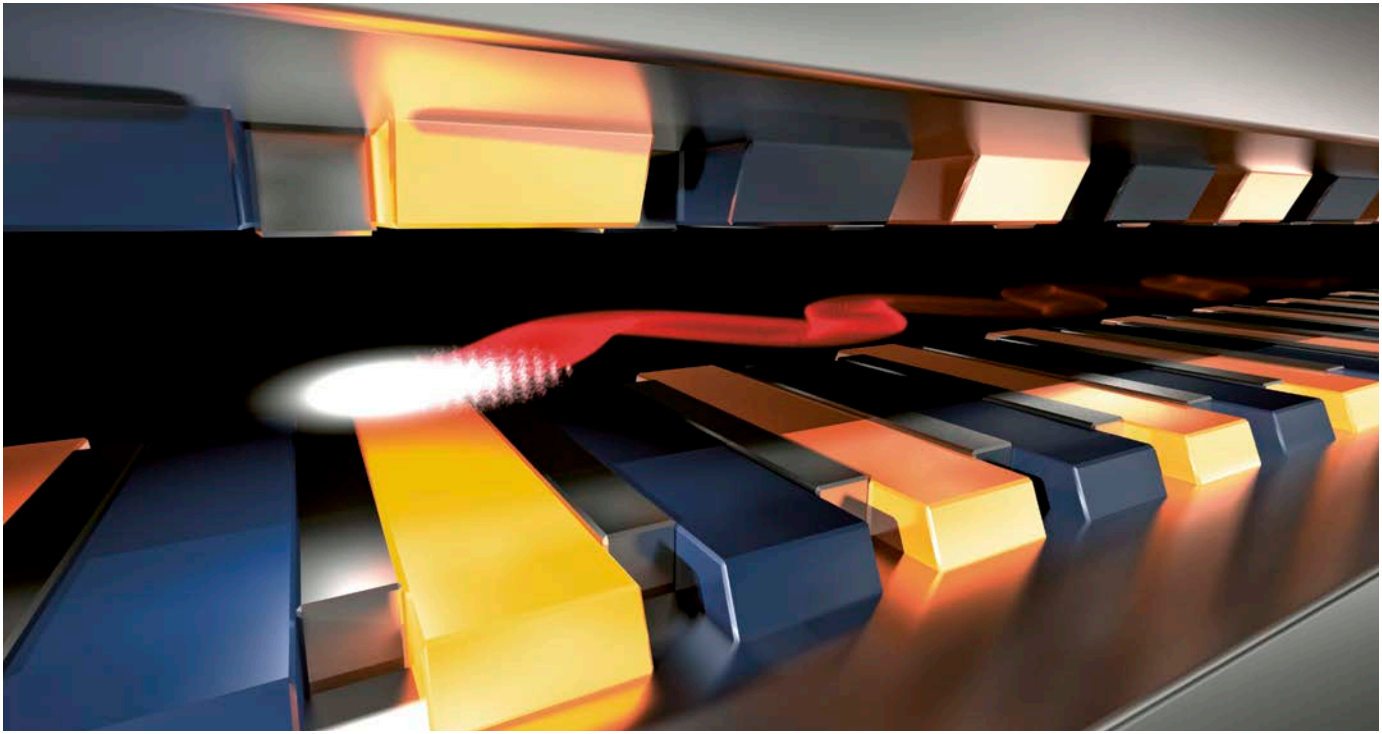
Enlightening Science



In brief

The European XFEL, located in the metropolitan Hamburg area, is a research facility of superlatives: The world's largest X-ray free-electron laser generates ultrashort laser X-ray light flashes—27 000 times per second and with a brilliance that is a billion times higher than that of synchrotrons, the best sources for X-ray radiation before the development of free-electron lasers. The facility features globally unique possibilities for research and industrial scientists to pursue discoveries in the nanocosmos towards use in society.

© European XFEL / Heiner Müller-Elsner

The free-electron laser is located in underground tunnels and construction was a joint effort of many partners. The 1.7 km long particle accelerator brings electrons to high energies.

© European XFEL / Heiner Müller-Elsner

Periodic arrangements of magnets called undulators force electrons on a slalom course. In the process, they emit X-ray radiation that amplifies more and more.

European XFEL GmbH

To construct and operate the European XFEL, the partner countries agreed on the foundation of an independent research organization—a non-profit limited liability company under German law named the European X-Ray Free-Electron Laser Facility GmbH (European XFEL), which employs more than 300 people. At present, Denmark, France, Germany, Hungary, Italy, Poland, Russia, Slovakia, Spain, Sweden, Switzerland, and the United Kingdom are the partner countries of the European XFEL.

The European XFEL GmbH closely cooperates with the research centre DESY and other organizations worldwide.

The construction costs amounted to 1.22 billion euro (at 2005 prices). Germany (federal goverment, the city state of Hamburg, and the state of Schleswig-Holstein) contributed 57 percent, Russia 26 percent, and each of the other partner countries between 1 and 3 percent. To a great extent, the facility was realized by means of in-kind contributions by shareholders and partners.

Opportunities

The unique research opportunities at the European XFEL are attracting top-level scientists from all over the world. This brings together very different scientific disciplines that challenge and foster one another. From this interplay grows a multitude of ideas that can lead to concrete products and product improvements. The facility will generate new knowledge in almost all the technical and scientific disciplines that are shaping our daily lives—including medicine, pharmaceutics, chemistry, materials science, nanotechnology, power engineering, and electronics.

The X-ray flashes will allow scientists ...

… to decipher the structure of many more biomolecules and cellular components than is possible today.

… to study fast biochemical processes, an important basis for the development of new medications and therapies.

… to better understand many chemical processes such as catalysis, which plays an important role in nature and in the manufacturing of most chemical substances produced in industry.

… to study new processes and materials that are required for harnessing solar energy.

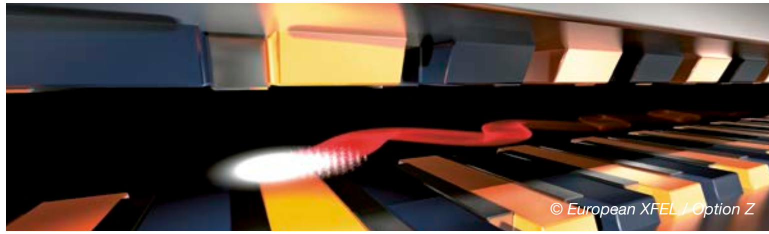
… to analyse the properties of various materials in order to develop completely new materials with revolutionary characteristics.

… to gain new insights into the nanocosmos in many other areas—for instance, to develop components with specific electronic, magnetic, and optical properties.

How it works

To generate the X-ray flashes, bunches of electrons will first be accelerated to high energies and then directed through special arrangements of magnets called undulators. In the process, the particles will emit radiation that is increasingly amplified until an extremely short and intense X-ray flash is finally created. The European XFEL uses several undulators to generate laser-like X-ray flashes with different characteristics.

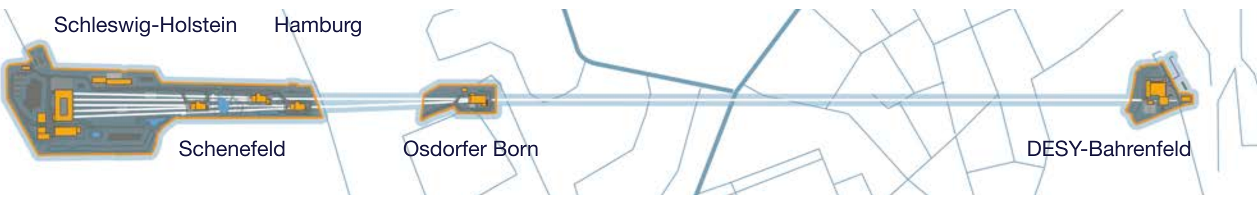
Computer visualisation of the acceleration process in a superconducting cavity resonator



Computer visualisation of an electron bunch in a so-called undulator in which the particles generate X-ray flashes

Location

The X-ray laser and the scientific instruments are located in underground tunnels and halls, which can be accessed on three different sites. The 3.4 kilometre-long facility runs from the campus of the accelerator research centre DESY in Hamburg to the town of Schenefeld in Schleswig-Holstein. The Schenefeld site hosts the research campus, where international teams of scientists carry out experiments with the X-ray flashes.



Research

Smaller, faster, more intense: The European XFEL is opening up areas of research that scientists could before only dream of. The facility's unique X-ray flashes are creating new opportunities in many areas of research. Using the European XFEL, scientists are able to map the atomic details of viruses and cells, take three-dimensional pictures of the nanocosmos, film chemical reactions, and study processes similar to those occurring deep inside planets. Researchers from around the world can apply for experiment time at the facility, generally a few days. A panel of international experts chooses the best proposals, providing access to the facility's complex scientific instruments.

Tiny structures

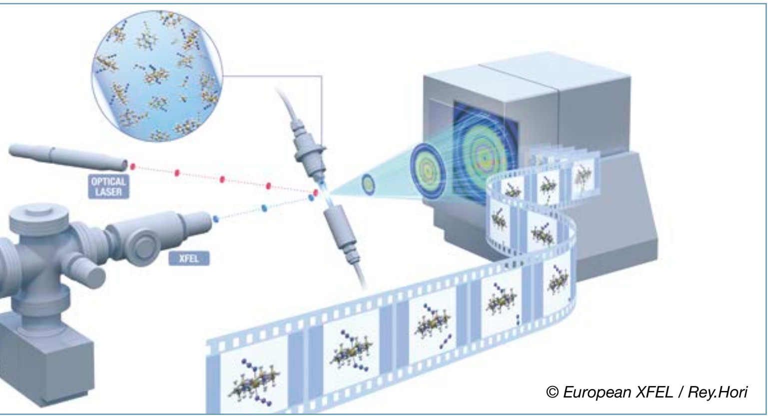
The wavelengths of the X-ray flashes are so small that it is possible to research the composition and structure of complex biomolecules and materials on the atomic scale. Research at European XFEL helps us gain a better insight into the structure of biological cells and develop new materials with optimized properties.

Ultrafast processes

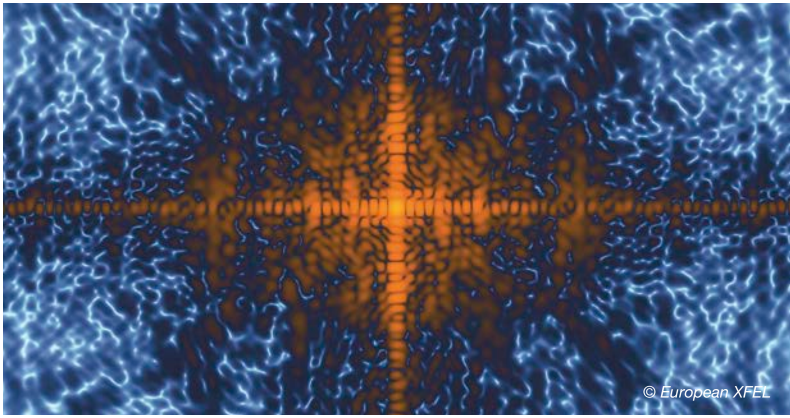
The X-ray flashes are so short that scientists are able to use them to film ultrafast phenomena such as the formation or breakup of chemical bonds. Research at the European XFEL enables us to better understand chemical processes, with the possibility of developing more efficient industrial production methods, for instance. These studies provide an essential basis for the development of new medicines.

Extreme states and small objects

The X-ray laser flashes can be used to study matter under extreme conditions: of temperature and pressure, such as occurring in the interior of planets, and at extreme electric or magnetic field strengths. This will reveal new knowledge about the properties of materials under such conditions. Other studies with small objects, single molecules, or atoms in extreme X-ray fields will pave the way for new X-ray methods.



The ultrashort X-ray flashes enable individual snapshots of chemical reactions, which can then be put together to provide a stop-motion film of the reaction.



Simulated diffraction pattern

Facility

- **Type:** X-ray free-electron laser (XFEL)
- **Total length:** 3.4 kilometres
- **Depth of the tunnels:** 6 to 38 metres below ground level
- **Accelerator:** linear accelerator (1.7 kilometres), which speeds up electrons to an energy of 10 to 17.5 billion electron volts (GeV), expandable to 20 GeV
- **Sites:** DESY-Bahrenfeld (2 hectares), Osdorfer Born (1.5 hectares), and Schenefeld (15 hectares). The research campus is located in Schenefeld.

Properties of the X-ray flashes

- **Flashes per second:** 27 000.
  The high repetition rate is what makes the European XFEL unique among the world‘s X-ray lasers. It is only possible thanks to superconducting accelerator technology operating at -271° C, which allows the almost lossless conduction of electric current.
- **Wavelengths:** 0.05 to 4.7 billionths of a metre (0.05 to 4.7 nanometres).
  The wavelengths of the X-ray flashes are so short that even atomic details become discernible.
- **Duration:** down to a few quadrillionths of a second.
  Thanks to this extremely short pulse duration, scientists can make films of ultrafast processes.
- **Brilliance (photons/s/mm²/mrad²/0.1% BW):** 5×10^{33} (peak), 1.6×10^{25} (average).
  The brilliance is a measure of the number of photons generated within a specific wavelength range. The peak brilliance of the European XFEL is a billion times higher than that of the best conventional X-ray sources.
- **Light quality:** Coherent.
  The coherence of the X-ray flashes makes it possible to use them for a wide range of interference experiments such as holography.

www.xfel.eu | **July 2017** | **Publisher** European XFEL GmbH, Holzkoppel 4, 22869 Schenefeld, Germany | **Layout** Studio Belser, Hamburg | **Typesetting** Rothe Grafik, Georgsmarienhütte | **Printing** Die Printur GmbH