll and yaw, and two translations, vertical and longitudinal translations. The longitudinal translation is a custom designed linear stage. The yaw rotation is based on a sine arm mechanism. The vertical and roll motions are combined in a single stage, closely integrated around the main linear stage. The system reaches repeatabilitys better than 1 µm or 1 µrad for all axes. The system is mounted on top of a vibration isolated bench in the clean room of the laboratory. The control software of the instrument allows direct control of every individual axis, and allows selecting the centre of rotation for both roll and yaw. The system includes inclinometers and autocollimators to control the relative orientation between the interferometer and the mirror under test. The system is integrated to the software of the interferometer, and includes features for automatic alignment of the interferometer to the mirror, or for automatic stitching acquisition, with selectable parameters. The system allows for full three-dimensional characterization of the optical surface of mirrors and gratings, and provides height map reconstructions with accuracy in the order of 1 nm, for flat or curved surfaces with lengths up to 1500 mm.

POSITIONING STAGE

The positioning stage consists on an integration of 5 motorized actuators for the positioning of the Fizeau interferometer. It has been designed to achieve the maximum compactness to give versatility to all possible measurements set ups. The stage has to operate on top of an antivibration system, thus the design included the weight as a requirement.

Design Description

The specifications for the positioning of the interferometer are listed below in Table 1 and Fig. 1.

The longitudinal actuator has a range of 1500 mm. The guides are mounted on the sides of an aluminum standard profile but on precise machined intermediate plates. The carriage is positioned by a ball spindle driven by a stepper motor. In order to avoid stresses caused by guidance errors between the spindle and the guides, a flexible nut support has been included. The system has been designed to reach a speed of 25 mm/s and a theoretical resolution of 8,3 µm at full step. The resolution is achieved by means of micro stepping down to 1/8 of step.

Table 1: Specifications Table

Axis	Specification	Value
X	Longitudinal Stroke	1500 mm
	Resolution	5 µm
	Guidance Flatness	<50 µm
Z	Vertical stroke	±10mm
Roll	Angular Range	20 mrad
	Resolution	1 µrad
Yaw	Angular Range	50 mrad
	Resolution	1 µrad

The vertical stage is mounted around the longitudinal one and it is based on the design of a double flexure that compacts the vertical movement and the rotation in a single following the concept *ALBA XALOC Beamline diffractometer table skin concept* [1, 2]. The angular resolution of the system is 5 µrad/full step, while the system is operated at 1/8-step.

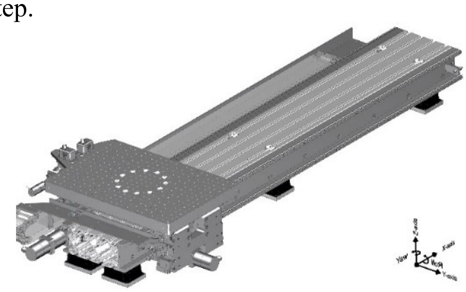

Figure 1: Representation of the axis.

The yaw actuator is the last stage mounted on the top of the vertical stage, and is the mechanical interface with the interferometer. The rotation is driven by means a sine arm. The mechanical architecture, allows for a fine yaw positioning resolution of 0,26 µrad/full step.

All axes include absolute encoders for positioning feedback and dynamic close-loop motion.

FEA Analysis

The design has been validated with simulation to check its stability (see Fig. 2). The lowest resonance modes, (at 49 Hz and 56 Hz) are related to the displacement of the full system due to the spindles compliance, although they but are within tolerance, particularly considering the weight of the system.

The skin concept flexures have been also calculated and optimized simulating the differential displacement between both plates for maximum Roll. The maximum stress is 198 MPa and in this case a high strength aluminium from serial 7000 has been chosen with a yield stress beyond

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500 MPa. With these values the maximum of 40% of the yield stress as a generic fatigue limit is assured.

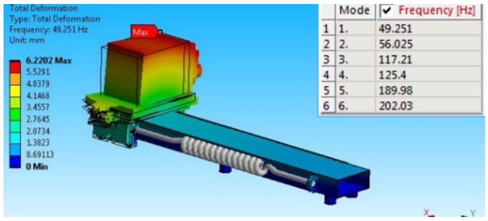

Figure 2: First eigen modes of the positioning platform.

Performances

Several tests have been done to check the motion performances. These tests have been done by means optical metrology, an interferometer and encoders. The results show that the longitudinal axis has a good resolution, well below 1µm, see this results in following graphs Fig. 3.

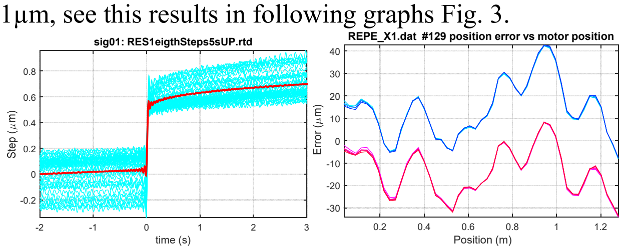

Figure 3: a) Longitudinal axis motion tests, resolution. b) Motion error.

Nevertheless, the system has poor guidance performance. Straightness and flatness are about 150 µrad, and in fact, positioning errors (Figure 3b) are partially caused by them. This is caused by the aluminium profile beam flatness as well as by the difficulty to align properly the two pairs sets of guides at opposite sides of the beam. This is one of the improvements to be done in a future upgrade. On the other hand, the yaw rotation has a good resolution as expected about 0,16 µrad per half step. Vibration tests have been also done and it is possible to see quite good response, there are not relevant resonance peaks below 150 Hz, the resonance modes are shown in next Fig. 4.

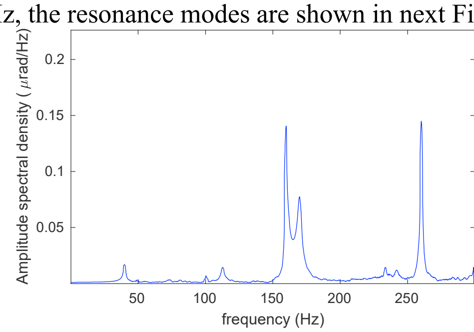

Figure 4: Stage resonance modes.

FIZEAU SYSTEM INSTRUMENT

The measurement system is based on the integration of several elements. The whole environment and tools give to the instrument system the capability to perform functional and accurate measurements. The stable environment of the optical laboratory stabilizes the temperature within ±around 0.1ºC. The set-up is installed on a vibration isolation bench. The described mechanical setup allows taking stitching measurements for optical elements up to 1.5 m long. Next picture, Fig. 5. shows the interferometer integrated at the ALBA Optics laboratory.

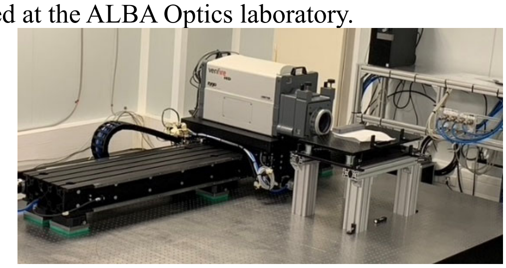
Figure 5: Picture of the Fizeau system at ALBA optics laboratory.

This mechanics, and Fizeau interferometer and its control are integrated into ALBA control system allowing interactive operation of the complete instrument. This allows for user friendly operation, with features like, for instance, automatic alignment of the interferometer optical axis to the surface under test. In addition, the measurement processing algorithms [3, 4] give automated functional data analysis allowing for easy determination of the main optical parameters of the optics under tests, as well as a high-resolution map reconstruction of its surface.

RESULTS

The new ALBA Fizeau Stitching Instrument allows for easy and quick measurements. This enables the full characterization of optics in short time and boosts the works on the optical set ups.

In the following Fig. 6, we give an example of a 1.4 m long flat mirror surface reconstruction obtained with this system. It is a 2D reconstruction with a spatial resolution of 0.09 mm, showing topography details at the nanometre level. It is perfectly visible the separation between the mirror stripes. In addition, the high-resolution performance allows even distinguishing coating defects on some of the mirror lanes.

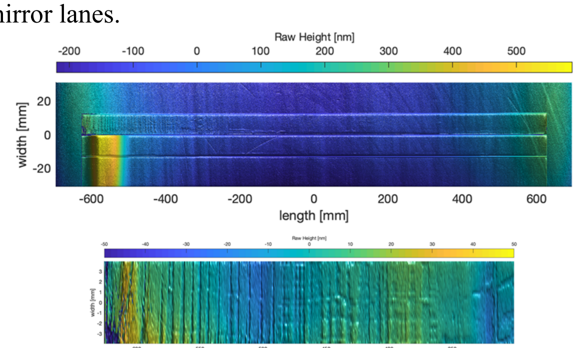

Figure 6: 1.4m long mirror surface map reconstruction.

Very similarly, Fig. 7 shows how the system reveals some characteristic features from traditional polished mirrors. Polishing passes are accurately distinguishable on the surface remodelling.

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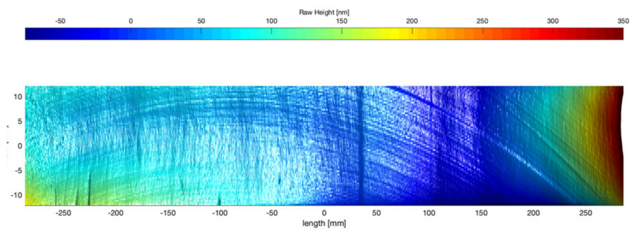

Figure 7: Example of map reconstruction.

Figure 8 shows some errors induced by IBF polishing, which are perfectly visible as a periodic pattern of square points.

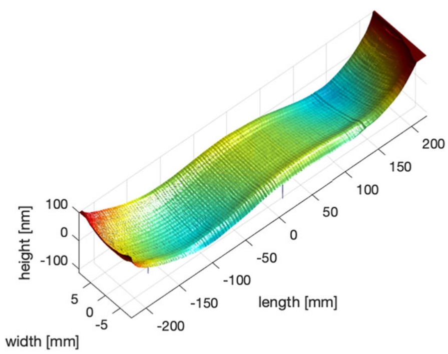

Figure 8: Example of map reconstruction.

The measurement is fast enough to allow to work on the optics setups. Next figures show examples of this, Fig. 9. First a 500 mm long mirror twist correction using the Fizeau system by monitoring the evolution of the adjustment. The two graphs show the surface mapping before and after the correction respectively.

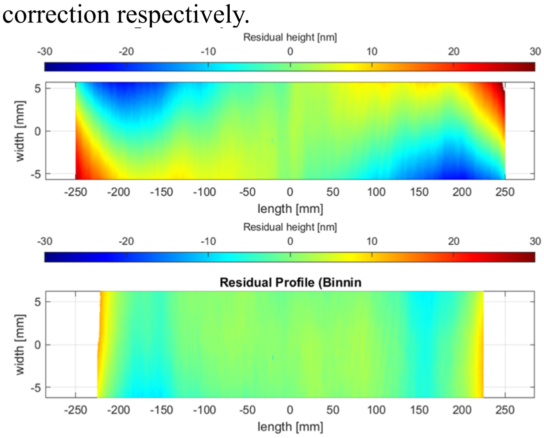

Figure 9: Mirror twist correction example.

Figure 10 shows a measurement result of a mirror with its bender. This is the surface reconstruction of an 800 mm flat mirror after the best fit meridional cylinder subtraction. The measurement provides a clear assessment of the sagittal radius of curvature and of the sagittal slope error. Also it is possible to find out the separation between stripes.

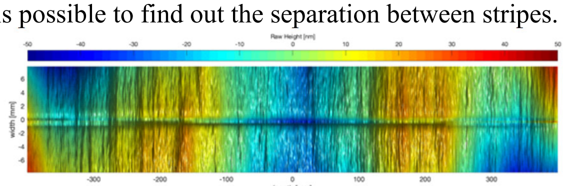

Figure 10: Mirror with bender metrology example.

It is possible to figure out the effect of the mirror holders clamping's. Below Fig. 11 is an example of the characterization of a mirror where it is clearly visible the local deformations of the contacts at the extremes of the mirror.

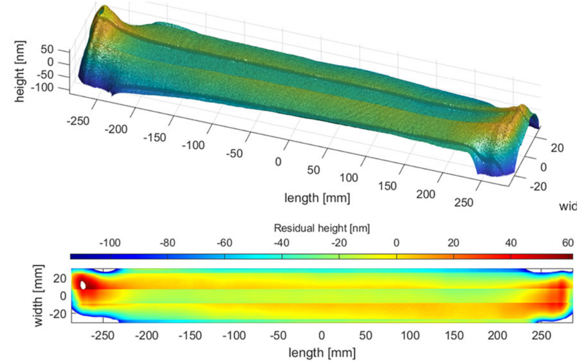

Figure 11: Clamps effect on a mirror.

CONCLUSION

The ALBA optics laboratory has been upgraded with a new Fizeau Interferometer. This instrument has been integrated mechanically with a long linear stage that allows for characterization of optical lengths up to 1,5 m. This mechanics also includes several linear and angular movements allowing for the automatic alignment of the Fizeau to the optics being tested. The system has been installed on a vibration isolation table in a temperature controlled clean room. The mechanics, the instrument and its control software have been integrated to ALBA control system providing an interactive interface of the whole system. In addition, an in-house developed data analysis software and algorithms, allow for automated quick extraction of the main optical parameters of the surface under test becoming very fast and easy to operate. All this combination together makes the Fizeau interferometer system at ALBA a very reliable instrument, accurate and with a sharp resolution. With this system it is possible to quickly extract optical surface map reconstruction, highly detailed and resolutive. The measurement and analysis are quick, easy and with enough resolution to allow distinguishing tiny features on the surfaces, like polishing patterns or other defects, as well as, clamp-induced deformations. This makes possible to work with the optics being tested, allowing to adjust holders and benders, for instance, on a straightforward and brief iterative process.

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