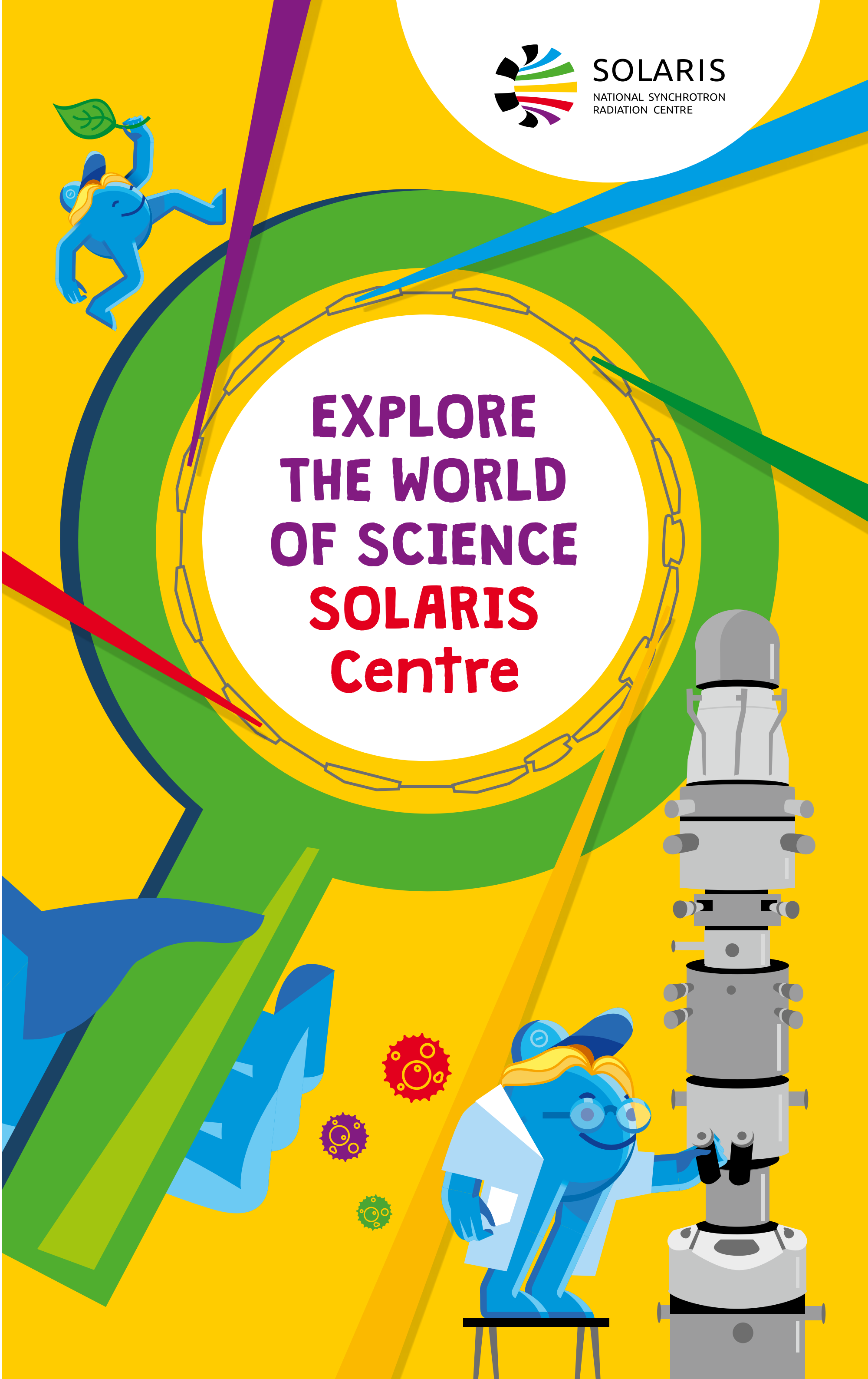
SOLARIS
NATIONAL SYNCHROTRON RADIATION CENTRE

EXPLORE THE WORLD OF SCIENCE SOLARIS Centre



Explore the world of science
SOLARIS Centre

Authors:
Agnieszka Cudek, Kinga Wróbel

Electronic version:
Marcin Czaja

Graphic design and typesetting:
Pracownia Register

Translation from Polish:
Alicja Rawska

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SOLARIS
NATIONAL SYNCHROTRON
RADIATION CENTRE

JAGIELLONIAN
UNIVERSITY
IN KRAKOW

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Welcome

to the fascinating world of science!

It's not only for brainy scientists and super nerds, it's for anyone who's curious about how things work. The superpower of all of us is paying attention to everyday stuff and asking questions that need answers.

Ever heard of particle accelerators? What about synchrotrons or cryo-electron microscopes? In this booklet, we'll dive into how synchrotrons work and why they, along with cryo-electron microscopes, are such big deals in the science world. You'll discover their vital roles in advancing biology, chemistry, physics, medicine, and technology. Plus, we'll show you how their discoveries impact our daily lives. So, get ready to join our lab hero – Elektro – as we unlock the secrets of our SOLARIS Centre!

What is a synchrotron?

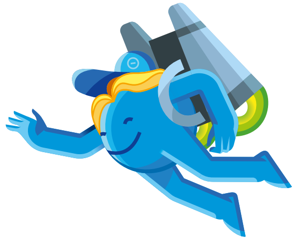
Synchrotrons are special devices that scientists worldwide use to explore our environment at incredibly small scales, down to the level of atoms and molecules.

Synchrotrons are circular accelerators where particles zoom around at astonishing speeds. At SOLARIS Centre, we accelerate electrons, sending them racing in a vacuum around the synchrotron ring, also known as the storage ring. As they whiz around, they pick up more and more energy. Now, here's where the magic happens: when these speedy electrons hit the force field of huge magnets that bend their path, they emit electromagnetic radiation called "synchrotron light."

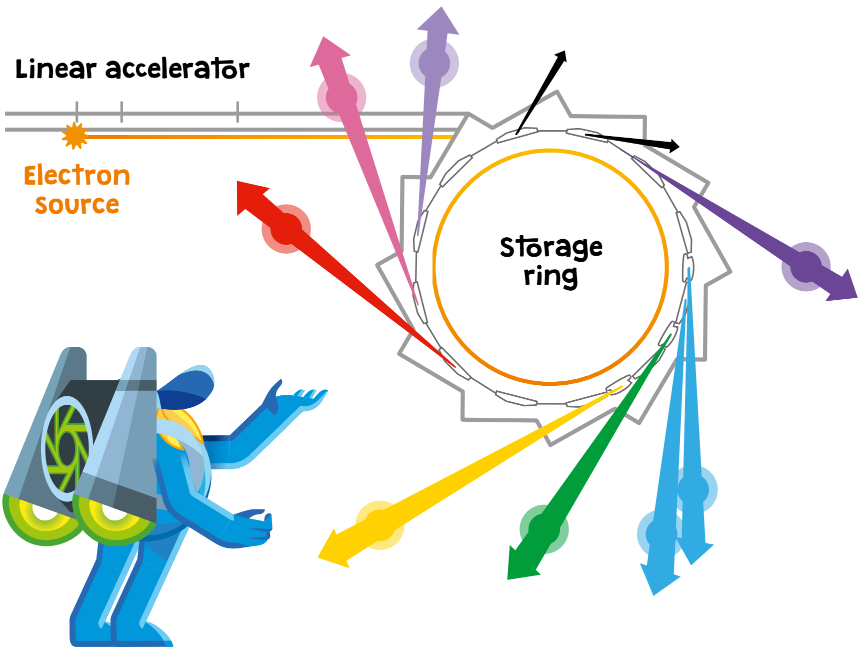
This unique light then travels outside the storage ring to dedicated research lines. There, at measurement stations, scientists direct the synchrotron light at samples. Specially designed detectors capture signals from these samples. After that, it's time for the real brainwork: scientists analyse these signals to unlock secrets about the world around us. Often, they discover new properties and phenomena in the matter that surrounds us.

Now, what is SOLARIS synchrotron? It's the only device that produces light used to conduct research in many natural, technical, and humanistic fields of science that can be found in Poland and Central/Eastern Europe. In total, there are only 13 synchrotrons on our continent, while 30 worldwide. They often operate at universities, our synchrotron is part of the Jagiellonian University in Kraków.

The main elements of a synchrotron – electron travel



There is no factory producing parts for synchrotrons anywhere in the world. Their elements are uniquely designed, which is why each synchrotron is different from others. This unique design is the result of a long-lasting collaboration of physicists, mechanics, designers, and electricians. SOLARIS synchrotron is special in this regard – it has a twin in the Swedish city of Lund. SOLARIS and Swedish MAX-Lab are the result of a joint venture, made accessible to Polish scientists even before the construction work of the Polish synchrotron started in 2010.



I. Electron gun and linear accelerator

The journey of electrons in the synchrotron begins 8 meters below ground level, which is where the electron gun is located. The gun is used to produce particles, which are later accelerated in the system. The gun consists of metal (barium oxide heated to a temperature of 1000°C) from which electrons are knocked out, which are then sent to the linear accelerator. The accelerator is an over 40-meter-long copper pipe covered with magnets, power supplies, and a number of other devices. Inside it, there is a vacuum – very similar to that in space. This vacuum prevents the electrons from colliding with the gas molecules remaining in the pipe, the so-called residual gases, which allows them to accelerate freely. Electrons in a linear accelerator, pushed by electromagnetic wave pulses, are accelerated to a speed of about 99,99% of the speed of light.

II. Storage ring, a circular accelerator

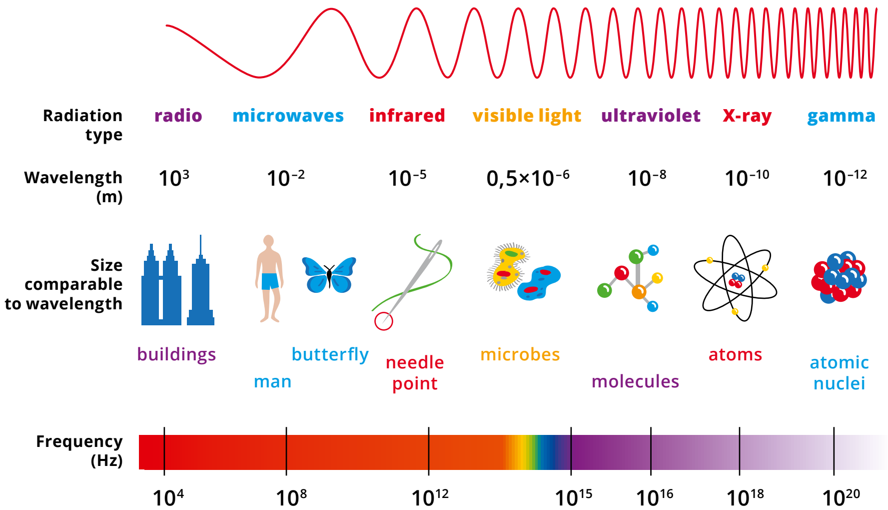
Electrons accelerated in this way travel in packets – similar to railway cars. Each of them contains over a billion electrons. In this form, they are sent through a pipe bent upwards (transfer line) to a circular accelerator located above the earth's surface. Resembling a circle, the storage ring, commonly called a ring, is a metal pipe filled with vacuum. In fact, this "circle" consists of 12 straight parts and as many curved ones. The electron movement path is controlled by a system of huge magnets. Scientists wait for a special

side effect of electrons twisting in a circular accelerator – this is where the electrons emit light, which is directed outside the ring to the research beamlines.

III. Synchrotron light

What is light, anyway? Is it the flash of a flashlight after dark or the glow of the Sun? Physicists say that it is a form of electromagnetic radiation that is visible to the human eye. It consists of photons, which are elementary particles that have no mass but carry energy. Light travels in straight lines and can be reflected, refracted, or even absorbed by various materials. It is essential for vision and plays a crucial role in different fields such as photography, physics, astronomy, and telecommunication.

Synchrotron light is significantly different from the light we see every day. As we already know, particles accelerated in a synchrotron emit synchrotron radiation – light. It is extremely intense, millions of times brighter than that which reaches the Earth from the Sun. It also has a wide range of wavelengths: from X-rays, through visible light, to infrared. The synchrotron light is of very high quality, which is why it can be used for research in many fields of science and technology.

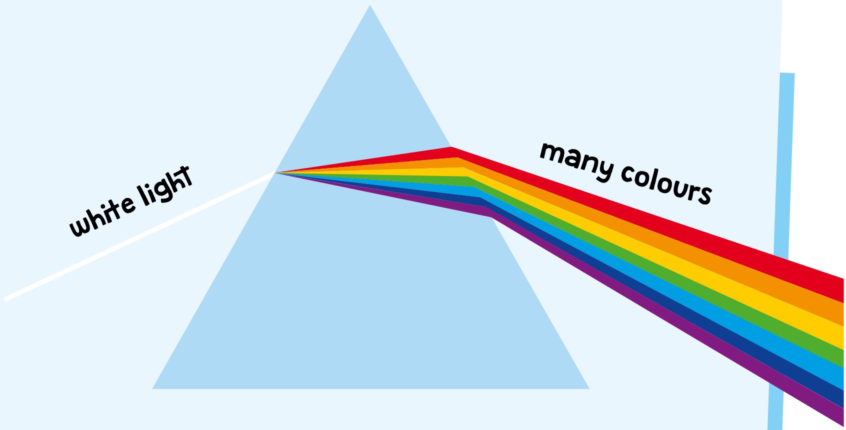


One of the most important features of synchrotron radiation is the high focusing of its beam, which lets scientists study various materials very precisely. That's why scientists around the world use synchrotrons like SOLARIS. Thanks to the provided beam of light, they can conduct experiments that allow them to learn about the properties and phenomena occurring in matter at the smallest levels, at the atomic and molecular scale.

FUN FACT

**Did you know:
white (visible) light consists
of many colours!**

Visible light splitting happens when white light breaks into different colours as it passes through a prism or crystal. Isaac Newton first discovered this, helping scientists understand that light is actually made up of many colours. You can see this cool effect in a rainbow when sunlight hits raindrops, creating those amazing colourful bands in the sky.



IV. Research lines and end stations

Research beamlines are the most vital element of SOLARIS Centre to all experiments and scientists. There are many different end-stations in synchrotrons, each using a particular type of light for specific experiments. For example, some beamlines use light that includes X-rays, while others use infrared or visible light. Scientists from all over the world travel to synchrotrons to conduct experiments that are not possible using other techniques or tools. With the help of synchrotrons, scientists can examine various materials, both on the surface and inside. In this way, they learn how these materials are built, their chemical composition, as well as their electrical and magnetic properties.

Most of the time, research beamlines in SOLARIS synchrotron use X-rays. You might know X-rays from the doctor's office when they check for broken bones. But, synchrotron light is far more intensive and focused. X-rays have a short wavelength, which means that they have high energy and can penetrate materials, making them great for studying the internal structure of samples. X-rays interact with atoms and electrons in the sample, getting dispersed or absorbed in a specific way. By measuring the patterns of scattered or absorbed X-rays, scientists can figure out the structure, composition, and behaviour of the sample.

FUN FACT

Did you know: SOLARIS synchrotron is unique!

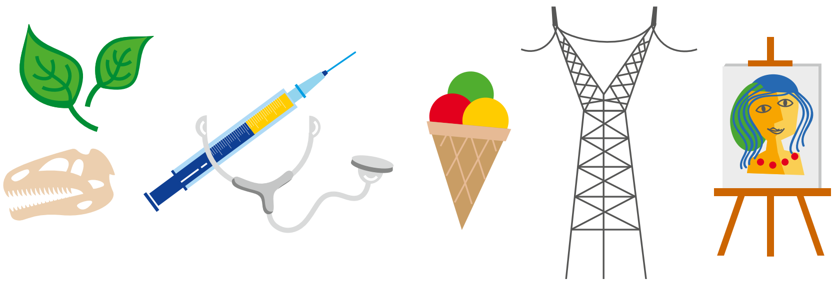
- *The name of the Centre and the individual synchrotron research beamlines refer to fantasy literature. Solaris is the title of one of the most famous novels by Polish science fiction writer Stanisław Lem. By adopting this name, the Centre's authorities paid tribute to the outstanding work of this writer, who has been an honorary citizen of Kraków since 1997.*
- *The circumference of the storage ring in which electrons run is 96 m. After one injection of the beam by the electron gun, the particles can loop around for up to 13 hours. To keep this going, the synchrotron consumes over 19,000 kWh of electricity per day. That's as much power as 2,800 family houses consume in a day!*
- *The energy gets used up to run 9 end-stations and 2 cryo-electron microscopes, all running non-stop 24/7. There are 7 research beamlines connected to the synchrotron – URANOS, PIRX, DEMETER, PHELIX, ASTRA, CIRI, and POLYX (other beamlines are in the construction phase). Ultimately, the Centre will have 20 beamlines and 4 cryo-electron microscopes.*
- *Electrons can freely move only in very high vacuum conditions – comparable to that in space. Such a perfect vacuum is ensured at Solaris by over 200 vacuum pumps installed at all infrastructures inside which electrons move.*

- *The whole accelerator system works smoothly with the help of complex programming and computer equipment. It's all made possible by 75 km of cables distributed across the Centre building and 26 km of optical fibres. To put it in perspective, that's about the distance from Kraków to Zakopane.*
- *Individual synchrotron infrastructure systems emit large amounts of heat when working. To maintain stable temperature, there is an extensive water cooling system. It uses very clean, demineralized water, which is distributed to individual components through pipes with a total length of over 14 km. It is the same distance as from the Centre to the Main Square and back.*
- *A synchrotron is an extremely sensitive structure where vibrations and ground movement can significantly impede research. Local public transport and cars driving on the surrounding roads may cause instability, which is why special solutions are used in the vicinity of the SOLARIS location/building. One of them is a roundabout that replaced a speed bump. Vehicles crossing this bump would produce vibrations that could affect research work. What is more, when a construction of the tram line running nearby was taking place, special foundations were used to dampen vibrations resulting from the trams running on the tracks.*

Why the need for synchrotrons?

Synchrotrons are extremely important tools for researchers working in many scientific fields, because a large number of experiments can only be carried out using synchrotrons. No other device can provide this amount of detailed information in such a short time.

The synchrotron light beam, extremely intense and focused, contains all wavelengths. For this reason, synchrotrons are ideal for experiments at the atomic and molecular levels. The knowledge acquired from experiments at synchrotrons is used in medicine, production of new drugs and vaccines, environmental protection, energy storage, materials science, nanotechnology, food industry, protection of monuments, and many others. Researchers conducting experiments at synchrotrons perform them free of charge, because the common goal of the research is to shape and develop global science.



Scientists, with the help of synchrotrons, make groundbreaking discoveries that change the world in real-time.

Discoveries made using synchrotron light

→ PROTEIN – THE BASIC BUILDING BLOCK OF EVERY ORGANISM

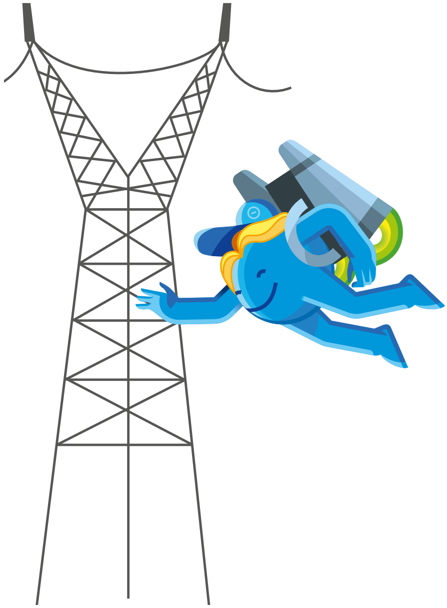
Thanks to the beam of synchrotron light falling on protein crystals, scientists can determine the position of atoms in a protein molecule and thus determine its 3D structure. This information is used to design drugs and vaccines. By analysing the 3D structure of a specific protein after a drug is administered, the researcher knows whether the drug works as intended. Nearly every modern drug you find at the pharmacy has been tested using synchrotrons or cryo-electron microscopy at some point during its development.

→ FIGHTING CANCER

As powerful as they are, synchrotrons are also used in diagnosing and fighting cancer. The experiments carried out make it possible to distinguish healthy tissues from diseased tissues on a cellular scale in a much shorter time than before. The method of infrared microspectroscopy helps pathologists diagnose cancer early without having to wait for another biopsy, reducing risks and side effects for patients.

SUPERCONDUCTIVITY

Synchrotrons are used to study the properties of superconducting materials, which means that materials that conduct electricity with zero resistance. They have many potential applications, for example in transmitting electricity without transfer losses. By studying the electronic structure of superconducting materials using synchrotron radiation, scientists can better understand how they work and how they can be improved.



BIOFUELS

The production of palm oil, used primarily in the production of sweets, generates huge amounts of waste. Thanks to research using synchrotron light, scientists have developed a modern technology for producing biofuels from fruit bunches and palm kernel shells. After analysing sample structures, scientists designed a much more effective catalyst, capable of converting palm oil waste into sustainable biofuels.

→ MONUMENTS AND ART CONSERVATION

Synchrotron radiation is often used to study works of art to obtain information about their history or structure. By shining synchrotron radiation at these objects, scientists can determine the chemical elements present and their distribution. This knowledge helps uncover the details of the artist's techniques and materials used, which then helps in renovation or conservation efforts. It was thanks to synchrotron radiation that it was possible to see a sketch of Vincent van Gogh's self-portrait, which he placed under the surface of one of his works and then painted over it.

ICE CREAM FLAVOUR

The way ice cream tastes and feels depends a lot on the size of its ice crystals. Smaller and rounder crystals usually make it taste better. Research at synchrotrons helped us figure out how ice forms and how different ways of making it affect the taste. It even led to new ice cream recipes that you might enjoy on a hot day!

FOSSILS AND EXCAVATION

Thanks to research done at synchrotrons, it is possible to look deep into fossils without having to damage them. Testing the density of the components of a rock sample gives an image of the bones and remains of organic materials hidden inside. Synchrotron-based X-ray tomography technique has enabled paleontological discoveries of samples dating back 125 million years.

SOLARIS Cryo-electron Microscopy (Cryo-EM)

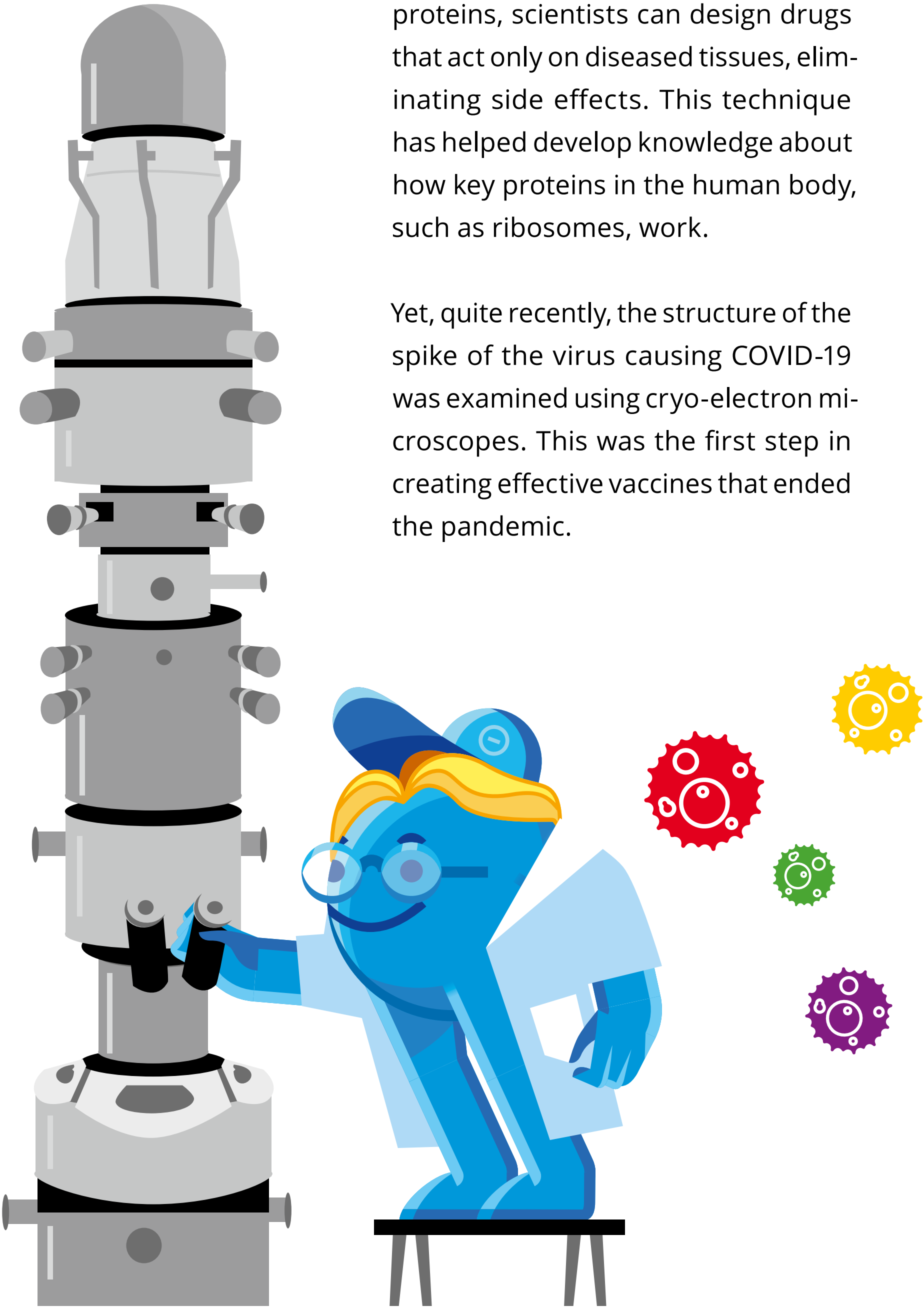
The SOLARIS Centre comprises not only the synchrotron. Research is also carried out under the Centre's roof using two of the latest generation cryo-electron microscopes. As we know, a microscope is a device that helps scientists see things that are too small to be seen with the human eye. The electron microscope is a powerful tool that allows scientists to observe at the atomic level! The electron microscopes at SOLARIS are not connected to the synchrotron, but uniquely compliment the Centre's infrastructure.

Cryo-electron microscopes are used to study tiny biological molecules, such as proteins and viruses, which are not visible even in the best light microscopes. Scientists use these tools to watch how these small molecules move and interact. It's like peeking into a secret world and helps us understand how they function.

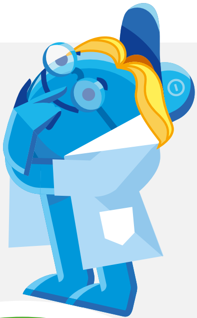
Samples for electron microscopy are frozen in liquid ethane and encased in a thin, amorphous layer of ice, which helps preserve the natural state of proteins and viruses. This quick freezing process allows them to be observed in a state that is very close to that in the natural environment.

Scientists take many photos of particles arranged at different angles to build a 3D model of the molecule. They use a complex computer system that puts together hundreds of thousands, even millions, of these photos to make the 3D image. Cryo-electron microscopes are an irreplaceable tool in the fight against many diseases. Thanks to the ability to analyse the structure of membrane proteins, scientists can design drugs that act only on diseased tissues, eliminating side effects. This technique has helped develop knowledge about how key proteins in the human body, such as ribosomes, work.

Yet, quite recently, the structure of the spike of the virus causing COVID-19 was examined using cryo-electron microscopes. This was the first step in creating effective vaccines that ended the pandemic.



Test yourself with SOLARIS quiz



1 What is a synchrotron?

- **a** Type of microscope.
- **b** Type of accelerator, which accelerates electrons.
- **c** Association for scientists.

2 What is the circumference of SOLARIS synchrotron?

- **a** 14 kilometers.
- **b** 80 meters.
- **c** 96 meters.

3 How intensive is the light produced in a synchrotron??

- **a** As intensive as the light from the Sun reaching Earth.
- **b** Million times greater than the light from the Sun reaching the Earth.
- **c** Synchrotron light is not as bright as the one reaching the Earth.

4 What are the names of SOLARIS research beamlines?

a. PIRX, DEMETER, PHELIX, URANOS, ASTRA, CIRI and POLYX.
b. Beamline 1, Beamline 2, Beamline 3, Beamline 4.
c. Lem, Herbert, Anderson, Clarke.

5 What is used to freeze the samples analysed in cryo-electron microscopes?

a. Liquid ethane.
b. Water.
c. They are not frozen.

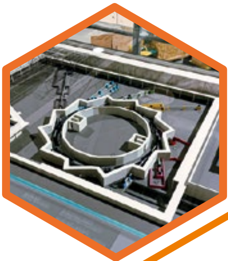
6 How many synchrotrons are located in Central-Eastern Europe?

a. 13
b. 1
c. 4

SOLARIS Visitors Centre

Visit the only synchrotron in Poland!

Book a free tour!



Self-guided tour with audio guide

Exhibits of synchrotron elements and samples

A model of synchrotron and research beamlines

SOLARIS VISITORS CENTRE

Graphic boards complementing audio content

Popular science **booklet**

A walk through accelerators using haptic technology

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JAGIELLONIAN UNIVERSITY IN KRAKOW

SOLARIS NATIONAL SYNCHROTRON RADIATION CENTRE

The project of the Minister of Education and Science entitled "Support for conducting scientific research and development work using the research infrastructure of the SOLARIS National Synchrotron Radiation Centre"

Have you ever heard about particle accelerators?
What about synchrotrons or cryo-electron microscopes?

SOLARIS Visitors Centre will tell you about how the synchrotron works, what it is used for, and why it and the cryo-electron microscope are so important to the world of science. You will also learn what role these devices play in the development of modern biology, chemistry, physics, as well as medicine and technology. You will learn about discoveries made at synchrotrons, so valuable in the everyday life of each of us.

The tour lasts about **90 minutes**.

You can visit us **all year round!**

We accept organised groups of up to **35 people**.

Age limit: **13+**

SOLARIS National Synchrotron Radiation Centre
Jagiellonian University

ul. Czerwone Maki 98
30-392 Kraków, Poland

zwiedzanie.solaris@uj.edu.pl
www.synchrotron.uj.edu.pl/zwiedzanie

@synchrotron.solaris.badania
@Synchrotron SOLARIS
@synchrotronsolaris
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notes


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SOLARIS
National Synchrotron
Radiation Centre
Jagiellonian University

ul. Czerwone Maki 98
30-392 Kraków, Poland
phone: +48 12 664 40 00
e-mail: synchrotron@uj.edu.pl
www.synchrotron.pl

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