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Sirius Project and Synchrotron Light

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ABSTRACT

Synchrotron Light or Radiation, is a type of electromagnetic radiation that spans a wide range of the electromagnetic spectrum – from ultraviolet radiation, to infrared light and x-rays. Synchrotron light is produced when charged particles, accelerated to speeds approaching the speed of light, have their trajectory deflected by magnetic fields. The Synchrotron Light Source is a large machine, capable of controlling the movement of these charged particles, typically electrons, to produce Synchrotron Light.

The light we see – produced by the sun, by lamps or flames, reflected by objects, captured by our eyes and finally used by our brains to shape and color the world – corresponds only to a tiny fraction of the so-called electromagnetic waves.

However, there are many electromagnetic waves, many types of light that we cannot see, but are produced in the most diverse natural and artificial phenomena. The study of these invisible waves leads not only to the understanding of the phenomena in which they are produced, but also to the development of technologies that use them, for example, to transmit and receive information.

Keywords
Physics, Sirius Project, Synchrotron light, Energy.

Introduction

Sirius (Figure 1), is the new Brazilian Synchrotron Light Source, will be the largest and most complex scientific infrastructure ever built in the country and one of the first 4th-generation Synchrotron Light Sources in the World. It is planned to put Brazil in a leading position in the production of Synchrotron Light and is designed to be the brightest of all the equipment in its energy class.

Synchrotron Light Sources are the best example of an open and multidisciplinary research infrastructure and is a key tool for the resolution of issues important to the Brazilian academic and industrial communities. The versatility of a Synchrotron Light Source enables the development of research in strategic areas such as food, energy, environment, health, defence and many others.

That is why this technology becomes increasingly popular around the world. It is also the reason why countries with strong, technology-based economies already either have one or more Synchrotron Light Sources, or are building them.

The first stage of the Sirius Project, the new synchrotron light source in Brazil, has just been inaugurated. Electrons were accelerated for the first time in the largest and most complex scientific facility ever built in the country, at the National Center for Research in Energy and Materials (CNPEM) in Campinas. The ceremony was attended by illustrious physicists who contributed to the creation and consolidation of the project, such as Antonio José Roque da Silva, general director of the Sirius Project and the CNPEM, as well as an alternate member of the board of SBF, and Rogério Cézar de Cerqueira Leite, the honorary chairman of the CNPEM board.

When finished, Sirius will be one of the best and most powerful sources of synchrotron light in the world. A synchrotron light source consists of a ring within which electrons circulate accelerated to almost the speed of light, causing these particles to emit a strong electromagnetic radiation. Researchers from a wide range of areas will be able to use Sirius-generated radiation to obtain images of biological materials, viruses and proteins, as well as the crystalline and molecular structure of soil samples, minerals and new laboratory-created materials.

The first stage of the project concluded the civil works and the delivery of the building that houses the entire research infrastructure, besides the conclusion of the assembly of two of the three electron accelerators. The delivery of the next phase of the project, scheduled for the second half of 2019, includes the start of the Sirius operation and the opening of the first six research stations for the Brazilian and international scientific community.

"The inauguration of the first phase of the Sirius project, which is the country's new source of synchrotron light, represents a fantastic achievement for Brazilian science and technology," said Marcos Pimenta, SBF president, who represented the company at the inauguration. "We will have in Brazil one of the most advanced laboratories in the world for the study and characterization of new materials and biological systems. In addition, since most of the equipment was made in Brazil, the Sirius project will also have an impact on the domestic industry, especially with regard to high technology instrumentation".

Figure 1: Sirius Laboratory.

The Brazilian Synchrotron Light Laboratory (LNLS) is responsible for the operation of the only synchrotron light source in Latin America.

With open facilities, LNLS receives academic and industrial researchers from several countries. Its idealization as National Laboratory represents a mark in the institutional design of scientific research in Brazil, which enabled the construction and the implementation of an open use research facility.

Brazil has access to an extremely sophisticated infrastructure, which can be used simultaneously by many research groups. Among its advantages is the efficiency in the use of its facilities since the laboratory operates all the time.

Furthermore, LNLS has its own team of qualified professionals, capable of providing technical support, in order for researchers from every area to have the access to this tool on their investigations, even having no previous knowledge in the use of synchrotron light sources. Its mode of operation also allows the maintenance of an inter- and multidisciplinary environment, which enriches the learning of young researchers.
With a challenging engineering project, the Laboratory was designed to attract researchers and engineers, whose capability provided the development of important technological fields for the country. The Laboratory also developed locally the knowledge about accelerator and beamline construction, with the production of components and equipment made in Brazil as much as possible. This strategy reduced the cost of the construction of its first synchrotron light source, and allowed the mastery of knowledge related to the maintenance and improvement of the machine and of the scientific instrumentation related to it.

As a result, Brazil was the first country in Southern Hemisphere to gather the technical competence to develop and operate a great scientific equipment such as the synchrotron light source.

The LNLS is currently building Sirius, a fourth-generation synchrotron light source, planned to be one of the most advanced in the world. Sirius will be the biggest and the most complex scientific infrastructure ever built in the Country, planned to put Brazil at a worldwide leadership position in synchrotron light generation.

The new synchrotron light source is designed to be the brightest among all the equipment in its energy class and to receive up to 40 beamlines. Sirius will open new research perspectives in many areas such as material science, nanotechnology (Figure 2), biotechnology and environmental sciences.

Figure 2: Development of a nanoparticle-based technology that will be used in chemotherapy.

Applications

Life science

Pharmaceutical companies and medical researchers are making increasing use of macromolecular crystallography. Improvements in the speed of data collection and solving structures mean that it is now possible to obtain structural information on a timescale that allows chemists and structural biologists to work together in the development of promising compounds into drug candidates. Both the anti-flu drug Tamiflu and Herceptin – used to treat advanced breast cancer – benefited from synchrotron experiments. Using synchrotron light in the infrared range, pioneering research is underway into developing new cancer therapies that can be tailored to the individual patient.In 2009, the Medical Research Council used the Diamond Light Source to compare the structure of hemagglutinin from the flu-virus strain that caused the 1957 "Asian" pandemic with the 1918 and 1968 outbreaks, to discover why some avian flu viruses are more able than others to jump the species gap.

Engineering

Synchrotron X-ray beams allow detailed analysis and modelling of strain, cracks and corrosion as well as in situ study of materials during production processing. This research is vital to the development of high-performance materials and their use in innovative products and structures. The Diamond Light Source have been used to study the processes behind pitting corrosion, which attacks the so-called corrosion-resistant metals used in containers for nuclear waste, and to understand how applied stresses can cause cracks to propagate through materials.

Environmental science

Synchrotron-based techniques have made a major impact in the field of environmental science in the last 10 years. High brightness allows high-resolution study of ultra-dilute substances, the identification of species and the ability to track pollutants as they move through the environment. Synchrotrons have been used to develop more efficient techniques for hydrogen storage and to study the way in which depleted uranium disperses into the local environment. Tiny heavy-metal samples excreted from earthworms have been compared with contaminated soil samples, revealing how earthworms survive in these environments and introducing the idea that earthworms could help to decontaminate land.

Physics and materials science

Determining the properties and morphology of buried layers and interfaces is an important area in solid-state science with synchrotrons being the meeting ground of state-of-the-art theory and high-precision experimental results. Many of the technological products of materials science are based on thin-film devices, which consist of a series of such layers. Structural studies of in situ processing of semiconducting polymer films are also likely to be an important area of growth in the coming decade. Diffraction of high-intensity X-ray beams is an ideal technique to study spin, charge and orbital ordering in single-crystal samples to understand high-temperature superconductivity. The SRS was used to help study giant magneto-resistance (GMR), which is now used in billions of electronic devices worldwide.

Cultural heritage

is a rapidly expanding area of research using synchrotrons. Scientists are using non-destructive synchrotron techniques to find answers to big questions in palaeontology, archaeology, art history and forensics. Scientists in the UK have used the SRS and the Diamond Light Source to study samples from the Tudor warship the Mary Rose to enhance their conservation techniques, and the ESRF has been used to study insects more than 100 million years old, preserved in amber.

Agriculture

In agriculture, Synchrotron Radiation may be used for soil analysis and for the development of more efficient and cheaper. Synchrotron Light Sources have application also in the mapping of the concentration, location and bioavailability of nutrients in plant species.

Synchrotron Impact

Seven Nobel Prizes are X-rays related works; one of them is the German Max von Laue's research the "Diffraction of X-rays by crystals". The facilities of Synchrotron is already proved and keep bringing good results in many areas. This particle allow very accurate analysis, presently many projects are running, one example is the group of investigators in Campinas (city of the Sirius project) that are developing one technology that can make the medicines of chemotherapic target specifically the cancer cells.

The SRS affected UK industry in several ways, the first being usage of the facility by industry investigate the properties of materials including structures of pharmaceuticals and their protein targets. Over its lifetime, the SRS had approximately 200 proprietary customers including government departments, industry, hospitals, museums, universities and other Synchrotron Radiation sources. The industry sectors that benefited the most from the use of the facility are pharmaceutical, chemical and healthcare industries.

Skills, technology and knowledge gained on the SRS have helped in the creation of new companies and one commercial service provider. These new companies are in a range of areas that include scientific instrumentation, detectors, cholesterol monitoring, software, cryogenics, mechanical instrumentation and drug discovery. These companies are creating impact through the stimulation of the UK's economy and the impact to people's daily lives that these activities will produce.

There was increased economic activity in the North West through the creation of jobs and the construction and operation of the facility between 1975 and 2008. This represented a direct financial impact of £600 million, the majority of which was spent in the locality of the SRS. Due to multiplier effects, this initial investment increased to create an estimated total financial impact of nearly £1 billion to the North West. The SRS also acted as a purchaser of goods and services in the local area and wider UK. Throughout its lifetime, the SRS has traded with over 300 local businesses. This purchase of goods or services from suppliers leads to a further chain reaction of purchases from their supply chain and also has indirect effects on employment, spend and taxation.

A 2.5 GeV light source has been in operation since 1994. Twenty seven beam lines, including six from insertion devices, are in operation, serving 1500-2000 users each year. About 500 papers are published each year based on work at the light source. Ten scientists returned to Korea to join the laboratory. Four became directors. Thirty professors who returned to the Pohang University of Science and Technology (Postech) are now users of the light source. Many others returned to become faculty at other Korean

Universities and are now as users at PLS. At least 40 PhDs have already been completed at Postech using the light source. About 100 PhDs have been completed at other universities in Korea using the light source. Many parts of PLS have been built in Korea (magnets, power supplies, vacuum chambers, ion pumps, klystrons, modulators, beam position monitors, etc.). The 2.5 GeV linac injector was designed and constructed in collaboration with China, although China & Korea did not have diplomatic relations until 2 years after this collaboration started. Collaborations with other countries included France, Italy, Japan, the UK, and the US. Several new companies were formed as a direct result of the light source project. These include Geumryong (magnets), VMT (ion pumps), a controls company, and an alignment company. Samsung & LG studied defects in LSI chips & LCDs for cellular phones.

The impacts expand itself to the arts and with the technology available at the Australian Synchrotron, we believed there was a good chance we could reveal the hidden portrait by subjecting small areas to radiation for only a fraction of a second. Edgar Degas's painting Portrait of a woman is an enigmatic piece. When it was first acquired by the National Gallery of Victoria in 1937, it was unveiled to mixed reviews. Some commented that it showed the hallmarks of the French painter's style around the 1870s. Others criticized its brown hues and the apparent discoloration across the woman's face. And, importantly, we could do this without damaging the artwork. After several months of planning, the painting arrived from the NGV early in the morning and we secured it in a custom mount, with the detector only 2mm above the painting's surface. We set up the coordinates of the area to scan so we could capture as much of the hidden portrait as possible. After some fine-tuning of the X-ray beam, we launched a scan that would take approximately 33 hours to complete, giving individual images in excess of 31 megapixels, which is beyond the resolution of most of today's best digital cameras.

IPANEMA, a research platform devoted to ancient and historical materials (archaeology, cultural heritage, palaeontology and past environments), is currently being set up at the synchrotron facility SOLEIL (Saint-Aubin, France; SOLEIL opened to users in January 2008). The new platform is open to French, European and international users. The activities of the platform are centred on two main fields: increased support to synchrotron projects on ancient materials and methodological research. The IPANEMA team currently occupies temporary premises at SOLEIL, but the platform comprises construction of a new building that will comply with conservation and environmental standards and of a hard X-ray imaging beamline today in its conceptual design phase, named PUMA. Since 2008, the team has supported synchrotron works at SOLEIL and at European synchrotron facilities on a range of topics including pigment degradation in paintings, composition of musical instrument varnishes, and provenancing of medieval archaeological ferrous artefacts. Once the platform is fully operational, user support will primarily take place within medium-term research projects for `hosted' scientists, PhDs and post-docs. IPANEMA methodological research is focused on advanced two-dimensional/three-dimensional imaging and spectroscopy and statistical image analysis, both optimized for ancient materials.

Discussion

The synchrotron light open for all sciences a completely new area of the acquaintance and researches. Based on this can provide an evolution in many knowledges, helping medicine, engineering, agriculture, nanotechnologies, etc. In a large scale, the synchrotron light can be the answer for the current questions and the key to solve problems that is present nowadays. This technology already proved that could be used in more area than we imagine, art, history, gadgets techs, among other things. This article was written to inform the benefits, impacts and one little part of the millions researches of the Synchrotron Light.

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