10-8-2019

SLAC National Accelerator Laboratory

Bruce Dunham

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October 8, 2019

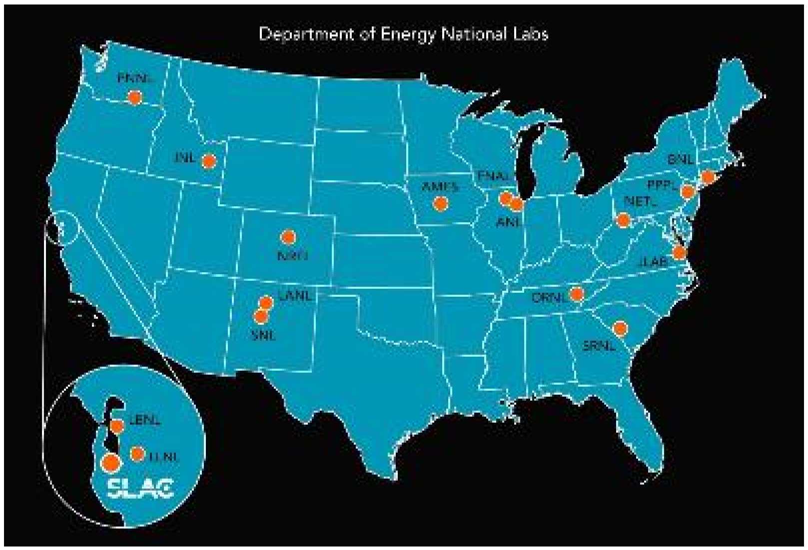
BOLD PEOPLE. VISIONARY SCIENCE. REAL IMPACT.

U.S. DEPARTMENT OF ENERGY Stanford University SLAC NATIONAL ACCELERATOR LABORATORY

Agenda

- U.S. Department of Energy
- Stanford University
- SLAC History to Today
- World's 1st Hard X-ray Free Electron Laser
- SLAC Science with Impact

The U.S. Department of Energy national laboratory system is unique in the world in scale and impact



Annual Budgets

- Department of Energy: **$35.5B**
- DOE Office of Science: **$6.5B**

DOE Mission Areas

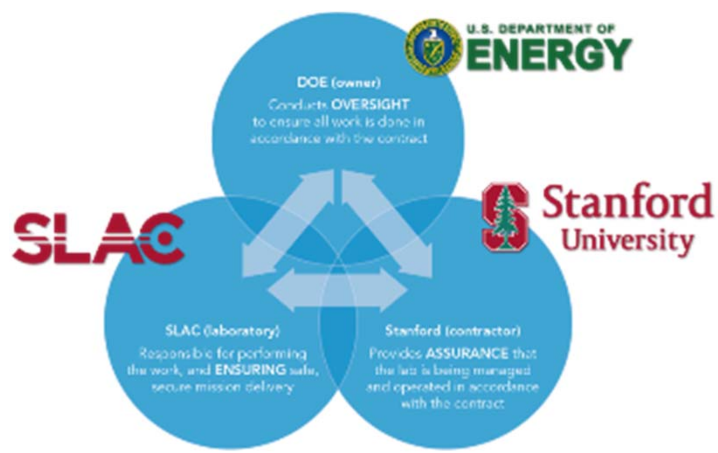
Beyond DOE Mission

- Human health, industry

SLAC National Accelerator Laboratory is a DOE national lab managed by Stanford University

SLAC

- DOE national labs are **Federally Funded Research and Development Centers**, as such they're government-owned, contractor-operated **(GOCO) facilities**
- **Stanford is the contractor for SLAC**, providing assurance the lab is being managed and operated in accordance with SLAC's DOE Management & Operating contract
- In general, **Stanford's policies and systems flow into the lab**, except as modified or limited by the contract
- **Stanford provides intellectual leadership** and helps attract key talent for the lab



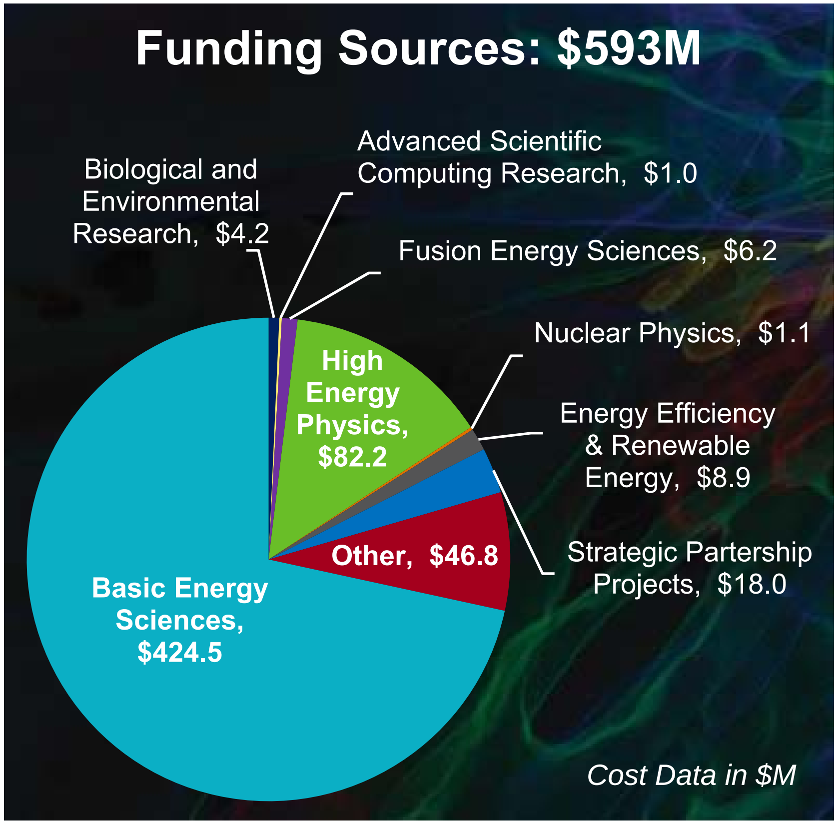
SLAC is a vibrant multi-program laboratory solving real-world problems and advancing national interests

Our Mission

We explore how the universe works at the biggest, smallest and fastest scales and invent powerful tools used by scientists around the globe. Our research helps solve real-world problems and advances the interests of the nation.

Our People

- 1,602 Full-time Employees
- 22 Joint Faculty
- 22 Visiting Scientists
- 2,931 Facility Users
- 145 Postdocs
- 207 Grad Students
- 120 Undergrads



The laboratory sits on 426 acres of Stanford land in the heart of Silicon Valley

Five joint institutes and centers with Stanford enable SLAC to pursue new research directions

- **Kavli Institute for Particle Astrophysics and Cosmology** furthers our understanding of the universe
- **Stanford PULSE Institute** advances the frontiers of ultrafast science
- **Stanford Institute for Materials and Energy Sciences** studies the science of energy-related materials
- **SUNCAT Center for Interface Science and Catalysis** explores atomic-scale design of catalysts critical to future energy technologies
- **Stanford-SLAC Cryo-EM Center** studies biosciences and materials science

Significant investment from Stanford continues to transform the lab, providing new infrastructure and capabilities


L-R: Science & User Support Building, Arrillaga Family Main Quad Renewal and Arrillaga Science Center


Stanford-SLAC cryo-electron microscopy facility


Undulator microfocus beamline at SSRL

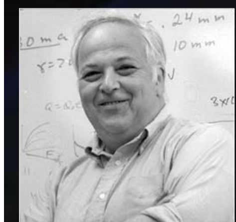

Stanford Research Computing Facility


Stanford Guest House

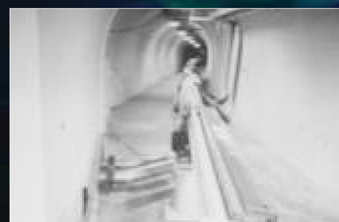
Research at SLAC has led and enabled fundamental discoveries since the laboratory's founding in 1962

SLAC

A History of Discovery and The Age of Colliders



Burton Richter, 1976 Nobel Prize in Physics (joint) for discovery of the J/psi subatomic particle

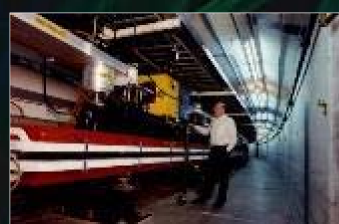


Positron-Electron Project (**PEP**), 1980-1990

Richard Taylor, 1990 Nobel Prize in Physics (joint) for demonstrating the existence of quarks

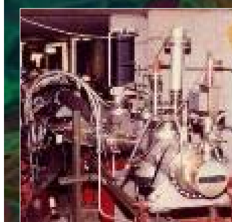
Stanford Linear Collider (**SLC**), 1987-1997

Martin Perl, 1995 Nobel Prize in Physics for discovery of the tau lepton elementary particle

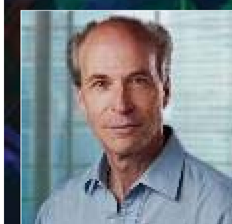


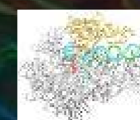
PEP-II, 1998-2008

Synchrotron and X-ray Research



Stanford Synchrotron Radiation Project (now the Stanford Synchrotron Radiation Lightsource, SSRL), 1974





3D atomic images of RNA polymerase II

Roger Kornberg, 2006 Nobel Prize in Chemistry for determining how DNA's genetic blueprint is read & used to direct the process of protein manufacturing

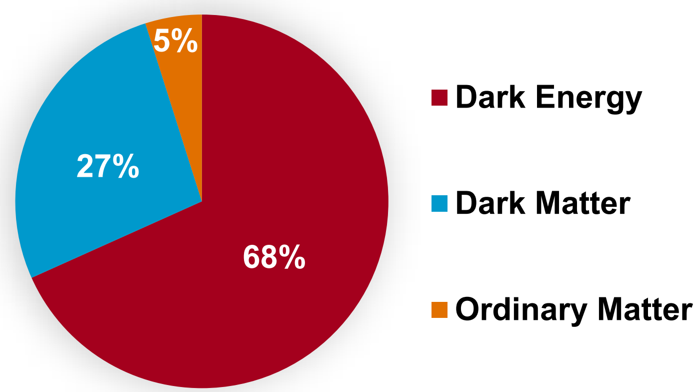
Brian Kobilka (Stanford), 2012 Nobel Prize in Chemistry for work on G-protein-coupled receptors

Frances Arnold (Caltech), 2018 Nobel Prize in Chemistry for inventing directed enzyme evolution

Today, SLAC designs, constructs and operates large-scale instruments to explore beyond the known universe

SLAC

- Exploring **high-energy gamma-rays**, **dark energy**, **dark matter** and **the origin of the universe**
- Using satellites, telescopes, underground detectors/facilities and **SLAC instrumentation capabilities**



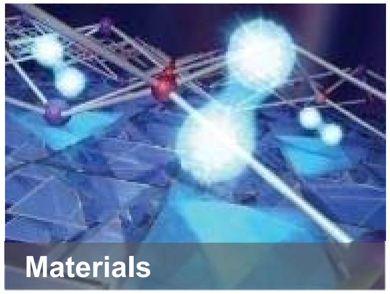

Fermi Gamma-ray Space Telescope

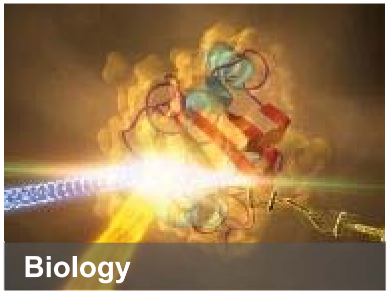

Large Synoptic Survey Telescope

LZ Next Generation Dark Matter Experiment


Super Cryogenic Dark Matter Search, SNOLAB

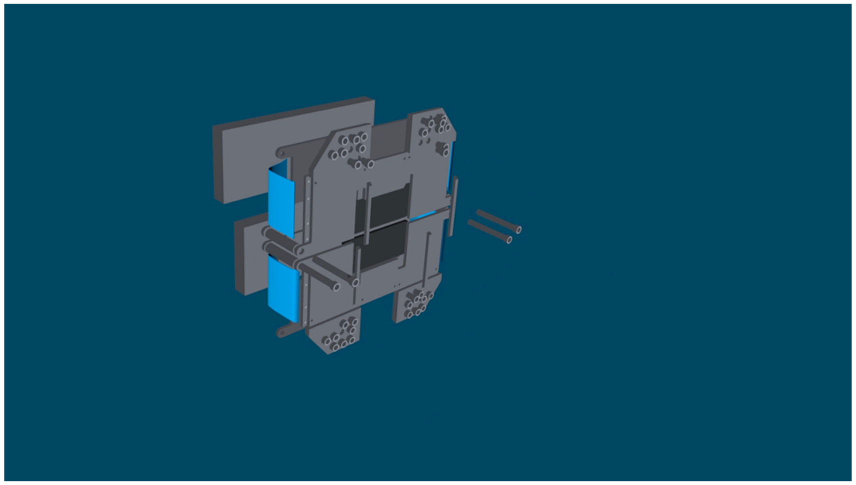
SLAC's linac was repurposed to build the world's 1st X-ray FEL to enable understanding of matter at fundamental time/length scales





LCLS opened up a revolution in X-ray science in 2009

- The world's brightest X-ray pulses – **1 billion times brighter** than those available before
- **Like a high-speed camera** with an incredibly bright flash, it takes X-ray snapshots of atoms and molecules at work
- Strings of snapshots form **"movies" showing chemical reactions** as they happen; e.g., how plants convert sunlight into useable energy

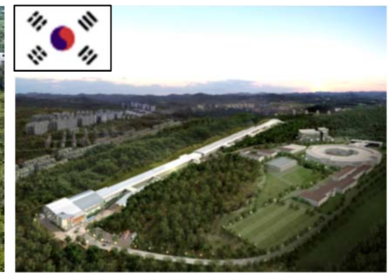


Success of LCLS has inspired strong competition

European XFEL,
Germany

SACLA,
Japan

SwissFEL,
Switzerland



PAL-FEL,
Korea

SCLF,
China

LCLS at SLAC,
United States

Boosting LCLS power and capacity with LCLS-II & LCLS-II-HE keeps the U.S. in the lead into 2030s

SLAC

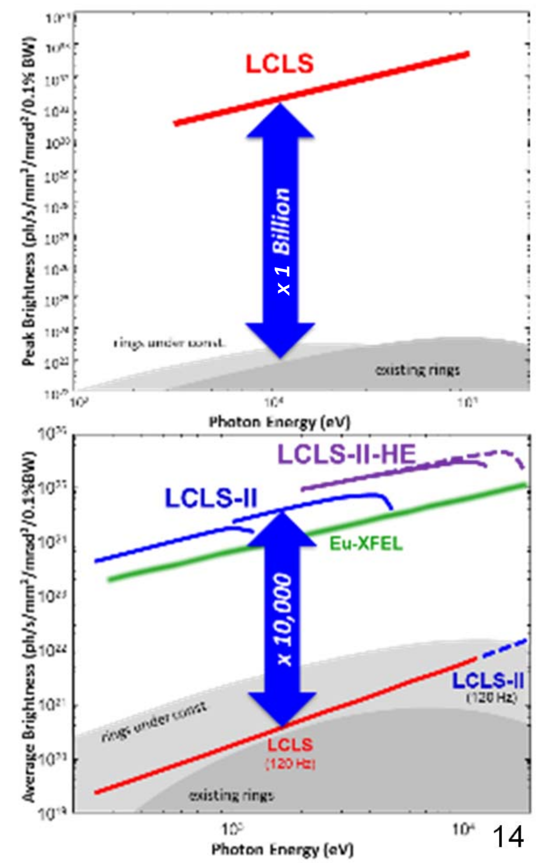
- New superconducting linear accelerator will create **nearly continuous X-ray laser beam** and works in parallel with existing copper linac
- Beam will be **10,000 times brighter** and **1,000 times more powerful**
- ~50% of total LCLS-II cost spend in **other national labs** using their core competencies

Fermilab

Argonne NATIONAL LABORATORY

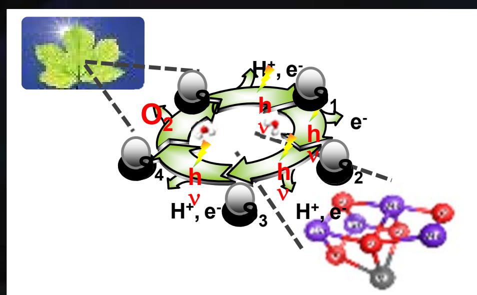
Jefferson Lab

BERKELEY LAB



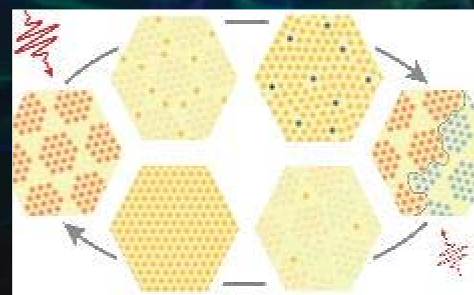
Leveraging our world-leading facilities, capabilities and expertise to broaden SLAC's scientific impact

Chemical Science



Using LCLS to capture the most complete and highest resolution picture to date of Photosystem II, a key protein complex in plants, to understand the past and create a greener future

Materials Science



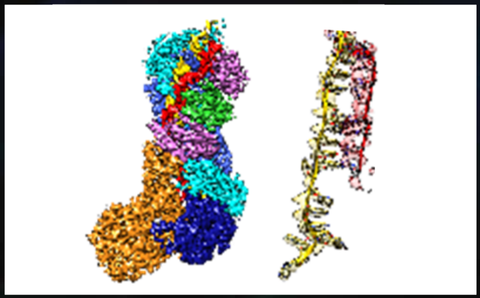
Using SLAC's instrument for ultrafast electron diffraction (UED) to switch the state of tantalum disulfide, leading to the development of new types of data storage devices

High Energy Density Science

Using SLAC's Matter in Extreme Conditions instrument at LCLS to simulate the interior of icy giant planets, allowing scientists to better model and classify planets

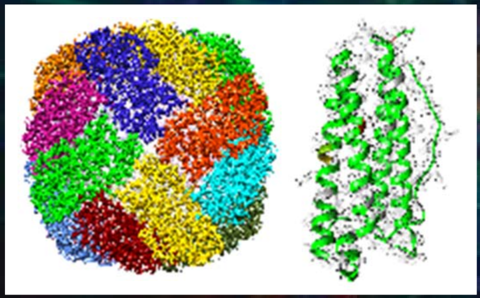
Adding important, new tools synergistic with the capabilities and science of our facilities: Cryo-electron microscopy

Type III CRISPR System



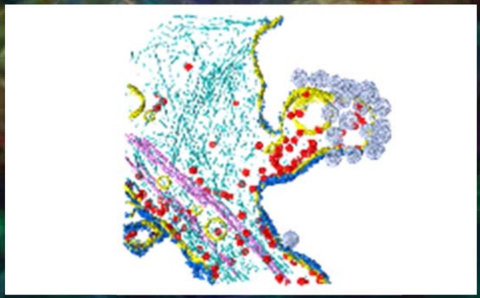
3.2 Å cryo-EM structure of csm-ssRNA reveals the interacting sites between the 10 proteins and 2 ssRNA in the complex to decipher the chemical mechanism of cleaving invading ssRNA

Human Apoferritin



1.7 Å cryo-EM structure of a protein nanomachine shows atomic positions of amino acids of proteins, water & ions demonstrating the readiness of using cryo-EM as part of the drug discovery process

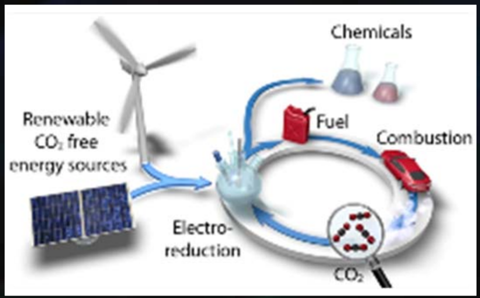
Chikungunya Viruses in Cell



Cryo-electron tomography of virus-infected cells reveals how neutralizing antibodies inhibit Chikungunya virus infection by preventing the virus budding

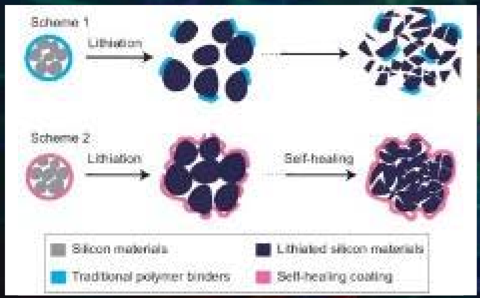
Applying our core capabilities and expertise to address real-world energy challenges

Atomic-scale Design of Catalysts



Conducting large-scale catalysis research at SUNCAT to accelerate discovery of future energy technologies, like making renewable fuels from carbon dioxide

Next-generation Battery Technology



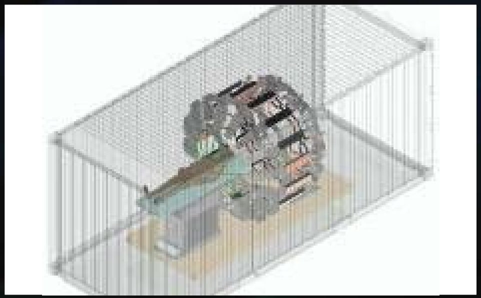
Advancing battery materials discovery by scientists at SIMES with novel X-ray characterization methods to make batteries smaller, cheaper and safer

Electric Power Grid

Developing new tools in our Grid Integration, Systems and Mobility group and at Stanford for modeling and optimizing the grid to support 21st century needs

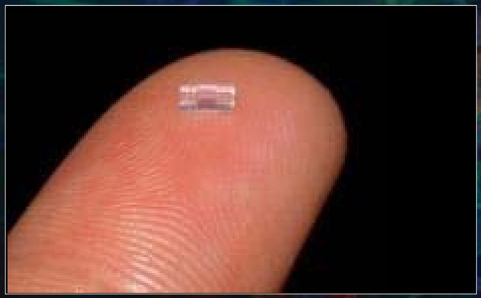
Advancing accelerators for real impact in a broad range of fields from medicine to national security

Device for X-ray Therapy (PHASER Project)



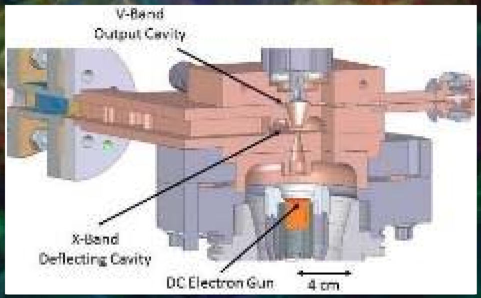
Using SLAC-developed high-power accelerator structures in a future device capable of delivering cancer radiation treatment in under a second instead of minutes

Microchip-sized Accelerator (Accelerator on a Chip)



Leveraging our accelerator proficiency to dramatically shrink the size and cost of particle accelerators used for medical therapy and imaging, and research in biology and materials science

Compact Source of Millimeter Waves



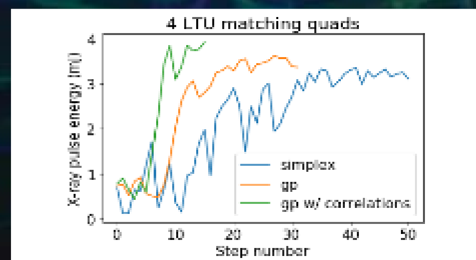
Applying our terahertz/ high-power radiofrequency expertise to generate high-frequency radiation with applications in science, radar, communications, security and medical imaging

Developing world-leading sensors, detectors and machine learning to advance X-ray science, high energy physics and computing

Superconducting (SC) Quantum Sensors

Developing sophisticated electronics (transition-edge sensors and SC quantum interference devices) for energy sensitive experiments in high energy physics and quantum information science

Machine Learning for Big Data



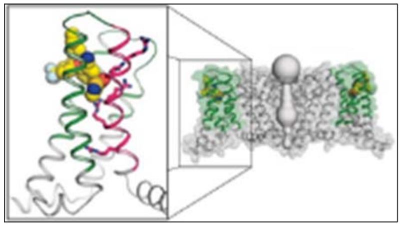
10x speed up tuning LCLS

Launching a new lab-wide machine learning initiative to address the rapidly developing, unprecedented big data needs from our facilities, particularly LCLS-II, -HE

Specialized Microchips

Designing application-specific integrated circuits (ASICs) for cutting-edge scientific research and applications, such as self-driving cars

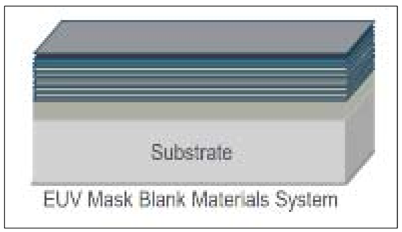
Partnering with Silicon Valley industry to develop new, disruptive technologies



Structure (left) shows how a potential drug blocks pain signals

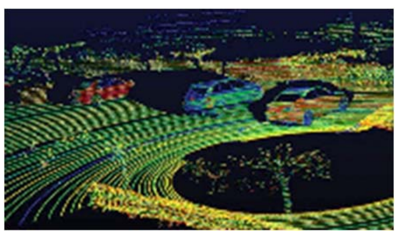
Genentech at SSRL

Actively using structure to guide development of novel therapeutics; led to 4 drugs in clinical use since 2011



Applied Materials

Extreme Ultra Violet (EUV) mask multi-layer mirror process development



Ouster

LIDAR technology for 3D mapping and self-driving cars

Summary

- SLAC is unique in the DOE complex due to support from Stanford
- Today, SLAC is world-leading in ultrafast and X-ray science and high energy physics, and expanding our impact in other areas of science and technology
- Continued support from Stanford and the Office of Science enables SLAC to contribute to a broader range of DOE mission needs