Europe turns on bright X-ray source

The opening of the superconducting European X-ray free-electron laser in Hamburg, Germany provides exciting opportunities for exploring a completely new world of science.

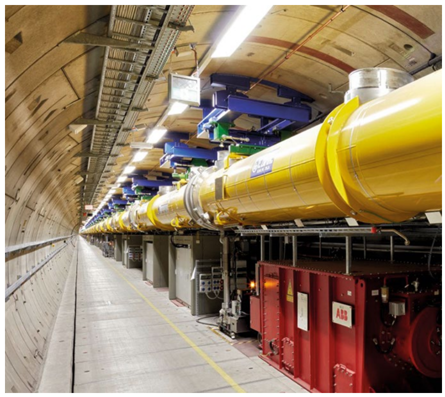
The long-awaited European X-ray free-electron laser (XFEL) at Schenefeld near Hamburg in Germany is now open and up and running. Following eight years of construction, the facility celebrated its official inauguration on 1 September 2017 and as we publish this issue the first user experiments are starting.

The European XFEL provides a coherent source of X-rays with energy ranging from 260 eV to beyond 20 keV using electrons accelerated to 8–17.5 GeV along a 2.1-km-long superconducting linear accelerator. The number of electron bunches (27,000 pulses per second) and the peak brilliance (5×10^{33} photons s^{-1} mm^{-2} $mrad^2$ (0.1% bandwidth)) of the source make it unique among XFELs built to date and gives users in Europe access to an X-ray source with unprecedented capabilities for experiments in biology, materials science, chemistry and physics.

To meet demands for performing cutting-edge science and technology, X-ray research has been undergoing a dramatic revolution over the past decades with the brightness of X-ray beams increasing at a rate surpassing Moore's Law — the famous exponential trend where the number of transistors on an integrated circuit doubles every two years. With intense ultrashort pulses matching the timescale of atomic motion, XFELs make it possible to probe dynamic and structural properties of matter in new ways and to create 'molecular movies'.

The genesis of the European XFEL dates back to 2003 when the German government announced plans to construct the XFEL as a European project. At present, 11 countries have signed up: Denmark, France, Germany, Hungary, Italy, Poland, Russia, Slovakia, Spain, Sweden and Switzerland. The UK is in the process of joining. The overall construction costs, including preparation and commissioning, amount to an estimated €1.22 billion (at the 2005 price level).

Germany, the host country, has funded the largest share (58%) of the cost of the project followed by Russia that has funded over 27% of the construction costs. Other international partners have contributed between 1% and 3%. The large contribution from Russia follows in the footsteps of other successful examples of Russian investments in scientific infrastructure in Germany, such as the Russian–German Laboratory at the synchrotron-radiation centre BESSY in Berlin. Russia also has a national project (SSRS4) to construct a fourth-generation photon source in Russia that will utilize the valuable experience gained by Russian scientists currently working in Hamburg.



Credit: European XFEL / Heiner Müller-Elsner

"We are very happy about the large interest from Russia and we already have much collaboration with groups in Russia that will be intensified now the user operation has started," said Thomas Tschentscher, the Scientific Director of the European XFEL.

Tschentscher expects that the European XFEL will have collaborative projects with other countries on extending the capabilities of the facility in terms of new instrumentation. Applications for beam time on the European XFEL will be evaluated by international proposal review panels featuring world-leading scientists not only from the countries participating in the European XFEL project, but also from all over the world.

An important and unique feature of the European XFEL is that it exploits an accelerator system based on superconducting technologies. Because much less energy is absorbed in the accelerating cavities, a larger number of electron bunches can be accelerated compared with in the warm, non-superconducting accelerators such as the Linac Coherent Light Source (LCLS) in Stanford, USA and the SPring-8 Angstrom Compact Free Electron Laser (SACLA) in Japan.

Interestingly, both the USA and China have firm plans to realize free-electron laser sources based on superconducting accelerators within the next few years, making the European XFEL the first of a new breed of superconducting X-ray sources. The new superconducting LCLS-II at Stanford is expected to be open in the early 2020s and China's SXFEL in Shanghai may be ready by 2019.

The European XFEL currently employs a pulsed radio-frequency driving scheme, similar to the Free-Electron LASer in Hamburg (FLASH) facility at the synchrotron-radiation centre DESY in Hamburg. This mode provides both a large number of electron bunches (27,000 pulses per second) and a high electron energy (15–20 GeV). The record-breaking number of electron bunches leads to a reduction in the time required for a set of experiments and enables an increase in the number of experimental stations up to 10.

The outstanding characteristics of the European XFEL are set to have an enormous impact on a number of fields. In materials science and structural biology, investigating materials or molecules at ultrafast timescales will help to develop new technological applications and aid in the design of novel materials. As for fundamental physics, the interaction of ultrashort and intense X-ray pulses with matter will open the path to investigating many as yet unexplored phenomena. The European XFEL will also aid planetary research. For example, studies of new material phases and structures at the highest pressures and temperatures may provide insights into the inner structure of solar and exo-solar planets. We look forward to exciting discoveries from experiments performed at the European XFEL. ❐

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