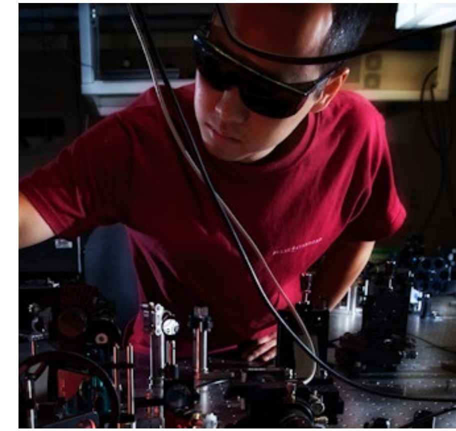
Photon Sciences at SLAC / Stanford University

Matthias Kling, Professor in Photon Science / Applied Physics, contact: **kling@stanford.edu**

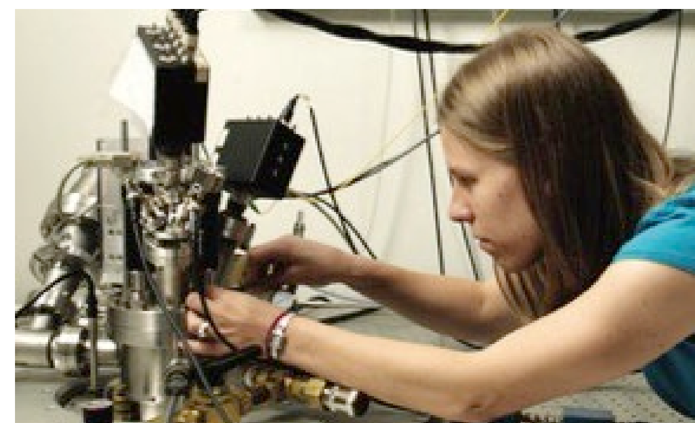
Interdisciplinary research teams driving internationally leading research



Photon Science has 38 faculty (12 full, 14 joint, 12 term-limited) **over diverse disciplines**

Applied Physics, Physics, Chemistry, Materials Science, Chemical Engineering, Electrical Engineering, Geosciences, Structural Biology, Bioengineering, ...

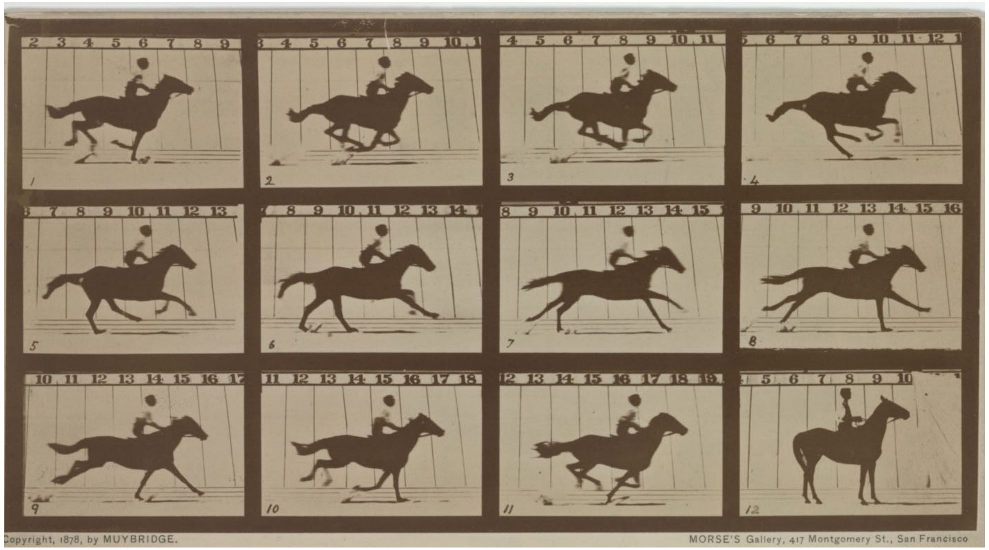
https://faculty.slac.stanford.edu/photon-science-faculty



- **Joint Research Institutes:**
  PULSE, SIMES, SUNCAT
- **Unique Facilities:**
  LCLS, **LCLS-II**, SSRL, UED, FACET, cryo-EM, ASC-labs, etc.

The time axis – recording (ultra)fast movies

The first movie (recorded at Stanford)

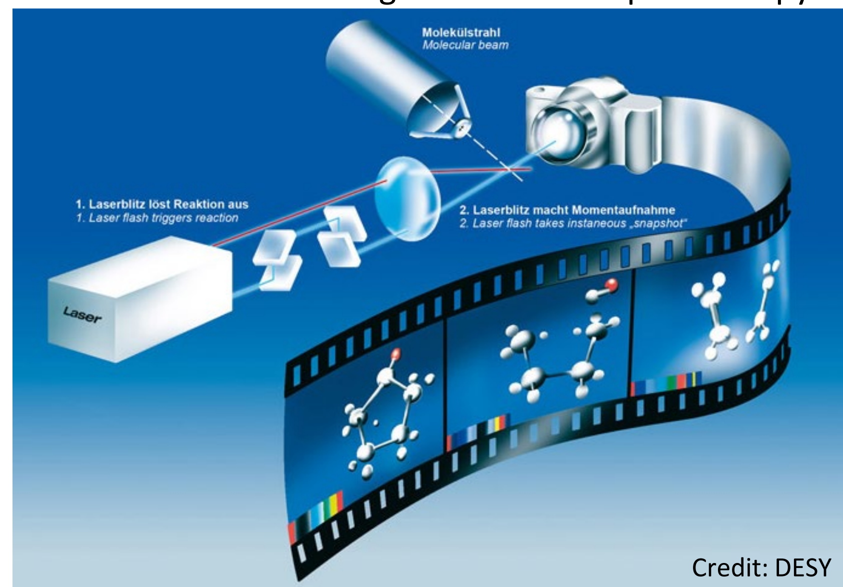


The Horse in Motion ("Sallie Gardner," Owned by Leland Stanford; Running at a 1:40 Gait Over the Palo Alto Track, 19th June 1878)

E. Muybridge

Nobel Prize
in chemistry
1999

Ahmed H. Zewail for „for his studies of the transition states of chemical reactions using femtosecond spectroscopy"



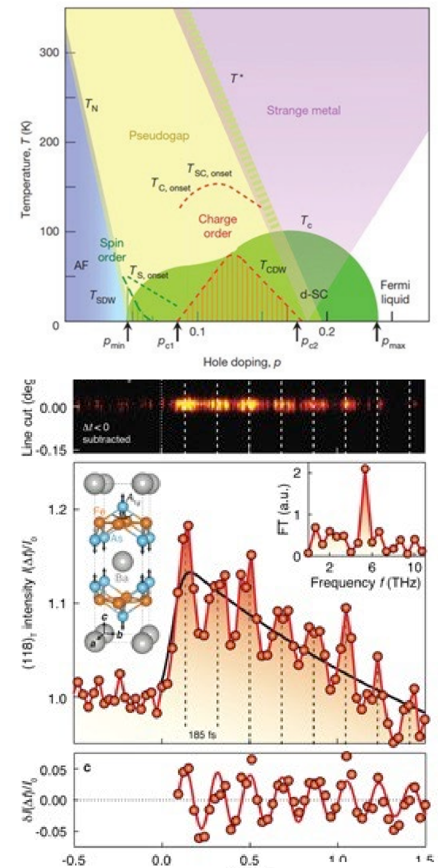
Credit: DESY

Now: attosecond flashes of light at Stanford
1 as = 0.000 000 000 000 000 001 s (10^{-18} s)

Stanford Institute for Material and Energy Sciences — SIMES

https://simes.stanford.edu/

- Why do **quantum electronic materials** have unique emergent properties?
- What are **pathways to convert** photons into energy and to store energy chemically?
- How can we **design and synthesize materials**, both physically- and bio-inspired, that exhibit these amazing quantum and energy transformative properties?
- How can we **best measure, probe, and simulate** the ultrafast photonic and electronic processes that drive all of the above?



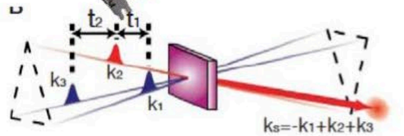
Contact: Director Harold Hwang, hyhwang@stanford.edu

Stanford PULSE Institute

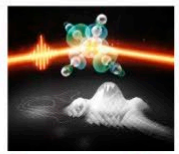
https://ultrafast.stanford.edu/

- **Ultrafast Theory and Simulation**

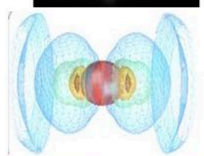
- **Attosecond science**



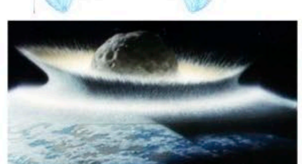
- **Ultrafast Chemistry**



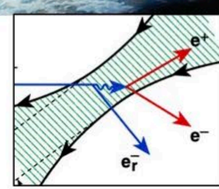
- **X-ray Movies of Molecules in Motion**



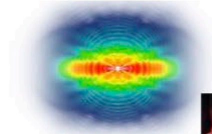
- **High Energy Densities**



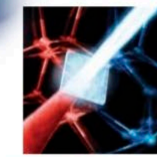
- **QED at the Schwinger limit**



- **Strong Field AMO Physics**

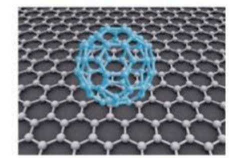


- **Solild State High Harmonics**

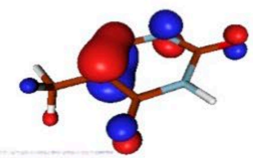


- **Nonlinear X-ray interactions**

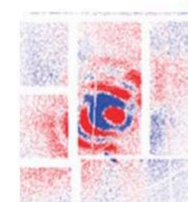
- **Electron Dynamics on the Nanoscale**



- **Ultrafast X-Ray Spectroscopy**



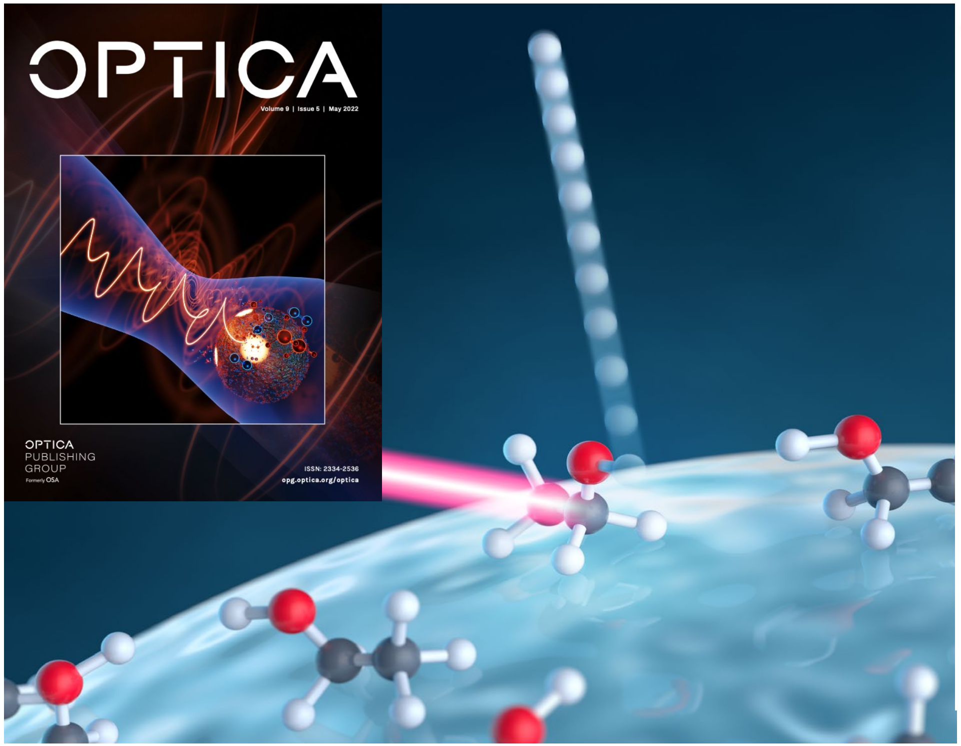
- **Ultrafast Materials Science**



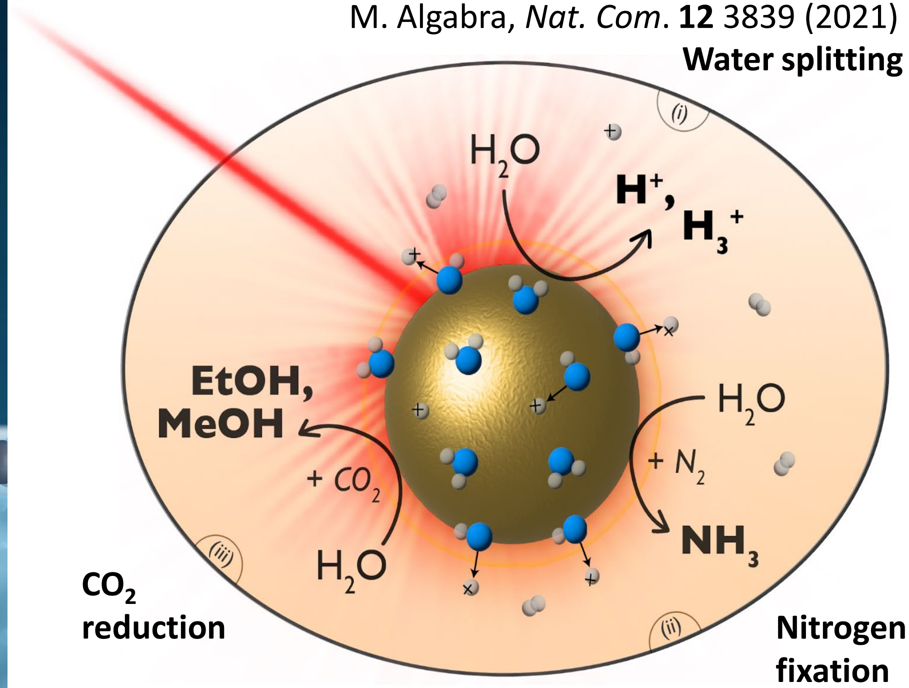
Contact: Director David Reis, dreis@stanford.edu

Ultrafast Dynamics on Nanoscale Surfaces (UDNS) @ PULSE

Reaction nanoscopy of nanocatalytic processes



M. Algabra, *Nat. Com*. **12** 3839 (2021)



P. Rupp *et al*., *Nat. Com*. **10**, 4655 (2019); W Zhang, *Optica* **9**, 551-560 (2022).

Unique X-ray Facilities at SLAC

SSRL Synchrotron Radiation

Contacts: Paul McIntyre & Piero Pianetta
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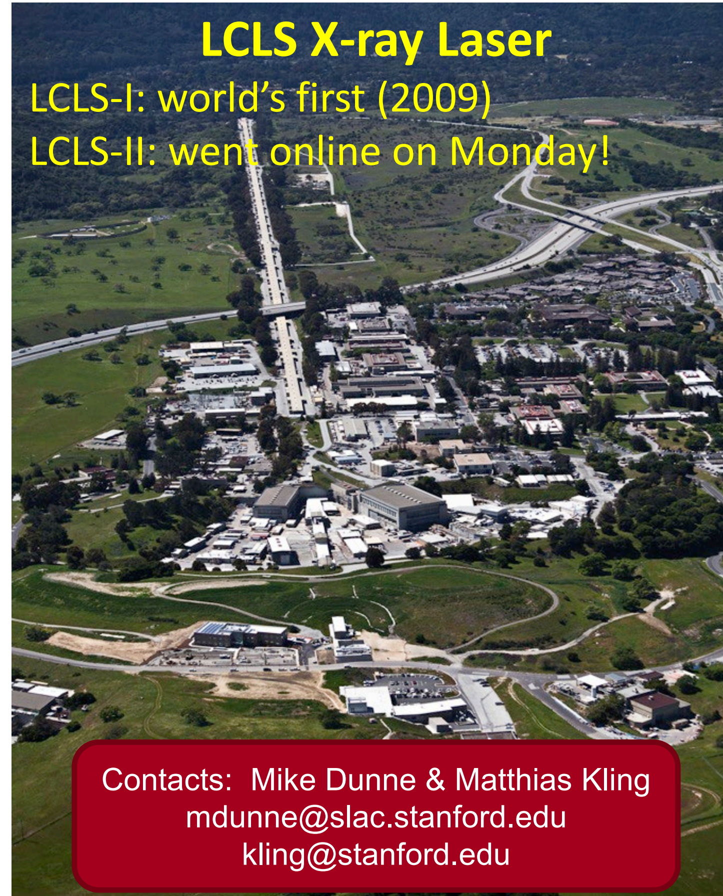
pianetta@stanford.edu

LCLS X-ray Laser

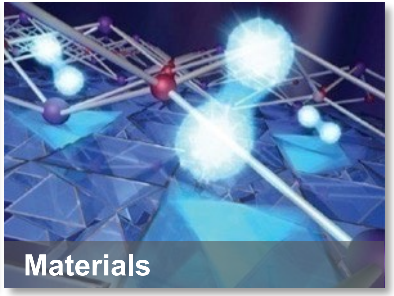
LCLS-I: world's first (2009)

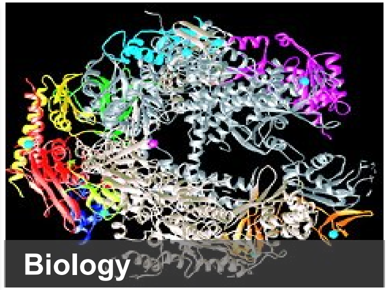
LCLS-II: went online on Monday!

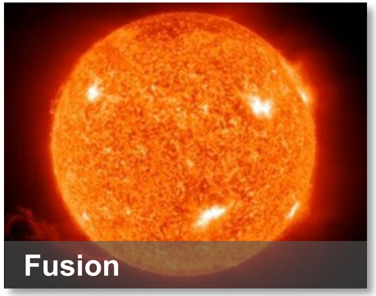


Contacts: Mike Dunne & Matthias Kling
mdunne@slac.stanford.edu
kling@stanford.edu

SLAC's unique facilities enable high-impact scientific discoveries addressing national challenges in climate, clean tech, microelectronics







The Linac Coherent Light Source delivers ultrafast x-rays for a broad range of science

World's first hard X-ray free-electron laser achieves first light

[LCLS] will give scientists an unprecedented tool for studying and understanding the arrangement of atoms in materials …and biological molecules, with wide-ranging impact on advanced energy research and other fields.

Stanford report, April 21, 2009

A billion times brighter than next brightest source…

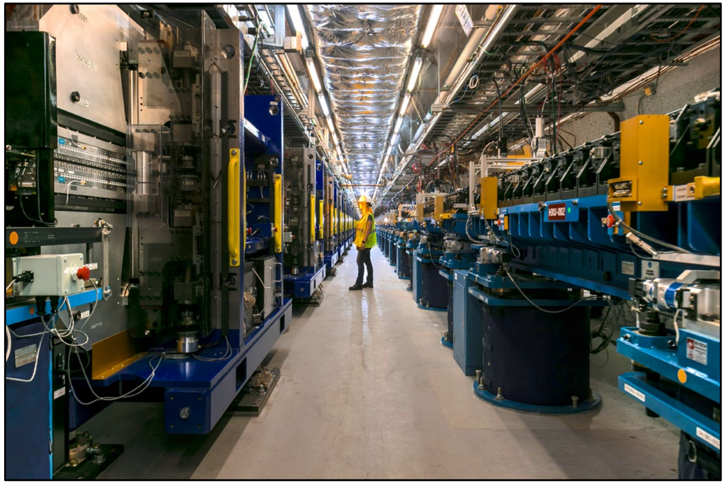
SLAC fires up the world's most powerful X-ray laser

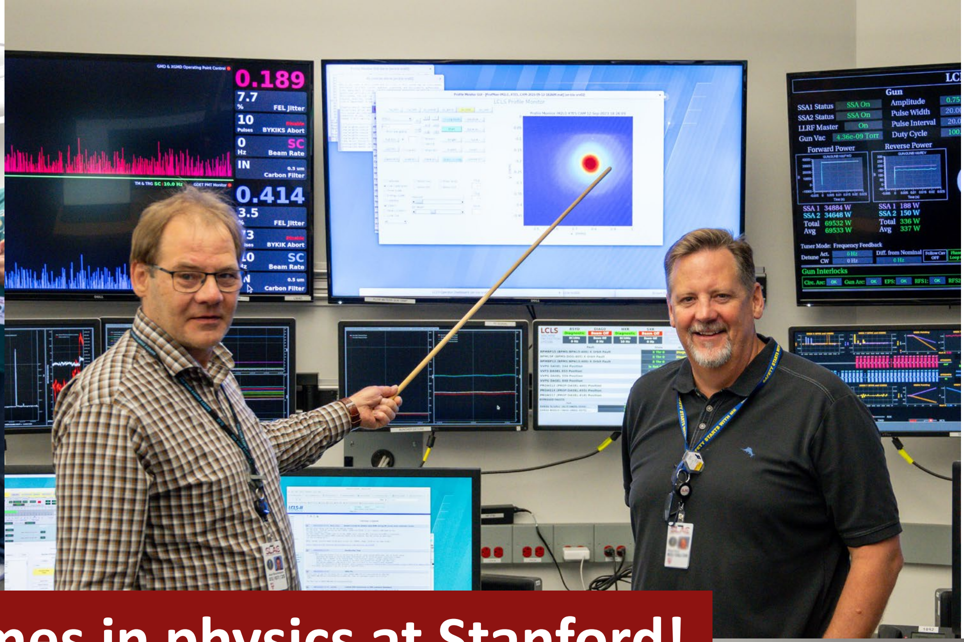
With up to a million X-ray flashes per second, LCLS-II transforms the ability of scientists to explore atomic-scale, ultrafast phenomena that are key to a broad range of applications.

Stanford report, September 18, 2023

Ten-thousand times brighter than LCLS

LCLS-II: Leading the world in Accelerator and X-ray science



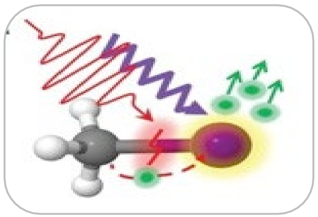


One of the most exciting times in physics at Stanford!

Results to date from LCLS have highlighted the key areas where coherence, fs time-resolution, and high rep-rate can have a revolutionary impact

Seeing how physics drives chemistry

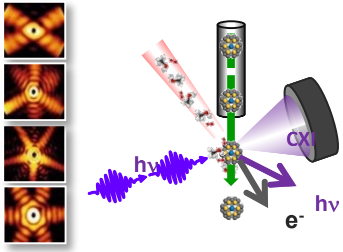
- Reveal coupled electronic and nuclear motion in molecules
- Capture the initiating events of charge transfer chemistry with sub-fs resolution



Ultrafast

The origins of catalytic acceleration

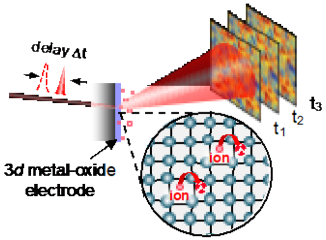
- Directly correlate catalytic reactivity with atomic structure in real-time
- Identify design principles for far-from-equilibrium chemical transformations



High repetition rate

Understanding material function and failure

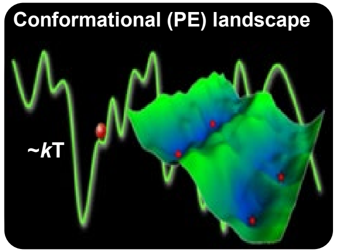
- Characterize dynamic systems without long-range order
- Directed design of energy conversion and storage materials



Coherence

Watching biology in action

- Study large scale conformational changes via solution scattering
- Physiological conditions
- Dynamics ties structure to function



Extreme brightness

LCLS-II and LCLS-II-HE will allow us to transform our understanding of dynamics in real-world chemical, material and biological systems

PULSE Ultrafast X-ray Summer School

Training the next generation(s) of x-ray free-electron laser researchers since 2007

UXSS 2022 | UXSS 2023

Stanford/SLAC | DESY/Hamburg

Annually since 2007 (3 years before LCLS)!
Since 2011 Joint with CFEL (Center for Free-Electron Laser Science),
2025 will include Paul Scherer Institute

Offering core courses in x rays, lasers and ultrafast science

APPPHYS 283: Ultrafast Quantum Physics (PHOTON 283), 2022

Intended for first-year graduate students who are interested in understanding the basic concepts of ultrafast quantum science to prepare for research in AMO physics, condensed matter physics, physical chemistry or quantum information science. The topics in this course are distinct from and complementary to AP 201 (Laser and X-ray Sources and Science) and AP 203 (AMO Physics and Quantum Optics). Topics for this course: Atomic structure probed in the time domain: Wave packets and quantum entanglement. Molecular structure probed in the time domain: Building up and then breaking down the Born-Oppenheimer picture. Extended quantum systems probed in the time domain: Band structure, phonons, and ultrafast disturbances interactions: From multi-photon absorption to tunnel-ionization. X-ray-matter interactions: Excitation, ionization, and linear and nonlinear scattering. Attosecond science: Impulsive excitation, Auger-Meitner decay, charge migration within molecules. Extreme time-domain quantum physics: high-field environments, and matter tunneling from the quantum vacuum.

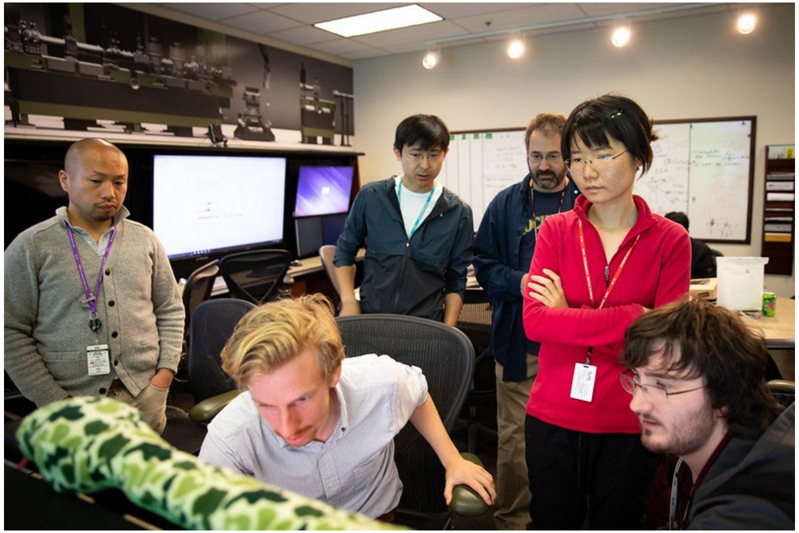
New in 2022

APPPHYS 325: Synchrotron Radiation and Free Electron Lasers: Principles and Applications. (PHOTON 325), 2023

Synchrotron radiation sources for scientific exploration, and x-ray FELs for studies of ultrafast processes at the atomic scale. Fundamental concepts in electron and photon beams, bending magnet and undulator radiation, one-dimensional and three-dimensional FEL theory and simulations, self-amplified spontaneous emission, seeding and other improvement schemes, x-ray methodology, techniques and instrumentation for the study of ultrafast phenomena. Includes selected laboratory tours of the Linac Coherent Light Source and/or Stanford Synchrotron Radiation Lightsource at SLAC.

Instructors: Kling, M. (PI) ; Marinelli, A. (PI)

Restructured in 2023



Come and join us – Photon Science at SLAC/Stanford

Getting to know us: Rotations opportunities

U.S. DEPARTMENT OF ENERGY

Stanford University