Brazilian Journal of Analytical Chemistry
2022, Volume 9, Issue 35, pp 87-92

FEATURE

SIRIUS – The Brazilian Particle Accelerator

Sirius is a 68,000 m^2 particle accelerator inaugurated in 2018 at the Brazilian Synchrotron Light Laboratory (LNLS), in the city of Campinas, SP, Brazil. The name is a reference to Sirius, the brightest star in the night sky. Budgeted at R$ 1.8 billion (about US$ 350 million), Sirius is the largest and most complex scientific infrastructure ever built in Brazil and one of the most advanced synchrotron light sources in the world. It was designed and developed by researchers and engineers from the Brazilian Center for Research in Energy and Materials (CNPEM), a private and non-profit organization, under the supervision of the Brazilian Ministry of Science, Technology, and Innovations (MCTI) – in partnership with Brazilian industry. It is financed with resources from the MCTI.

Brazilian Synchrotron Light Laboratory (LNLS). (Photo: Divulgação/CNPEM)

ACCELERATORS

The great scientific equipment Sirius has at its core state-of-the-art particle accelerators capable of producing and controlling the movement of electrons at speeds close to the speed of light, which generate synchrotron light, a special type of light capable of revealing the microscopic structure of organic and inorganic materials.

A synchrotron light source is composed of two main sets of particle accelerators: an Injector System and a Storage Ring. The conditioning of the electron beam in the accelerators requires an ultra-high vacuum chamber that delimits the region traversed by the electrons, radiofrequency cavities used to replace the energy lost by the electrons in the form of radiation, and a set of auxiliary systems that allow the particle accelerator to function as a whole.

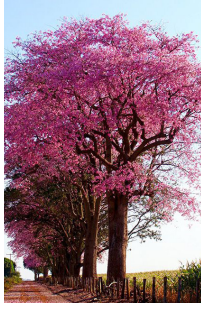
Sirius – the Brazilian Synchrotron Light Source. (Photo: Divulgação/CNPEM)

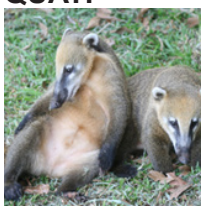
BEAMLINES

The beamlines are the experimental stations where the materials are analyzed. They are like complex microscopes that focus the synchrotron radiation so that it illuminates the samples being studied and allowing the observation of their microscopic properties. The Sirius beamlines, named after Brazilian fauna and flora, are designed to house advanced scientific instrumentation, suitable for solving Brazilian development's strategic areas. The light source can house up to 38 beamlines (from bending magnets and insertion devices), six of which are between 100 and 150 meters long, extending outside the main building experimental hall. Initially, a set of 14 beamlines is planned to cover a wide variety of scientific programs. The first six beamlines are in the installation and commissioning stage and are part of a first delivery package. A second beamline package will deliver another eight beamlines, with construction expected by 2022.

Technical Information Regarding the Beamlines

BEAMLINES Photo of what originated the BL name	**Main Technique / Description / Application**
CARNAÚBA 	**X-Ray Nanoscopy** CARNAÚBA (Coherent X-rAy NAnoprobe BeAmline) is the longest beamline of the Sirius with approximately 145 meters between the light source and the sample environment, which allows a high optical demagnification and to reach nanometric spatial resolutions.
CATERETÊ 	**Coherent and Time-resolved X-ray Scattering** The CATERETÊ (Coherent And TimE REsolved ScatTEring) beamline will provide unique capabilities in biological and soft materials imaging and dynamics experiments with particular focus on the application of coherent X-ray scattering and diffraction techniques.
CEDRO 	**Circular Dichroism** CeDRO (Circular DichROism Beamline) will be a beamline dedicated to Circular Dichroism (CD) spectroscopy in the ultraviolet region. This spectroscopy is applied to the structural analysis of chiral molecules, including biomolecules such as proteins, nucleic acids, and carbohydrates.
EMA 	**X-ray Spectroscopy and Diffraction in Extreme Condition** The EMA (Extreme condition Methods of Analysis) beamline is planned to make a difference where a high brilliance (high flux of up to 1×10^{14} photons/sec with beamsize down to 0.1×0.1 μm^2) is essential, as is the case with the study of materials under extreme thermodynamic (pressure, temperature and magnetic field) conditions.
IMBUIA 	**Infrared Micro and Nanospectroscopy** IMBUIA (Infrared Multiscale Beamline for Ultra-resolved Imaging Applications) is a beamline dedicated to experiments in micro and nano-infrared spectroscopy in the medium IR range. These experiments allow for compositional analysis of virtually any material and are essential for the research in new materials, with emphasis on biological and synthetic materials.

BEAMLINES Photo of what originated the BL name	**Main Technique / Description / Application**
IPÊ 	**Resonant Inelastic X-ray scattering and Photoelectron spectroscopy** IPÊ (Inelastic scattering and PhotoElectron spectroscopy) is a beamline optimized for high resolution Resonant Inelastic X-Ray Scattering (RIXS) and X-ray Photoelectron Spectroscopy (XPS) applied to the study of the chemical composition, electronic structure and elementary excitations of solids, liquids and gases.
JATOBÁ 	**Full X-ray Scattering and PDF Analysis** The JATOBÁ beamline is being built to produce a high-energy, high-photon flux beam focused on micrometric dimensions and will be dedicated to the study of a wide range of materials using the full X-ray scattering technique.
MANACÁ 	**Macromolecular Micro and Nanocrystallography** MANACÁ (MAcromolecular Micro and NAno CrystAllography) will be the first macromolecular crystallography beamline of Sirius and will be optimized for micrometric and sub-micrometric focus. The project includes two experimental stations, also including beams with dimensions of 0.5×0.5 micrometers (nano station) and 10×7 to 100×80 micrometers (micro station), dedicated to the study of three-dimensional structures of macromolecules, particularly complex arrangements such as viruses, membrane proteins and protein complexes and ligands.
MOGNO 	**X-ray Micro- and Nanotomography** The MOGNO beamline will be dedicated to obtaining three-dimensional images of different materials, in multiscale, in a fast, non-invasive way.
PAINEIRA 	**Powder X-ray Diffraction** The PAINEIRA will be a beamline optimized for the X-ray diffraction of polycrystalline materials in Debye-Scherrer geometry. It is aimed primarily at the structural characterization of materials in the powder form, such as ceramics, pharmaceuticals, minerals, catalysts, amongst others. The beamline will operate in high-throughput mode to rapidly characterize numerous samples. In addition, it will offer reaction cells and accessories for conducting experiments under in situ conditions as well as perform studies on functional materials and devices for energy storage and catalysis, for example.

BEAMLINES Photo of what originated the BL name	**Main Technique / Description / Application**
QUATI 	**X-ray Spectroscopy with Temporal Resolution** The QUATI (Quick X-Ray Absorption Spectroscopy for Time and space resolved experiments) beamline will be dedicated to high-quality X-ray absorption spectroscopy experiments, with temporal and spatial resolution on a millisecond scale and in situ conditions.
SABIÁ 	**Soft X-ray Absorption Spectroscopy and Imaging** The SABIÁ (Soft x-ray ABsorption spectroscopy and ImAging) beamline operates in the soft X-rays region using undulators to provide polarization control and plane gratings for monochromatization. The main techniques available are X-rays absorption spectroscopy (XAS) and photoemission electron microscopy (PEEM).
SAPÊ 	**Angle-Resolved PhotoEmission Spectroscopy** SAPÊ (Angle-resolved PhotoEmission) is a beamline dedicated to angle-resolved photoemission spectroscopy (ARPES) experiments, with high energy and momentum resolution, in the vacuum ultraviolet (VUV) spectrum range. Such experiments allow the analysis of the electronic structure of crystalline materials and are an essential tool for the study of the frontier of new materials, with special emphasis on topological materials and 2D materials.
SAPUCAIA 	**Small Angle X-ray Scattering** SAPUCAIA is a beamline dedicated to small-angle X-ray scattering for solid, liquid and gel-like samples. This technique allows to comprehend fundamental biological mechanisms through the determination of complex structures of proteins without the need for their crystallization. Moreover, this technique also is capable to give information of many different nanometric structures and agglomerates.

Although the project is well advanced, there is still a lot of work to be done, as highlighted by Harry Westfahl Jr., Director of the Brazilian Synchrotron Light Laboratory (LNLS/CNPEM). The next beamlines to be opened to researchers will support frontier scientific research with the potential to benefit areas such as agriculture, the environment, energy and new materials, as well as health.

About CNPEM

The Brazilian Center for Research in Energy and Materials (CNPEM) houses four laboratories mentioned below, which are considered world references and are open to the scientific and business community:

- The Brazilian Synchrotron Light Laboratory (LNLS) is a state-of-the-art lab responsible for operating Sirius. This lab houses multi-user facilities open to the Brazilian and international scientific community

and allows the investigation of the composition and structure of matter in its most varied forms, opening new perspectives for research in areas such as materials science, nanotechnology, biotechnology, environmental sciences, and many others.

- The Brazilian Biosciences National Laboratory (LNBio) is dedicated to cutting-edge research and innovation focused on biotechnology and drugs development.
- The Brazilian Biorenewables National Laboratory (LNBR) employs biotechnology to address scientific and technological challenges of sustainable economic development. It aims to accelerate the transition from an industrial production based on fossil resources to a bio-based and renewable industry, which promotes Brazil's technological independence and reduces environmental impacts.
- The Brazilian Nanotechnology National Laboratory (LNNano) conducts research with advanced materials, with great economic potential for the country

In addition, the four laboratories mentioned have their own research projects and participate in the transverse research agenda coordinated by CNPEM, which articulates scientific facilities and competences around strategic themes.

Aerial view of the Brazilian Center for Research in Energy and Materials. (Photo: Divulgação/CNPEM)

Source: With information from the Brazilian Synchrotron Light Laboratory (LNLS) and the Brazilian Center for Research in Energy and Materials (CNPEM).