

ABOUT THE IMPLEMENTATION OF A METROLOGICAL SYSTEM FOR THE BRAZILIAN SYNCHROTRON LIGHT LABORATORY

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Abstract – LNLS operates the only synchrotron light source in Latin America. There is an on-going project to develop the 4th generation light source Sirius, to be commissioned in 2018. This paper discusses some aspects about the creation of mechanical metrology teams to assist in the development of new components and measurement techniques for the new accelerator. The metrological system comprises the deployment of management policies and the definition and pursuit of a core competency set.

Keywords: ISO 10012, ISO 17025, length, metrological system, metrology, particle accelerators.

1. INTRODUCTION

Brazilian Synchrotron Light Laboratory – LNLS, responsible for the operation of the second generation light source UVX since 1997, is now working in the Sirius Project, fourth generation light source that will allow a new era in scientific investigations of matter. Sirius will be commissioned in 2018.

This project, state-of-the-art in its category, is requiring developments in many areas, including vacuum, materials and mechanical design. Several components of the new accelerator are being designed internally, and metrology is an essential part of the process.

One of the key aspects to the performance of particle accelerators is the alignment between its components [1]. The micrometric alignment tolerances are demanding new techniques to be used. The alignment activities are a synergy between metrology and geomatics. In addition, the beam lines (experimental stations, where synchrotron radiation is used to research) instrumentation need to be assembled with a high level of precision.

Based on those needs, it was envisaged that teams dedicated to metrology should be formed at LNLS, which is divided in three divisions. The Accelerators Division works with the specification of new machines and electronics for accelerating structures (radio frequency cavities), timing and beam diagnosis. Because of the nature of their job this division does not have mechanical metrology needs. The other two divisions have mechanical metrology needs with particular focus. In the Engineering Division, the nucleus of metrology is part of the Mechanical Design Group. For the Scientific Division the metrology is part of the Beam Lines

Instrumentation Support Group. Because of the nature of the activities, the focus is on dimensional and optical metrology. Other quantities are also measured, such as Force or Torque, but Length is more relevant in the day-to-day developments. The Mechanical Design team performs Coordinate and Large Volume measurements, while the Beam Lines Instrumentation Support team metrology is dedicated to Nano and Optical metrology.

This paper deals both with technical background for the formation of metrology teams and with organizational aspects that are necessary to allow a functional and efficient workflow. Many authors have studied the concept of a body of knowledge in the area of metrology [2-3].

Reports on the implementation of a management system for metrology or research institutions are not quite new [4-5]. However, many challenges are peculiar to different institutions and this paper will explore how technical requirements converged to the nucleation of formal teams dedicated to metrology.

The theoretical and philosophical aspects of metrology are dealt with in many scientific articles [6-12] and the subject of education and training in metrology disciplines is present in many of them.

This article is divided in two descriptive sections; we will explore aspects about training and competencies needed for metrologists in section 2. In section 3 we discuss some aspects about the implementation of the metrology teams and give an overview of the management system created.

2. METROLOGY CORE COMPETENCIES

The implementation of a metrology team faces some difficulties regarding human resources, due to the multidisciplinary characteristics of the field and the required high degree of specialization of the professionals.

At LNLS the metrology team started the activities with only a few members, mainly one coordinator for each division. One year after the beginning of the teams, some human resources were hired and the task force is now composed of two engineers, two technicians and four interns. Their education encompasses areas like Mechatronics, Mechanics, Quality Control and Physics.

Typical instruments that the Mechanical Design Metrology operates for inspecting parts and measure large volumes are portable coordinate measuring machines –

pCMM, Coordinate Measuring Machines – CMM, Laser Trackers, Optical Levels and Theodolites. The Beam Lines Instrumentation Support Metrology normally use instruments like Laser Interferometers and Autocollimators to characterize moving stages and high-precision instrumentation.

Frota and Finkelstein [2] studied extensively the requirements for education in measurement and instrumentation. They explore the limitations on educational tools. Here we identify the assembly of disciplines related to the daily work performed in the laboratory. Some basic background on statistics, geometry, physics and technical drawing is necessary. Those are premises that we consider for metrology staff. Nevertheless, a whole assembly of knowledge disciplines is fundamental to the area, as follows:

- Manufacturing processes;
- Signal processing;
- Transducers;
- Automation;
- Optics;
- Surveying;
- Geometrical and dimensioning tolerances – GD&T;
- Design and analysis of experiments – DAE.

The list may continue, depending on specific needs. One of the first steps for initiating the teams was to list the above disciplines. Normally just a few of them are simultaneously present in undergraduate and/or graduate programs. In fact, analysing Brazilian universities graduate programs we could only find one program on Mechanical Engineering that has a focus on metrology, with many if not all the disciplines being part of the regular curriculum [13].

The core competencies for metrology include also knowledge on uncertainty estimation [14].

Training in metrology is a recurrent theme in literature, and several studies tend to approach graphical and virtual methodologies [15-19]. An effort is being made at this beginning of implementation to capacitate human resources. Graduate classes and “in company” training are efficient methods for gaining knowledge, but also on-the-job training and study are important. Another relevant point is the internal dissemination of information.

Specific guides published by the International Bureau of Weights and Measures like the International Vocabulary of Metrology – VIM and the Guide to the Expression of Uncertainty in Measurements – GUM are of great importance in the field of metrology and generally serve as a basis for introducing the metrological culture for non-metrologists and people who are initiating in the area [20]. The concept of traceability is also fundamental for those working with metrology [21].

A digital library has been created, with a compilation of the aforementioned guides and standards. The goal is to have a centralized compilation of documents to assist the staff both with the basis of metrology and with a benchmarking of techniques already in use by metrology groups working with particle accelerators around the world. In addition to those guides, a literature review was performed. A comprehensive collection of articles is now available in themes like particle accelerators alignment, sensors, and instruments calibration.

GD&T is a very important subject within the metrology body of knowledge; as the metrology at LNLS is highly

tighten to mechanical developments, it is crucial that the same language is being used from the design to the inspection, including the machine shop. Modern GD&T has two approaches, the American Society of Mechanical Engineers – ASME standard and the International Organization for Standardization – ISO collection. The ASME Y14.5 is based on the envelope principle, whereas the ISO GPS departs from the opposite direction, using the independence rule as the main idea. The last revision of ASME Y14.5 is from 2009 and all the aspects of GD&T is condensed on a single standard. The Geometrical Product Specification – GPS standards are a set of several standards, and each one of them being reviewed independently each five years.

The team adopted the use and dissemination of the latter. Using ISO, for its international nature, is advantageous for industrial partners’ cooperation. Also in the GD&T theme, the metrology team of the Engineering Division adopted the use of dedicated software to treat the data acquired through the CMM software. The use of standard compliant software has many advantages in terms of metrological reliability and also by mitigating CMM overload. This is possible because much of the time of use of the CMM is spent for result analysis and report preparation.

3. MANAGEMENT SYSTEM

The ISO 17025 is normally adopted for the accreditation audit for metrology laboratories [22-23]. The Brazilian National Metrology Institute – NMI, INMETRO, created an organism (Cgcre) to be responsible for the accreditation of laboratories belonging to the Brazilian Calibration Network (RBC). The audits focus on both technical and management requirements of the standard.

There are no plans to request an accreditation for the metrology laboratories at LNLS. However, ISO 17025 can always be used in the development of a management system. In addition, ISO 10012 provides a complete set of requirements that is focused on measurement processes. The two standards constitute the foundation of LNLS metrological quality system.

For the functioning of a metrology system it is essential to build a document, called quality manual, which explains the implementation of metrology at the organization, and establishes quality policies [24-25]. Also, this document lists a responsibility matrix, where the role of each person is detailed.

For the organization of the metrology, a complete set of procedures, forms, databases and registries was created. This documentation includes reports, instruments and software management. Among the operational procedures we can cite as more important:

- Identification of registries, Folders structure and data storage;
- Good practices in measurements, cleaning and identification of measured parts;
- Organization, cleaning and environmental monitoring of the laboratories;

For the technical procedures a description of how to use each instrument was developed.

Intercomparison studies between laboratories is important to quality assurance [26]. Different quality tools

can be used successfully in measurement system analysis [27]. With the maturation of the metrological system we intend to form patternships with metrology laboratories in order to establish interlaboratorial comparisons.

We started to use an online platform to manage service requests from the technical groups of LNLS. With this system it is possible to communicate with the client, attach files and generate statistical reports. A complete dataflow was proposed in order to perform a metrology service. Among other steps, the operator must perform a critical analysis of the request to be able to implement the best measurement strategy.

4. CONCLUSIONS

Despite the metrology teams being created recently, we notice that using a systematic approach to its implementation the teams' activities are evolving in a good pace. Many developments are already being made in the last few months using the metrology team assets. In the context of Sirius, some successful examples can be cited: dimensional analysis of booster magnets (correctors, quadrupoles and sextupoles), machining tests for the storage ring magnets, prototype inspection of vacuum chambers, ceramic tubes for magnets characterization (rotating coil system) and beam position monitors. Besides, many moving stages present in beam lines and vibrating wire bench were characterized in house using laser interferometry.

For the alignment tasks, notably optical techniques to inspect and fiducialize (relate the hidden magnetic axis of a magnet to an external coordinate system constructed from the magnet geometry) magnets are being developed in cooperation between the divisions.

We conclude that the combination of the adoption of a quality system with the search for the use of right tools and knowledge base are fundamental for the success of metrological implementation. The support from the organization where the metrology is placed is a decisive factor in the pursuit of a functional, effective and reliable measurement system.

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