Compact X-ray laser lab aims to reveal deep secrets of life, matter and energy

ASU building world's first compact X-ray free electron laser to advance biomedical research, renewable energy and computing

By Joe Rojas-Burke, ASU News
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X-rays allow us to view inside the human body to diagnose broken bones and other hidden problems. More recent X-ray advances are making it possible to see events at the scale of atoms and molecules, revealing targets for new medicines and new materials for renewable energy and advanced computing.

About this story

There's a reason research matters. It creates technologies, medicines and other solutions to the biggest challenges we face. It touches your life in numerous ways every day, from the roads you drive on to the phone in your pocket.

The ASU research in this article was possible only because of the longstanding agreement between the U.S. government and America’s research universities. That compact provides that universities would not only undertake the research but would also build the necessary infrastructure in exchange for grants from the government.

That agreement and all the economic and societal benefits that come from such research have recently been put at risk.

Learn about more solutions to come out of ASU research at news.asu.edu/research-matters.

An invention called the X-ray free electron laser (XFEL) opened a brand-new window on the chemical reactions of the molecules of life as they unfold in real time. The technology and the fundamental insights it provides hold promise to help speed the development of new cancer treatments, drugs to fight viral pandemics and powerful quantum computers.

But massive costs have limited access. The first XFEL cost around a billion dollars to build and requires a giant, atom-smashing, kilometer-long particle accelerator facility. Fewer than 10 XFEL instruments exist worldwide.

Arizona State University set forth to innovate and develop the world's first compact version of an X-ray free electron laser, or CXFEL. Dramatically smaller and less expensive, this garage-sized instrument promises to expand opportunities for researchers to explore atomic-scale events important for biochemistry, microelectronics, bioenergy applications, drug discovery and development, quantum computing and more.

"We believe this is the start of a new paradigm that will enable many institutions to follow in our footsteps, providing novel instruments for scientific breakthroughs," said William Graves, who leads the CXFEL project at ASU.

The compact approach accelerates electrons to near light speed, structures them and collides them with an intense laser beam to produce a highly directed beam of coherent X-rays that can access atomic-scale details invisible to longer wavelength light. The CXFEL instrument will fire extremely short X-ray pulses on the scale of a millionth of one billionth of a second, or a femtosecond. Like the strobe lighting of high-speed photography, these fleeting X-ray pulses can capture the ultra-high-speed movements of electrons and atoms.

The CXFEL project is housed in the basement of the Biodesign Institute's C building and comprises two light sources. The first, called the Compact X-ray Light Source (CXLS), resulted from ASU investments in research infrastructure and the generous contributions of the late Leo Beus and his wife Annette Beus. Due to these strategic early investments, in 2023, ASU received a $90.8 million, five-year award from the National Science Foundation — the largest NSF research award in the university's history — to build and complete the CXFEL as the first compact XFEL light source worldwide. Together, the two instruments will enable a national-lab caliber user facility for forefront X-ray science. ASU President Michael M. Crow said it is one of the most significant ASU research projects to date, "and it is one that will have a positive impact in many critical areas related to the world's grand challenges."

The scientists at ASU are on their way to finalize the commissioning of the CXLS light source and begin using it to record the structure and dynamics of complex biomolecules and quantum materials. This latest milestone means that key power, safety and operational parameters have already been successfully met, with the ability of the instrument to generate a stable electron beam and ultrashort X-rays to begin its first measurements for ASU and other scientists later this year.

The light sources will advance a broad range of fundamental science and applications. "For example, it will be extremely exciting to make a movie of how a virus binds to a cell and then visualize all the processes that allow the virus to enter the cell," said ASU scientist Petra Fromme. Such information could be critical for better preparing the world against a future pandemic.

"Another example would be to see how a cancer cell hides from destruction by the immune system," said Fromme, director of the Biodesign Center for Applied Structural Discovery and a Regents Professor in the School of Molecular Sciences. This could usher in a new wave of cancer therapies.

CXFEL technology will also help investigators advance renewable energy research, quantum technologies and semiconductor research and manufacturing.

"The potential for few-femtosecond, or even shorter, soft X-ray pulses with the future CXFEL is particularly exciting," said Robert Kaindl, a professor in ASU's Department of Physics who leads the transition of CXFEL to a user facility. "They provide us with a 'time microscope' to observe and unlock the most fundamental electron movements responsible for chemical reactions and quantum correlations in materials."

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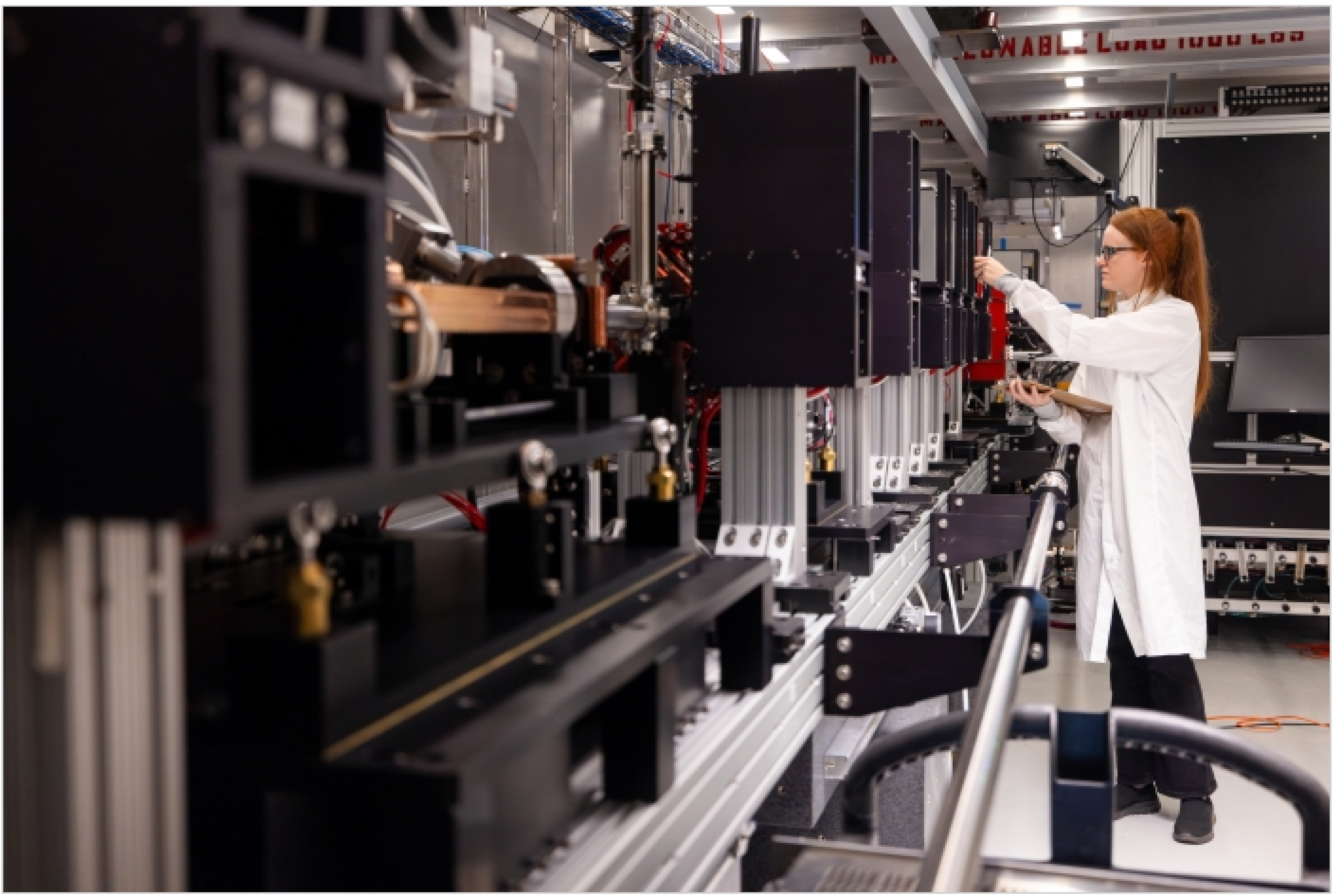
Main image



Research Lab Assistant Antonella Semaan observes the laser at work in the CXFEL Lab in Biodesign C on Nov. 16, 2023. Photo by Samantha Chow/ASU