Creating the Future

SLAC National Accelerator Laboratory

NATIONAL
ACCELERATOR
LABORATORY

A Force for Discovery

Since its opening in 1962, SLAC National Accelerator Laboratory has been helping create the future.

We built the world's longest linear accelerator, discovered some of the fundamental building blocks of matter and created the first website in North America.

Our top-notch research facilities attract thousands of scientists from all over the world each year. Along with our own staff scientists, they're working to discover new drugs for healing, new materials for electronics and new ways to produce clean energy and clean up the environment.

SLAC's revolutionary X-ray laser is revealing intimate details of atoms and chemical reactions and making stop-motion movies of this tiny realm, with the goal of doing the same for living cells.

Our scientists are also exploring the cosmos, from the origin of the universe to the nature of dark energy, and developing the smaller, more efficient particle accelerators of the future.

Six scientists have been awarded Nobel prizes for work done at SLAC, and more than 1,000 scientific papers are published each year based on research at the lab.

As our second half-century unfolds, we're just getting started.

A current photo of the SLAC research yard fades into a sepia-toned shot taken while the buildings were under construction in October 1965.

Wielding a Revolutionary X-ray Laser

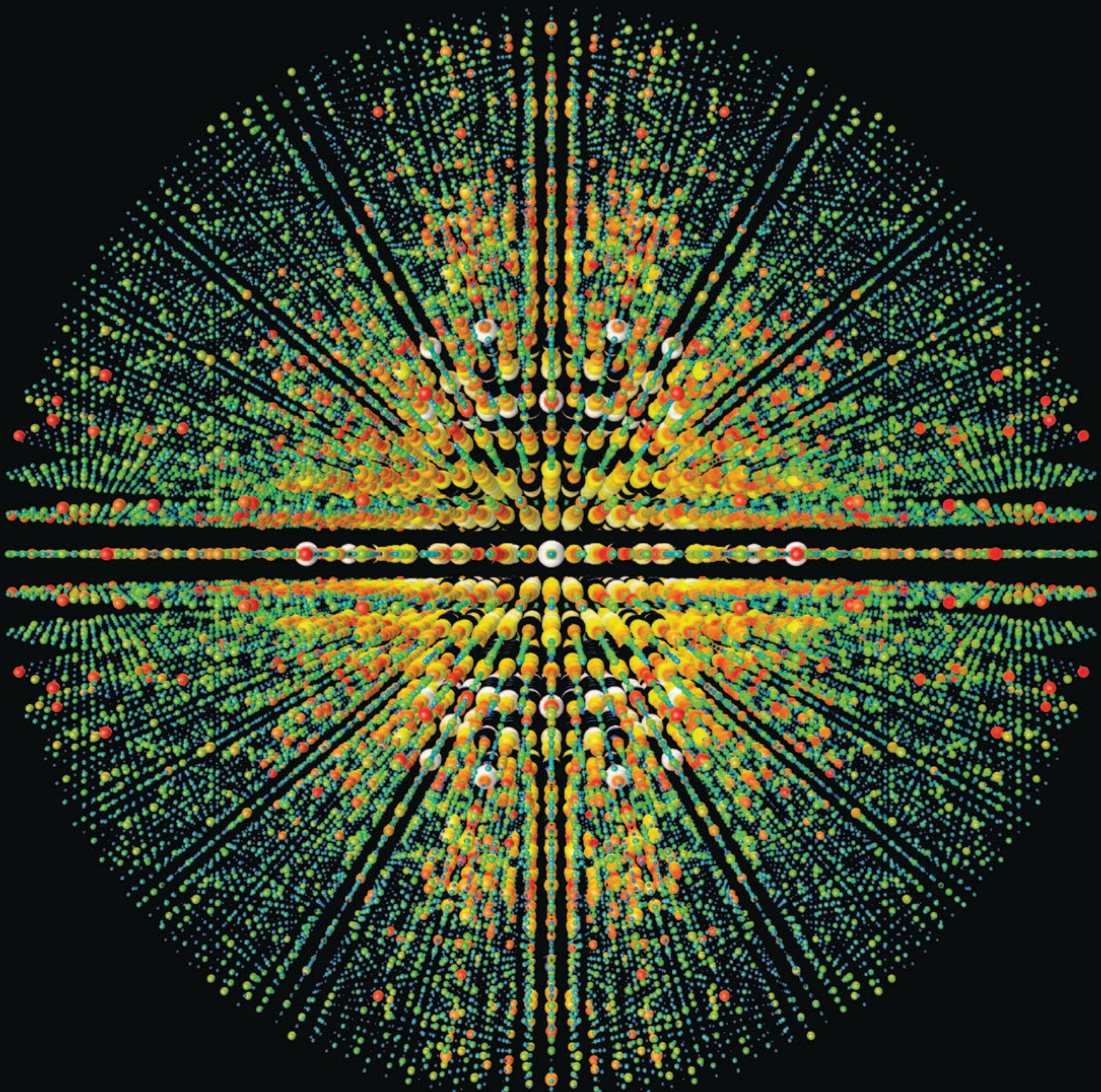
SLAC is home to the world's first hard X-ray free-electron laser, the Linac Coherent Light Source.

Its intense laser beam, a billion times brighter than any X-ray source before, makes snapshots of atoms, cells and chemical reactions in action. It comes in pulses so brief – just millionths of a billionth of a second long – that the LCLS can "freeze" the movements of these tiny things and string those images together into stop-action movies.

The excitement of exploring this new frontier draws scientists from all over the world to compete for time on the LCLS beam. They use it to probe the molecular machines that make living things run, the materials and chemistry that enhance everyday life and the extreme, exotic conditions in the hearts of distant planets and exploding stars.

Since opening in 2009, the LCLS has proved so popular that only one in four experimental proposals can be accepted. Plans are afoot to add more capabilities and a second X-ray laser, LCLS-II, to accommodate even more world-class research.

This 3-D visualization combines more than 15,000 patterns made by X-rays scattering off nanocrystals of Photosystem I, which helps plants make fuel from sunlight. Taken during experiments at SLAC's Linac Coherent Light Source, the patterns allowed scientists to reconstruct the structure of this important protein complex.



Designing Materials from the Atom Up

It's no accident that the three classic ages of humankind are named for materials: Stone. Bronze. Iron. Advances in materials go hand in hand with the development of culture.

Now we're entering the era of Materials by Design, in which we manipulate matter, atom by atom, to make custom-designed materials with exactly the properties we need.

Imagine having materials that transmit electricity with 100 percent efficiency, keep computers on their smaller-faster-better trajectory and allow factories to manufacture products with much less energy and waste.

SLAC is teaming with Stanford University on a design cycle that makes these visions possible.

Theorists predict the properties of new materials. Computers simulate how they would work. Lab scientists cook them up. And SLAC's powerful X-ray beams probe and test the new materials. The results feed back into theories, and the cycle starts again.

Graduate student Hsueh-Hui Kuo holds a probe for measuring the electronic structures of superconducting materials, like the one whose atomic structure seemingly surrounds her in this illustration. Superconductors are valued for their ability to conduct electricity with 100 percent efficiency, and they are a key focus of studies at the Stanford Institute for Materials and Energy Sciences, a joint institute of SLAC and Stanford.

Wringing More Energy from the Sun

If we could make energy from sunlight the way plants do – with great efficiency and no pollution – we'd be set.

The road to that clean energy future is not straightforward, but SLAC scientists and their colleagues are making steady progress.

They're reinventing the lithium-ion batteries that power laptops, video cameras and cell phones. If only those rechargeable batteries could store more energy, they could power cars, too. Scientists are experimenting with new types of electrodes that could make that happen.

Others are taking a close look at photosynthesis, the process plants use to turn sunlight into energy, with the goal of understanding each tiny chemical step and using what they learn to create new energy technologies.

They're designing new catalysts – helpful promoters of chemical reactions – to make steps of the energy cycle cleaner and more efficient, and improve manufacturing processes to boot.

And they're devising new materials and devices for solar cells, fuel cells, batteries and other solutions for humanity's energy needs.

SLAC senior scientist Mike Toney, right, and SLAC/Stanford postdoctoral researcher Alex Ayzner with a piece of thin-film photovoltaic material. Materials like these convert sunlight to energy, and scientists at SLAC and Stanford are working to make them cheaper and more efficient.

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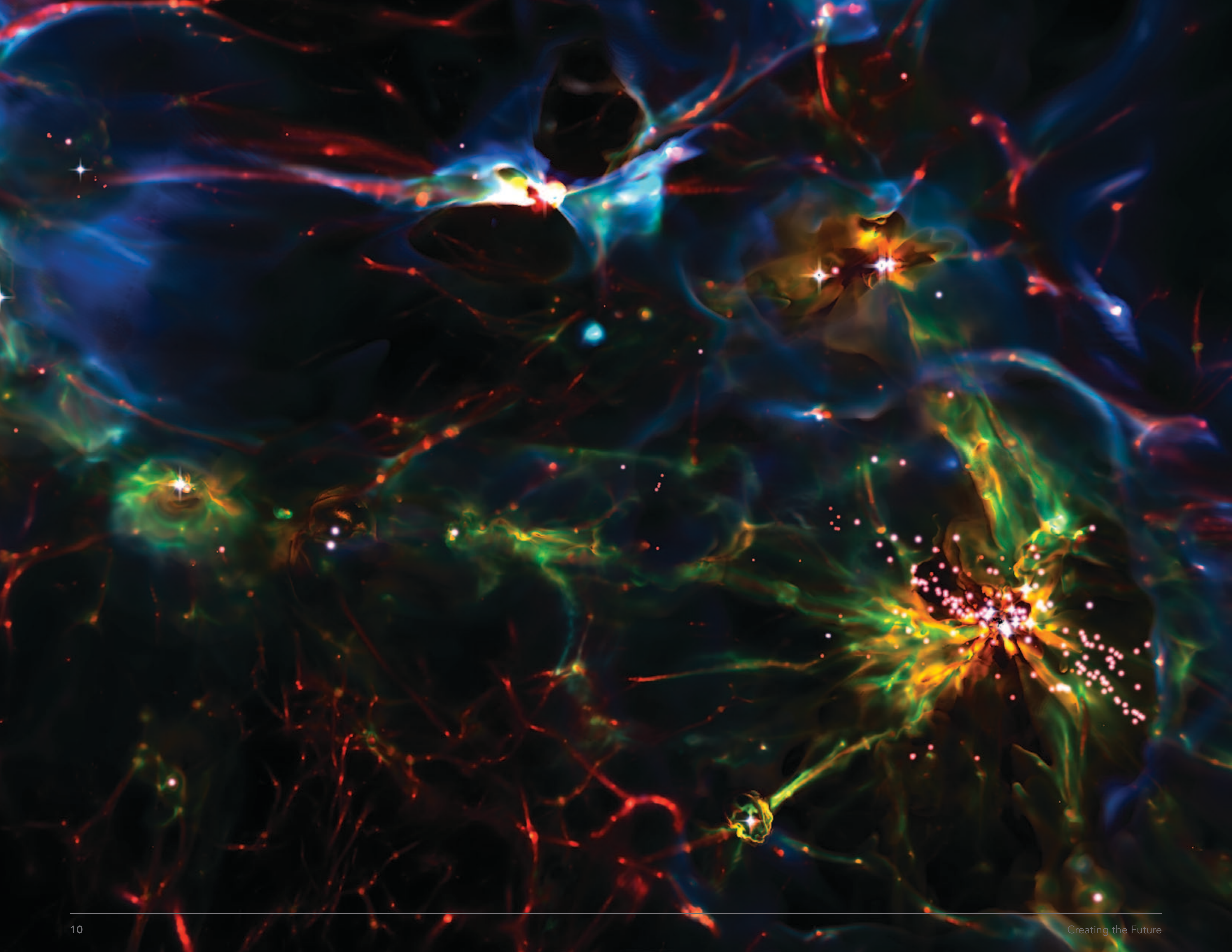

Exploring Cosmic Mysteries

SLAC scientists got their start using an accelerator to explore fundamental building blocks of the universe and the forces that rule them.

Now they're extending that search into the depths of the Earth and the farthest reaches of space. They're looking for the dark matter that clumps stars into galaxies and the dark energy that's tearing the universe apart. They're searching for the origins of mass at Europe's Large Hadron Collider.

And they're helping design and build new tools for that quest, including:

- An orbiting telescope to capture high-energy light from violent cosmic events
- The world's biggest digital camera to scan the skies for evidence of dark energy
- An underground tank of liquid xenon to capture neutrinos
- Super-cooled germanium wafers that lie in wait for dark matter
- A detector to catch debris from the most powerful particle collisions ever

These observations work hand in hand with sophisticated theories to give us an ever-deeper understanding of the universe, from its birth in the Big Bang to its evolution into a place that can nourish life.

A visualization from the SLAC/Stanford Kavli Institute for Particle Astrophysics and Cosmology shows one of hundreds of regions where small galaxies (in yellow) will combine over a few billion years to form galaxies like our Milky Way. Reddish areas are regions where stars have not yet formed.

Paving the Way with Theory

Theories are not just bright ideas.

In physics, as in other areas of science, they are a crucial part of the cycle of discovery, posing questions for experiments to explore and making sense of what those experiments find.

Physicists develop theories in the language of mathematics. By working through the math in a rigorous, insightful way, they discover where a theory leads – it's often a surprising place – and find gaps in their understanding.

Then they invent new particles or interactions to fill the gap, use computers to simulate this new way of thinking and compare the results with data from experiments. As theorists bring more sophisticated calculations into the discussion, they allow experiments to probe nature more deeply.

Theories invented by SLAC physicists help describe the nature of quarks and leptons and point to new symmetries of nature. They describe exciting results that could come from measurements in cosmology and from particle collisions at the Large Hadron Collider in Europe. These theoretical signposts give experimenters a much better idea of where to look for the next big discovery.

From left: Theoretical physicists Stefan Hoeche of SLAC, Ezequiel Alvarez of the University of Buenos Aires and Ahmed Ismail of SLAC discuss new physics models that could explain puzzling results involving top quarks coming from proton–antiproton collisions.


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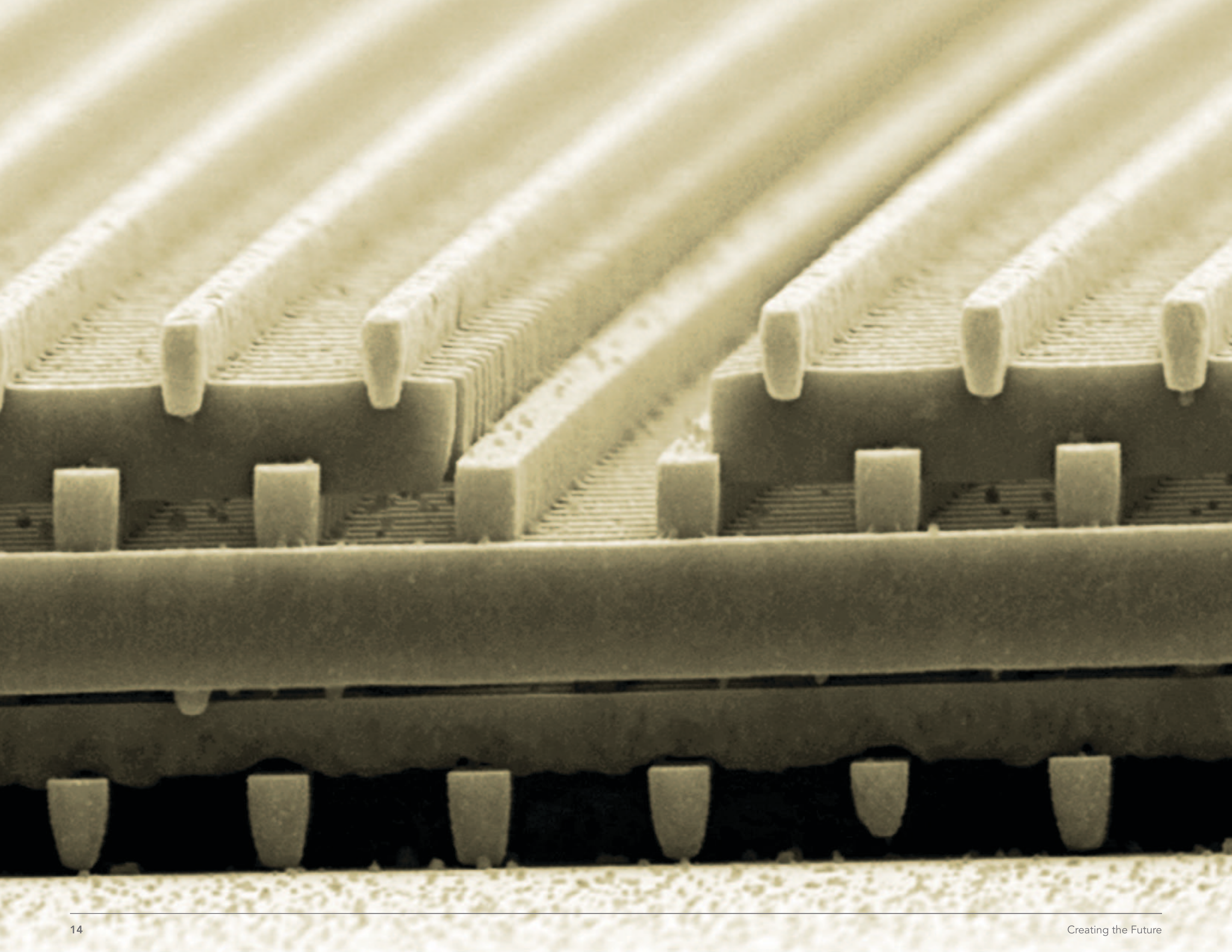


Shrinking the Particle Accelerator

Particle accelerators aren't just for science. Of the 30,000 accelerators in use today, most are doing other work: Diagnosing disease. Shrinking tumors. Sterilizing food packaging and medical supplies. Strengthening materials for cabling, tires and other rugged products. Implanting ions in semiconductors. Screening cargo. Cleaning up pollution.

SLAC is a leader in the quest to make these accelerators smaller and more powerful.

Part of the lab's two-mile linear accelerator has been converted into a test bed for new accelerator technologies. In one experiment, electrons "surfing" on waves of plasma – a hot gas of charged particles – reached 1,000 times higher energies over a given distance than ever possible before.

These studies have the potential to make more accelerators available in medical offices, manufacturing plants and other places where they can do good things for society.

Tiny devices made of silicon and powered by lasers offer a cheaper, more compact way to accelerate particles. This electron microscope image shows part of an experimental "accelerator on a chip" fabricated as part of a SLAC/Stanford research project. A channel in the silicon structure, at top center, confines light to power the accelerator.

Improving Health and the Environment

At SLAC, better health has long been a natural byproduct of accelerating particles.

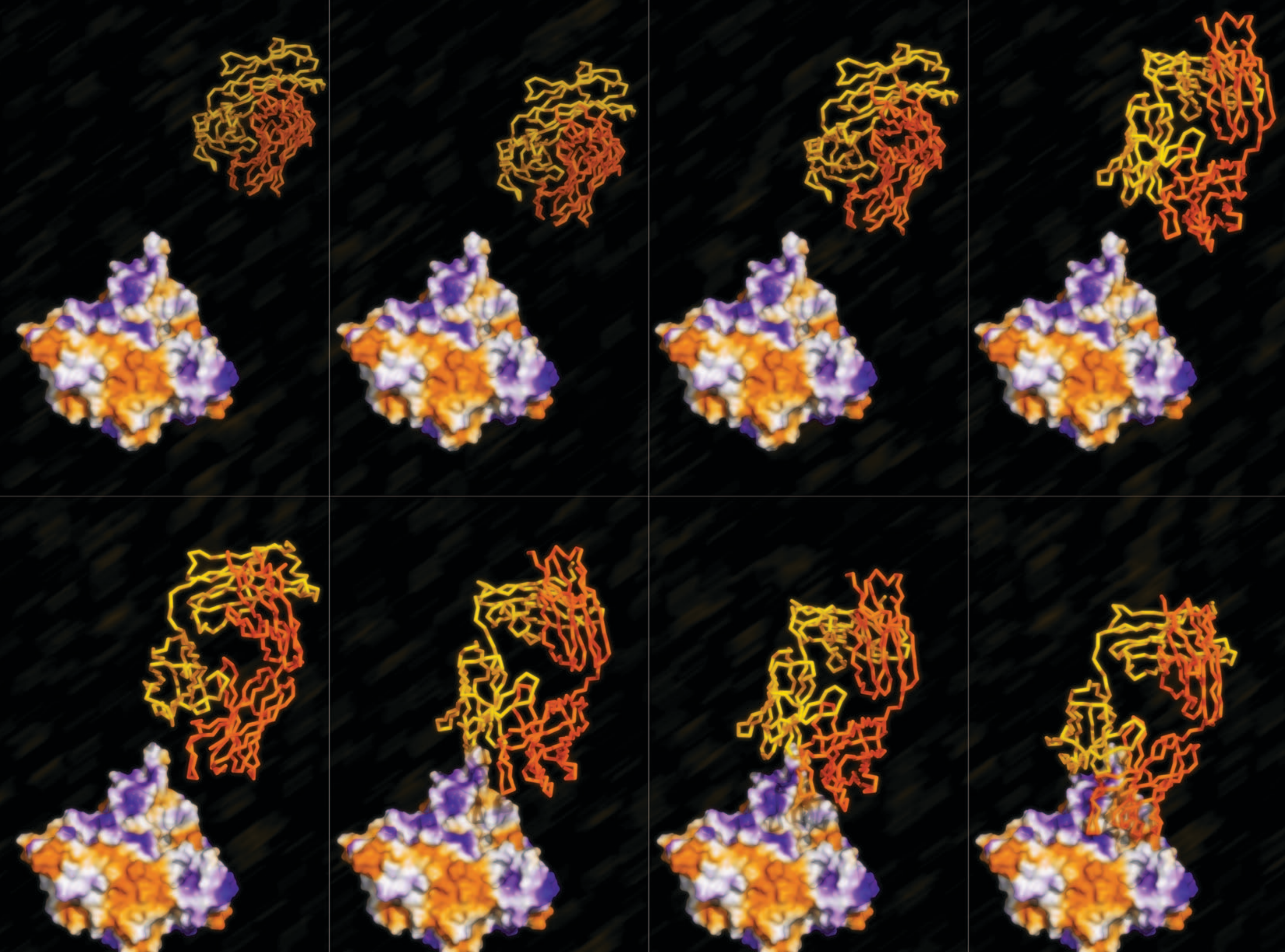
For instance, software developed for particle physics experiments has morphed into the gold-standard method for planning cancer radiation treatments.

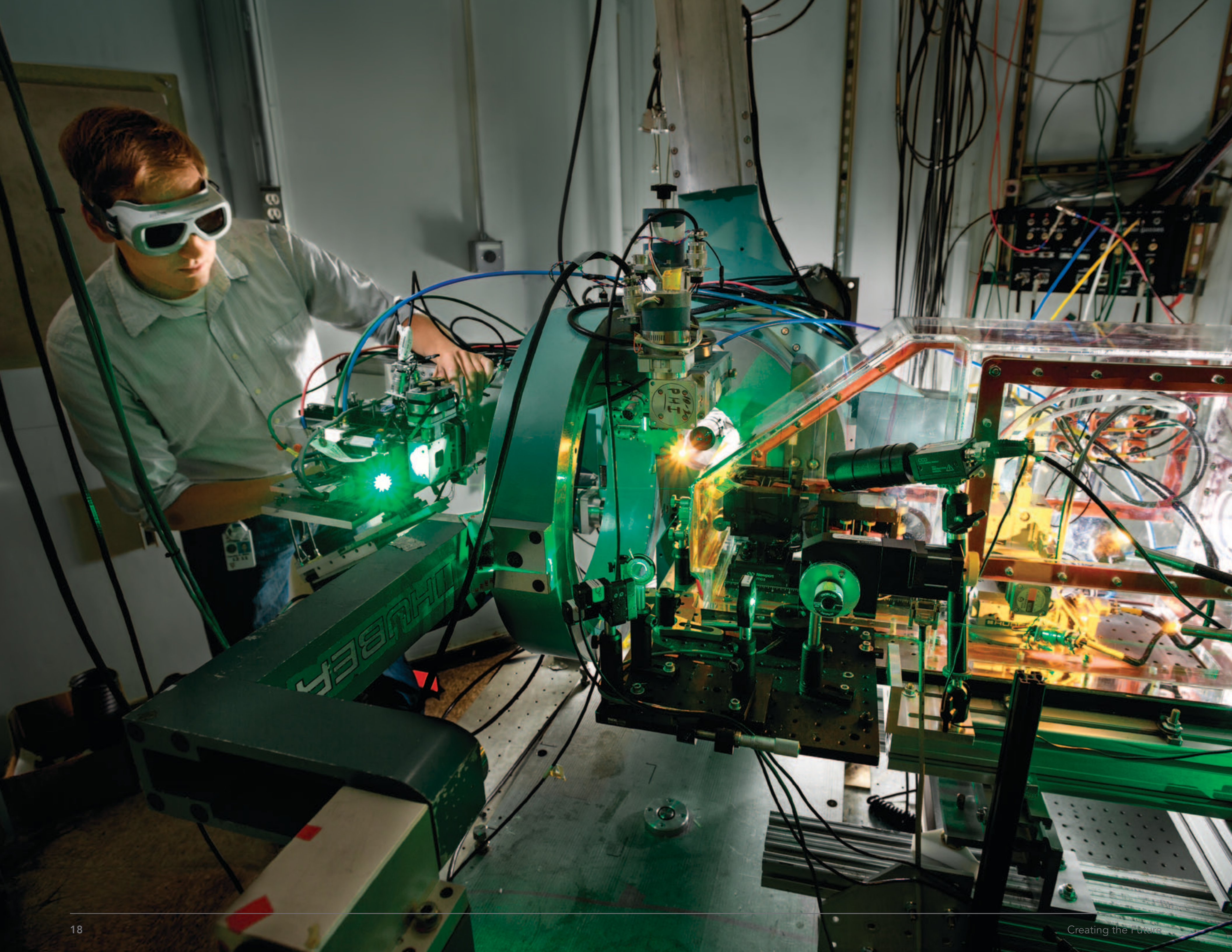
Our physicists are working with doctors to develop a way to zap tumors with high-energy electrons, greatly shrinking treatment times.

And our brilliant X-ray beams give scientists an unparalleled look at the gateways where germs enter cells, allowing them to design better drugs to keep the invaders out. Research here has helped create drugs that fight influenza, block blood-vessel growth in tumors, treat end-stage melanoma and battle HIV.

The same X-ray beams help scientists track, understand and clean up pollutants – from uranium leaching out of mine tailings into the Colorado River to natural arsenic making its way into wells in Bangladesh, sickening millions. By analyzing soil samples in a SLAC X-ray beam, researchers pinpointed the source of the arsenic and helped reduce the risk of poisoning.

In this illustration, an antibody (yellow and orange) approaches a receptor on the surface of HIV, where it will bind and neutralize the virus. Experiments at SLAC determined the structure of this antibody, which was taken from people with an unusually strong immune response to HIV, and discovered exactly how it fit into the viral receptor. Armed with that knowledge, scientists were able to tweak the antibody to improve the fit and create a more potent defense against HIV infection.




HUBER
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Opening Our Doors to the World

SLAC operates “user facilities” that are open to scientists from all over the world, and about 3,400 of them take us up on the invitation every year.

They compete for a chance to use our sophisticated, often one-of-a-kind equipment, which no single company or university could afford to build or operate.

The lab’s Stanford Synchrotron Radiation Lightsource started the tradition in 1973. It was the first large X-ray facility to open its doors to outside researchers, and upgrades keep it on the cutting edge of science.

Then came the Linac Coherent Light Source, the world’s first hard X-ray free-electron laser, which opened for experiments in 2009.

At SLAC’s newest user facility, called FACET, scientists come to test technologies for the next generation of particle accelerators.

We count a growing number of researchers from private industry among our users. New policies are opening those doors even wider, making the lab’s wealth of equipment and know-how available to people with the best ideas for making discoveries and advancing the technologies that keep American industry competitive.

Stanford graduate student Tim Miller uses SLAC’s Stanford Synchrotron Radiation Lightsource to look at a special class of materials with potential for developing new battery technologies. First he gives the material a kick with light from a green laser; then an X-ray beam snaps an image of the material’s response.

On the cover:
A visualization of the speed of hydrogen gas in a rotating galaxy from the early universe. Yellow lines represent fast-moving gas and purple lines are regions of slower-moving gas.

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The SLAC research yard at night.

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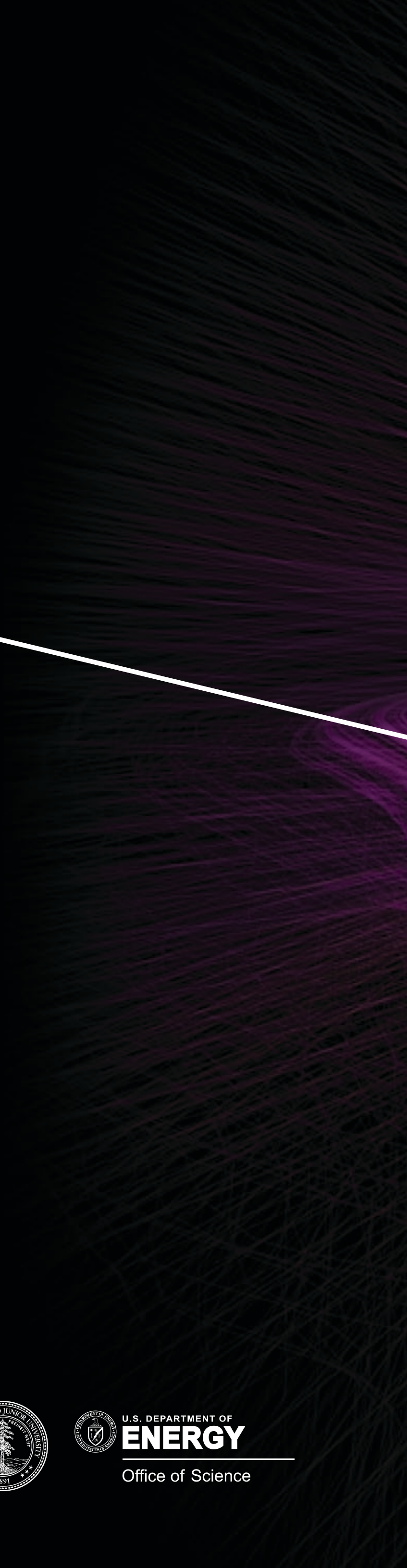

Great Lab. Great University. Great Science.

The 426-acre campus of SLAC National Accelerator Laboratory is located in Silicon Valley, 30 miles southeast of San Francisco, Calif., on the Stanford University campus.

For more information about SLAC, please visit slac.stanford.edu.

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