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THE LNLS METROLOGY BUILDING – ENVIRONMENTAL CONTROL RESULTS*

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Abstract

Modern synchrotron light sources require high mechanical stability throughout its facilities, frequently demanding characterization processes in the micro and nanometer scales. In this context, the Brazilian Synchrotron Light Laboratory (LNLS) built a new facility with several controlled environment rooms to minimize disturbances during optical and mechanical metrology procedures and to support advanced instrumentation development for the new Sirius' beamlines. The building design imposed very strict requirements regarding temperature, humidity and particles. This work presents the environmental control validation results and the floor vibration assessment enlightening the influence of the building machinery. Temperature variations below ± 0,1 °C were successfully achieved for all rooms, relative humidity is also better than 50 ± 5 % and the floor RMS displacement did not exceed 15 nm. The building is fully operational since early 2017 and currently hosting several tests on monochromators, mirrors, front-ends and many other systems for the Sirius beamlines.

INTRODUCTION

Sirius is a 4th generation 3 GeV synchrotron light source currently under construction [1] by the Brazilian Synchrotron Light Laboratory (LNLS), designed to provide high brilliance and coherent flux based on a 5-bend achromat lattice with 0.25 nm·rad natural emittance [2,3]. The beamlines of this new generation synchrotron have started to be designed with highly demanding requirements to preserve the extraordinary properties of the source. To achieve such requirements, it is necessary to develop high-end mechanical and optical elements and instrumentation able to guarantee precision and stability during beamline operation. However, before installation of any instrumentation in the beamlines, it is necessary to validate the equipment performance, which can only be done with precision metrology. Also, to take reliable measurements, several parameters must be considered, like the uncertainties of the measurement equipment, the test setup and the environmental disturbances, which can be related to temperature stability, air convection and turbulence, air cleanness, atmospheric pressure and humidity, and vibration [4].

This paper describes the environmental control results of the new LNLS Metrology Building, whose design concepts were detailed at the 2016 MEDSI Conference [5]. Also, the performance of the inertial bases/floor on top of which the metrology laboratories were installed is presented considering the influence of the building machinery.

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PROJECT REQUIREMENTS

The LNLS Metrology Building was designed following a layer-based architecture, in which the outer layers have a proper environmental control that contributes for the stability of the inner ones. The goal of this architecture is to provide the laboratories (inner layers) a highly stable environment, minimizing the influence of the large thermal and humidity variations that may naturally occur outside the building [5]. The building contains three layers and each of them has one or more rooms controlled by independent air handling units (AHUs). The design requirements for each area inside the building are presented at Table 1:

Table 1: Environmental Requirements

Room	T [°C]	RH [%]	Particle
Building Shed	23±1.5	-	-
Assembly Room 1	22±1.0	50±10	-
Assembly Room 2	22±0.5	50±10	-
Mech. Metrology	22±0.1	50±5	-
Optical Metrology	22±0.1	50±5	ISO 7
Gowning Room and Buffers	22±0.1	50±5	ISO 8

ENVIRONMENTAL CONTROL RESULTS

The whole layer concept efficiency is based on stabilizing an outer layer to diminish the external thermal load on the inner layers walls. Aiming to that result, the first system tuned was the main shed, which has the more relaxed requirements and where more general and less precise tests take place. Figure 1 shows the comparison between the shed and external temperature variation, measured along a day. All the results displayed on this paper refer to the same day, 28/04/2018.

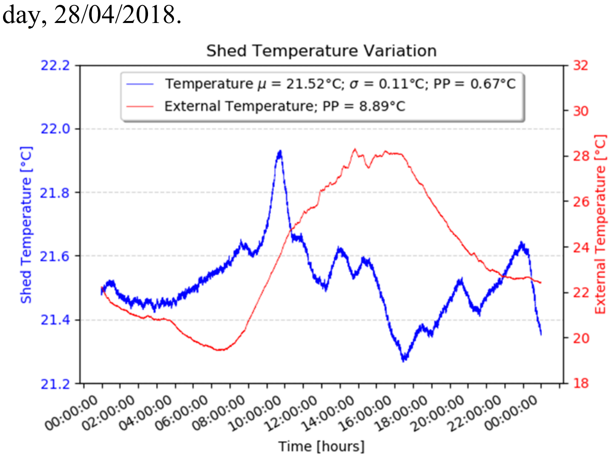

Figure 1: Temperature variation inside and outside the Metrology Building over one day.

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For the Sirius beamlines, mirrors and crystals are being specified with figure errors at the nanometer-level, which must be carefully verified before final installation. Such verifications are conducted at the Optical Metrology Laboratory (OML). For that, the applied instrumentation (autocollimators, interferometers) is required to work at its full performance, avoiding any external disturbances. Aiming to enable measurements at this scale, the OML had the strictest environmental project requirements, as exhibited in Table 1. Figure 2 shows the room temperature and humidity variation over one day.

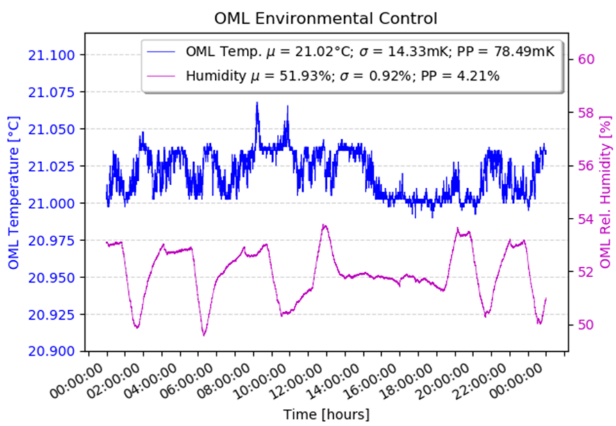

Figure 2: OML temperature and humidity variation during a day. A peak-to-peak value of 78.49mK is achieved.

Even with the OML temperature stabilized, there were some locations more influenced by the air flow fluctuations, specially near the air diffusers. One problem faced during the room commissioning was that the Long Trace Profiler (LTP) [6,7] was installed right below one of the air diffusers, consequently its capacitive sensors being affected. Aiming to circumvent that situation, an enclosure was installed around the LTP bench, providing a passive thermal insulation to the area and physically blocking the air flow. That configuration eliminated forced air flow and reduced the temperature variation on the LTP test area by a factor of 2, considering peak-to-peak (PP) values, enabling high precision optical metrology to be conducted. Figure 3 show a comparison between the temperature variation in and out the LTP enclosure.

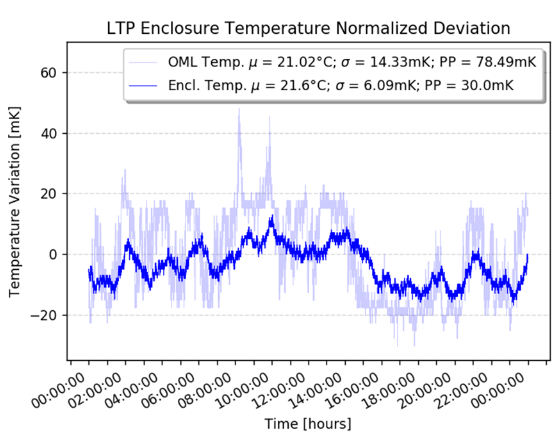

Figure 3: Normalized Temperature Variation at the OML room and inside the LTP enclosure.

Although the other rooms had more relaxed requirements, equivalent results were achieved regarding temperature and humidity control.

VIBRATION ASSESSMENT

Besides the environmental control, another aspect that could influence on the metrology results is the vibration transmission throughout the floor. Although the laboratories were built on isolated foundations, the building is near the LNLS Machine Shop and may also suffer influence from the HVAC system machinery.

About Inertial Bases/Floors

In 2013, the LNLS Mechanical Design Group conducted a study to define the Sirius tunnel floor foundation. After analyzing the soil geophysics, two special blocks prototypes were constructed based on the MAXIV and DLS designs. Several vibrational tests were carried out to characterize the blocks and, although both performed well, the MAXIV option offered slightly better results and was chosen as the base-design for the Sirius' tunnel.

To take advantage of these existing foundations, the Metrology Building was constructed around it.

Instrumentation and Methodology

In order to evaluate the influence of each HVAC component, measurements of the machines sequential starting were carried out. Six regions of the building area were analyzed, from the chillers and pumps yard to the metrology laboratories special foundations. As the observed vibration levels were small, the Wilcoxon 731A seismic accelerometer was used (1000V/g sensitivity and 0.05-450Hz frequency range). For each region, the measurement consisted in a 30 minutes acquisition at a rate of 1kHz, starting the machines one by one and giving each one sufficient time to reach permanent regime before starting the next.

Results and Conclusions

From the data collected it was inferred that the greatest contribution on the building overall vibrational level is from the HVAC system water pumps. Even though they are supported by spring-isolated inertial bases, the pumps system excited the larger frequency range as demonstrated in Figure 4. Nevertheless, the vibration levels inside the metrology rooms (special foundations) were attenuated by a factor of 3 when comparing to the shed and machine room (industrial floor). Also, the final integrated RMS displacement at the metrology rooms is at 20nm. The RMS offset data presented in Table 2 is integrated from 1 to 450Hz and the column *Cultural Noise* refer to the vibration level with the HVAC system turned off.

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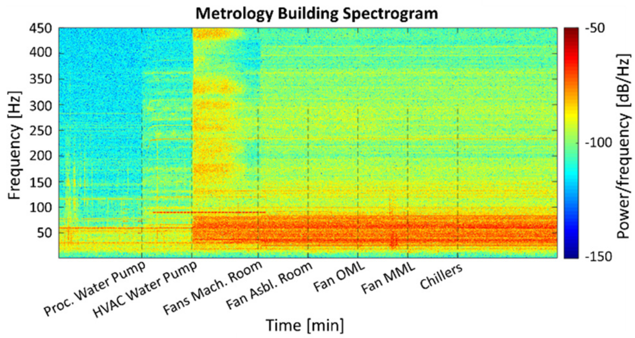

Figure 4: Frequency contribution analysis on HVAC machinery sequential start.

Table 2: Comparison Between Integrated RMS Displacement (1-450 Hz) with HVAC Machinery Turned On and Off

Room	RMS Displacement[nm]	Cultural Noise[nm]
Pump Hall	70	7
Machine Room	50.2	4.5
Building Shed	33.6	2.2
Assembly Rooms	12.7	1.25
Mech. Metrology	11.5	1.1

STATUS

Metrology Equipment

The building is now fully operational and several metrology equipment were installed since its inauguration on the beginning of 2017. The portfolio now includes big stationary equipment such as a high-end Coordinate Measuring Machine (CMM) used to gauge dimensional and geometrical features on parts and assemblies, and fiducialize beamline components; a Spindle Error Analyzer (SEA) with a granite structure and capacitive sensors to characterize rotating stages at the nanometer scale; a LTP with a full granite base and a Fizeau Interferometer to characterize the beamline optics with sub-nanometer resolution; among some other portable equipment such as autocollimators, interferometers, laser trackers and measuring arm.

Tests and Systems Examples

With the Sirius Storage Ring to be delivered until the end of 2018, the LNLS groups dedicated to beamline instrumentation are already testing the first prototypes from a whole bunch of in-house developments. The High Dynamics Double Crystal Monochromator (DCM) is already on final phase of its assembly, with a stability performance never achieved before [8]. The first mirror system prototype was designed, manufactured and tested for mechanical stability [9]. Also, some of the optics were already received and are being assembled on the system prototype to be characterized at the OML. The PIMEGA-135D real time X-ray imaging detector being developed at LNLS [10] had its most critical mechanical parts verified at the CMM. A whole front-end prototype was assembled and commissioned inside the building [11]. In summary, the Metrology Building has become one of the main LNLS infrastructures, and it is already contributing for the development and validation of Sirius' instrumentation [12].

Upgrade to Clean Rooms

Although very stable, the building still lacks space for careful vacuum-compatible assemblies. The Assembly Room #2, where the CMM is installed and where monochromators such as the DCM are assembled, has already been upgraded to a clean room. An absolute filter was installed on its AHU and the room access was restricted to authorized staff with proper clothing.

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REFERENCES

[1] A. R. D. Rodrigues *et al.*, "SIRIUS Status Report", presented at IPAC'18, Vancouver, Canada, May 2018, paper THXGBD4, to be published.

[2] L. Liu, F. H. de Sá, and X. R. Resende, "A New Optics for Sirius," in *Proc. IPAC'2016*, Busan, Korea, May 2016, paper THPMR013, pp. 3413–3416, DOI:10.18429/JACoW-IPAC2016-THPMR012

[3] Wiki-Sirius, https://wiki-sirius.lnls.br

[4] V. V. Yashchuk *et al.*, "Advanced environmental control as a key component in the development of ultrahigh accuracy *ex situ* metrology for x-ray optics", *Optical Engineering*, vol. 54, no. (10), p.104104, Oct. 2015.

[5] H. G. P. de Oliveira *et al.*, "The LNLS Metrology Building", in *Proc. MEDSI'16*, Barcelona, Spain, Sep. 2016, pp. 17-19, doi.org/10.18429/JACoW-MEDSI2016-MOPE08

[6] B. C. Meyer, M. B. Silva, "A New Optics Metrology Laboratory at CNPEM: Metrology Capabilities, Performance, and Future Plans", in Proc. SPIE Vol. 10385, 103850C (2017).

[7] B. Meyer *et al.*, "Commissioning of the LNLS Long Trace Profiler (LTP VI)", presented at IWXM 2018, Hsinchu, Taiwan, June 2018.

[8] R. Geraldes *et al.*, "Offline Results of the New High-Dynamic DCM for Sirius", presented at MEDSI'18, Paris, France, June 2018, paper WEOAMA01, this conference.

[9] R. Geraldes *et al.*, "The Design of Exactly-constrained X-ray Mirror Systems for Sirius", presented at MEDSI'18, Paris, France, June 2018, paper WEOAMA04, this conference.

[10] J. Polli *et al.*, "Medipix Detectors Developments at the Brazilian Synchrotron Light Laboratory LNLS for Sirius", presented at IFDEPS 2018, Annecy, France, March 2018.

[11] L. M. Volpe *et al.*, "High Heat Load Front Ends for Sirius", in *Proc. MEDSI 2016*, Barcelona, Spain, Sep. 2016, paper WEPE06, pp. 324-326, doi:10.18429/JACoW-MEDSI2016-WEPE06

ISBN: 978-3-95450-207-3 doi:10.18429/JACoW-MEDSI2018-TUPH43

[12] L. Sanfelici *et al*., "Solutions for the SIRIUS' Beamlines in a Nutshell", presented at the 13th International Conference on Synchrotron Radiation Instrumentation (SRI2018), Taipei, Taiwan, June 2018, to be published.