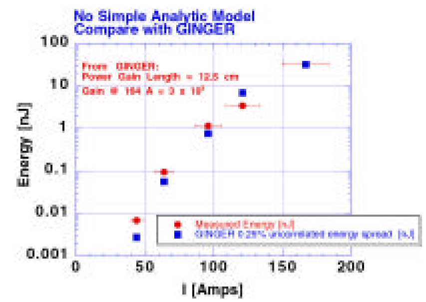
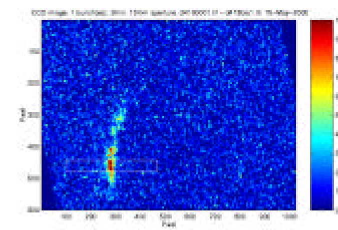
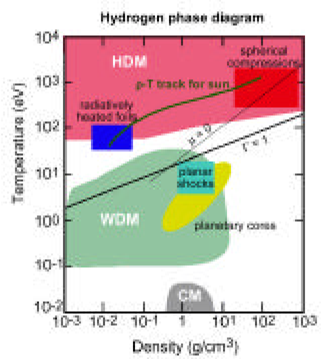
Linac Coherent Light Source (LCLS) Overview

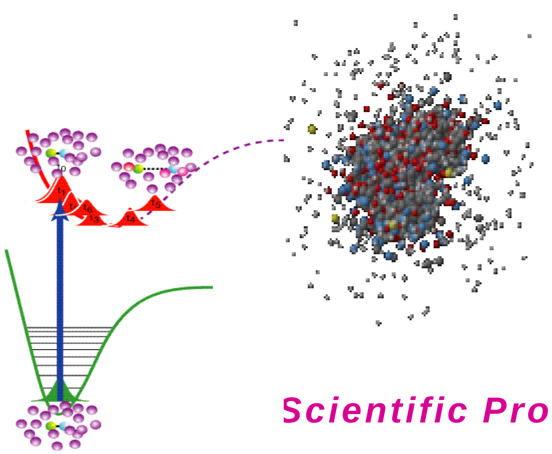
- A Framework for the Scientific Case







Research and Development



Scientific Program

Keith O. Hodgson
SSRL Director

Jonathan Dorfan
SLAC Director

October 10, 2000

A Multi-laboratory Collaboration Taking Advantage of Evolution and Convergence of Technologies to Enable LCLS

APS/ANL - NSLS/BNL - LANL - LLNL - SSRL/SLAC - UCLA

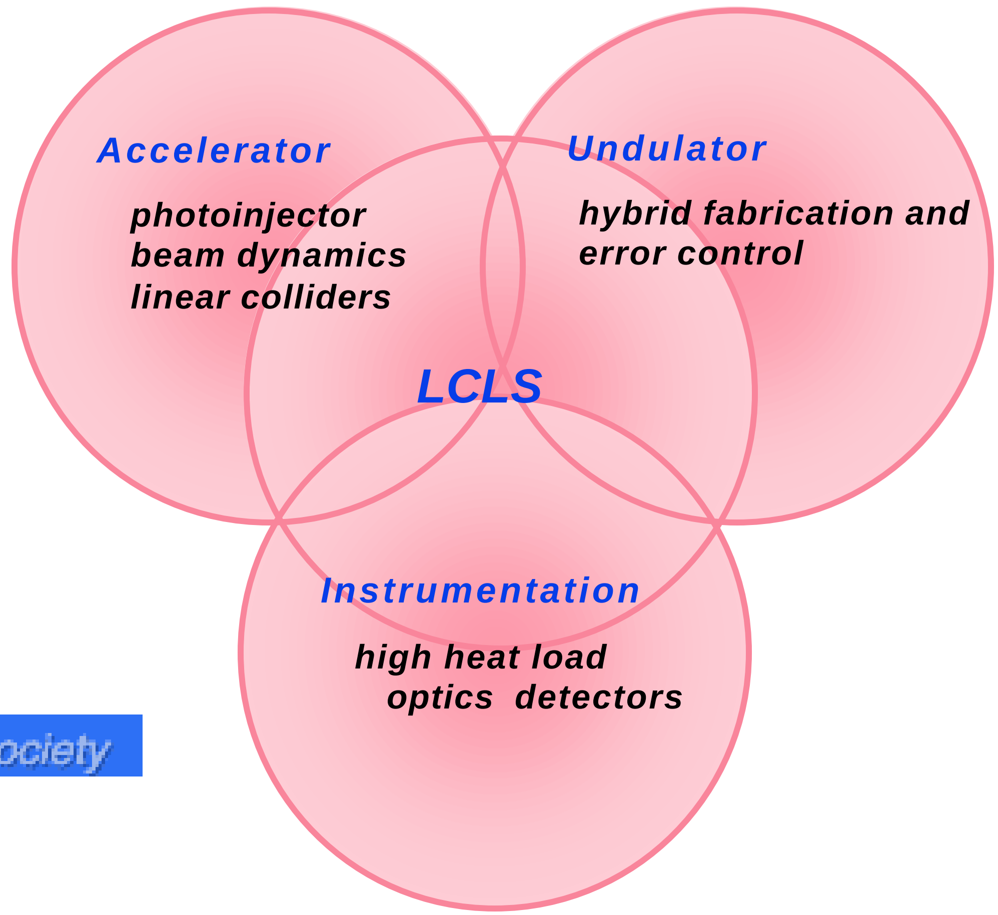
ADVANCED PHOTON SOURCE

nsls

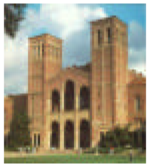
LLNL

Stanford Linear Accelerator Center

SSRL



Los Alamos
science serving society



UCLA

LCLS - an R&D facility engaging a broad range of experience and capabilities drawn from the synchrotron and high energy physics communities

Members of the LCLS Scientific Advisory Committee (SAC)

SAC Meetings

October 15, 1999
March 30-31, 2000
July 14, 2000

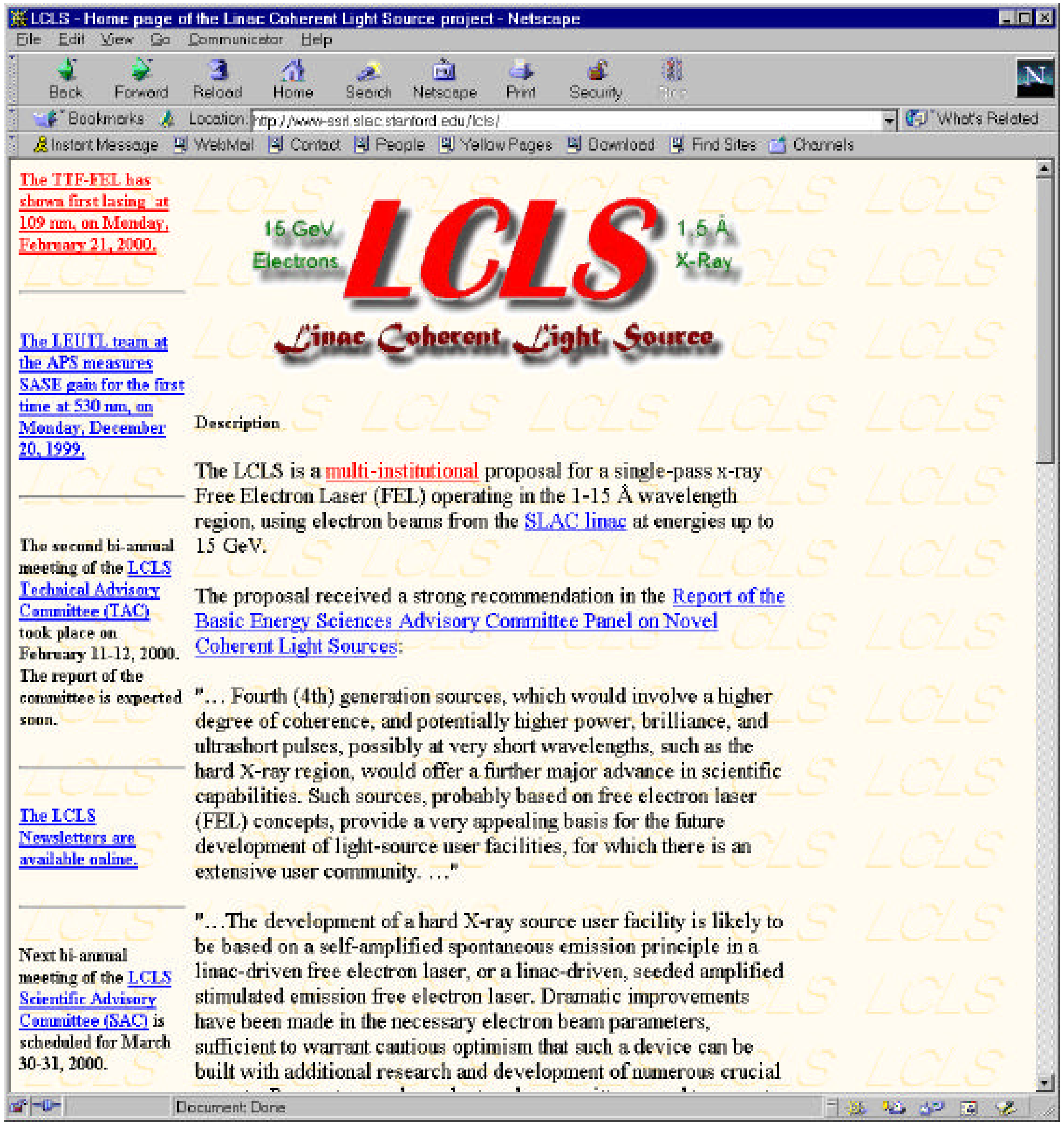
Phil Bucksbaum	University of Michigan
Roger Falcone	University of California, Berkeley
Rick Freeman	University of California, Davis
Andreas Freund	European Synchrotron Research Facility (ESRF)
Janos Hadju	Uppsala University
Jerry Hastings	National Synchrotron Light Source (NSLS)
Richard Lee	Lawrence Livermore National Laboratory (LLNL)
Ingolf Lindau	SSRL, Stanford Linear Accelerator Center (SLAC)
Gerd Materlik	HASYLAB
Simon Mochrie	University of Chicago
Keith Nelson	Massachusetts Institute of Technology
Francisco Sette	European Synchrotron Research Facility (ESRF)
Sunni Sinha	APS, Argonne National Laboratory
Brian Stephenson	APS, Argonne National Laboratory
Z.-X. Shen	Stanford University
Gopal Shenoy	**APS, Argonne National Laboratory, Co-Chairman**
Joachim Stohr	**SSRL, Stanford Linear Accelerator Center (SLAC) Chairman**

Members of the LCLS Technical Advisory Committee (TAC)

Bill Colson	**Naval Postgraduate School (NPS), Chairman**
Dave Attwood	Lawrence Berkeley National Laboratory (LBNL)
Jerry Hastings	National Synchrotron Light Source (NSLS)
Pat O'Shea	University of Maryland (UMD)
Ross Schlueter	Lawrence Berkeley National Laboratory (LBNL)
Ron Ruth	Stanford Linear Accelerator Center (SLAC)

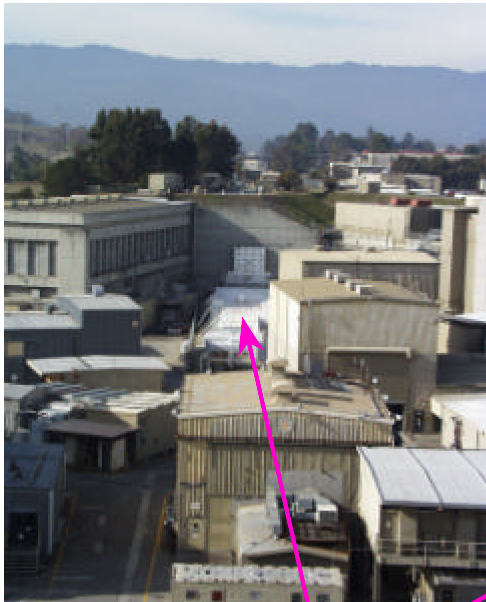
TAC Meetings

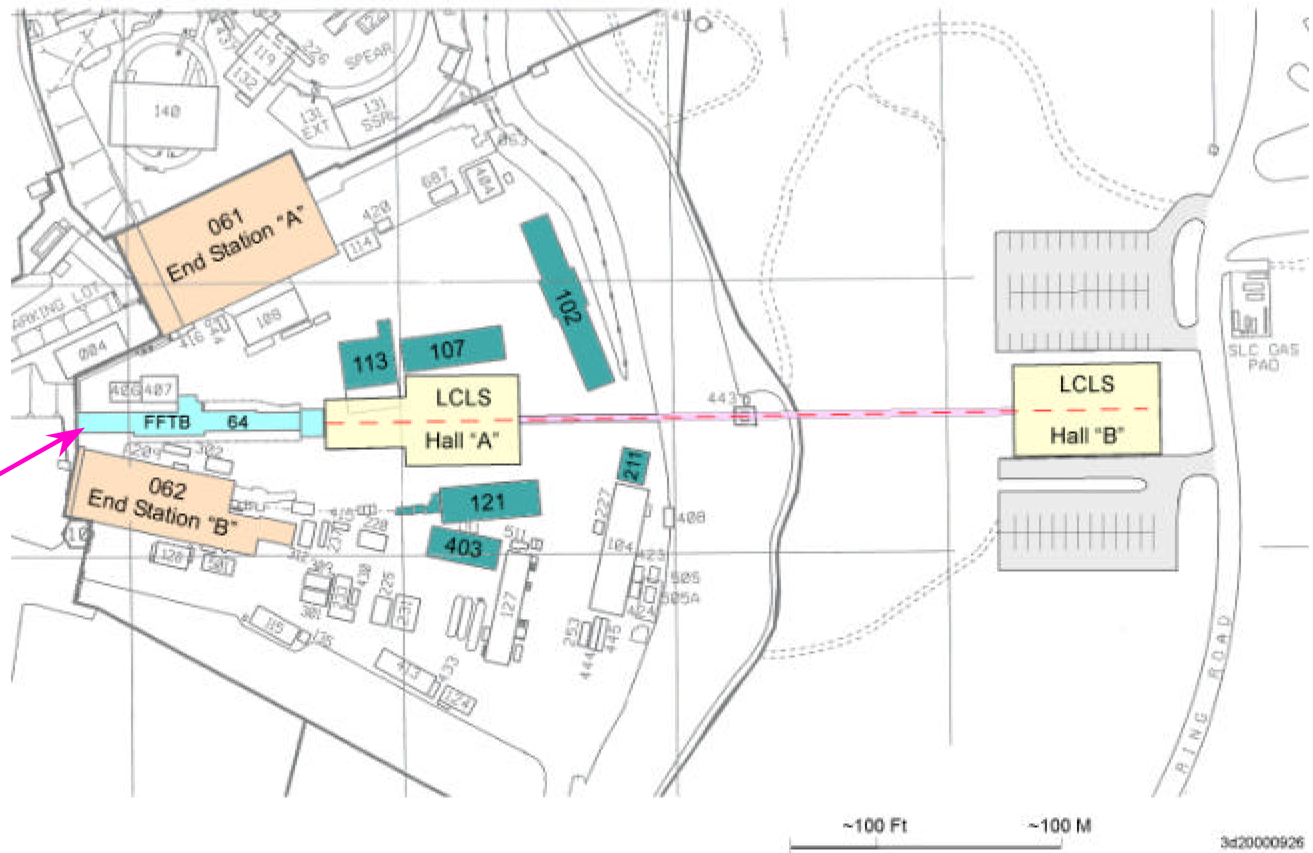
July 14-15, 1999
February 11-12, 2000
May 19-20, 2000



•WWW site (www-ssrl.slac.stanford.edu/lcls) provides on line information to scientific community

- Review committee activities and schedules
- Technical reports
- Highlights of R&D and links to activities worldwide
- Parameter design database





FFTB hall for undulator and diagnostics

Space in SLAC Research Yard for near (A) and far (B) experimental halls providing maximum flexibility with short and long beam lines

Strengthen baseline design

- Effort is ~ 14 FTEs from the collaborating institutions
- Covers all aspects of R&D and design, from photo-injector to experimental areas

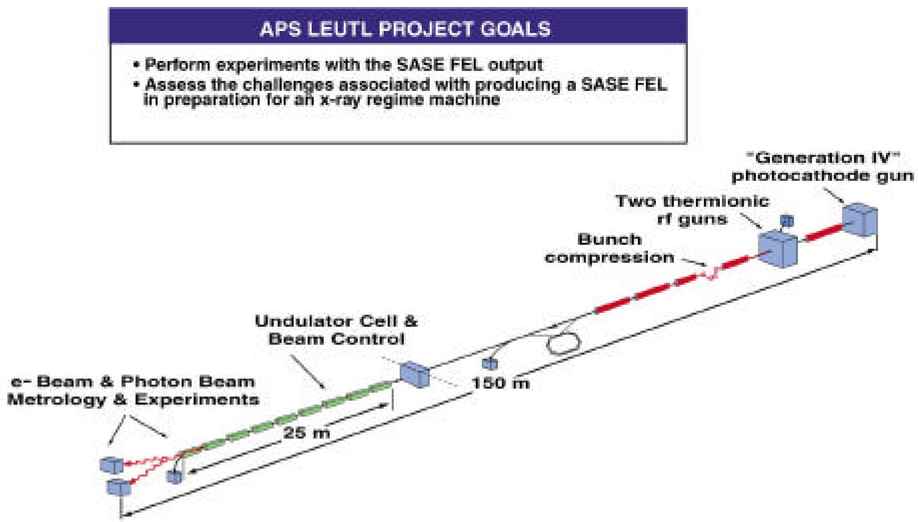
Experimental studies

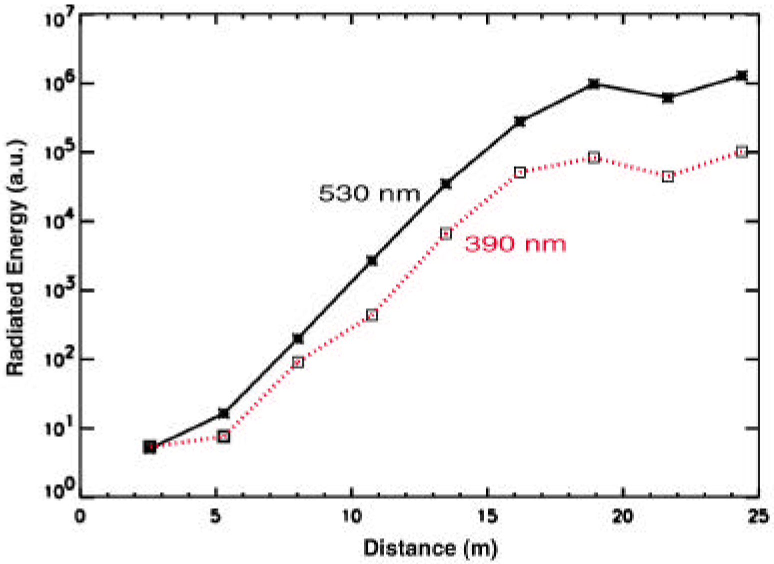
- Source brightness, e^- bunch compression, SASE experiments
- A large body of experimental data is accumulating that confirms the validity of the SASE theory and simulations and the premises of the LCLS design

Chronology of recent SASE experiments

- *High-Gain-Harmonic-Generation (HGHG), NSLS*
  - Large output power at 5.3 µm
- *TTF FEL, DESY*
  - Gain >3000 in the range 80-180 nm, possible saturation
- *VISA, LCLS collaboration*
  - Initial results show gain at 0.8 µm
- *LEUTL, APS*
  - Gain $>10^5$ observed at 530 nm
  - Saturation observed at 390 & 530 nm

Recent Results from the APS LEUTL FEL Facility





Recent results (unpublished) from APS LEUTL facility showing remarkable exponential gain in FEL radiation at 530 and 390 nm with clear saturation behavior, as predicted theoretically.

SASE-based FELs – The Global Picture - I

BESSYII – Berlin

- Flagged as a project in a call for large-scale facilities on the 200MDM range
- 2 GeV Linac, quasi-CW mode of operation
- VUV & soft X-ray facility
- Study group has been formed

SPring8 – Japan

- R&D plan, with start 5/2001, has been announced (~ 2M$/yr over 5 years)
- 5 GeV Linac based on C-band technology
- In collaboration with accerator physicists from KEK (KEK has responsibility for Linac and photocathode; Spring-8 for undulator)

Daresbury

- Study group formed to explore what to do with the site in the post-SRS era when DIAMOND is in operation (~ 5 years)
- A cluster of various FELs, including SASE-based, is being considered

TESLA Test Facility – DESY, Hamburg

Phase I:

- ~300 MeV superconductivity Linac
- Testing of SASE-concept
- First lasing Feb. 2000
- Lasing 80-180 nm, gain 10^3-10^4

Phase II:

- 1 GeV superconductivity Linac
- Under construction – fully funded
- VUV & soft X-ray laboratory
- Wavelengths down to 6 nm (fundamental; 3 nm in 3rd harmonic)
- Operational in 2002/03

TESLA 1Å XFEL – DESY, Hamburg

- Integral part of the proposed TESLA (next generation Linac for high-energy physics)
- Technical Design Report, including scientific case*, to be completed in the Spring of 2001
- Time-schedule: operational 2009/10

* a series of workshops held April-October 2000

Signing a Memorandum of Understanding on Cooperation in a Joint Effort to Develop the Technological Base for a Free Electron Laser

January 21, 2000

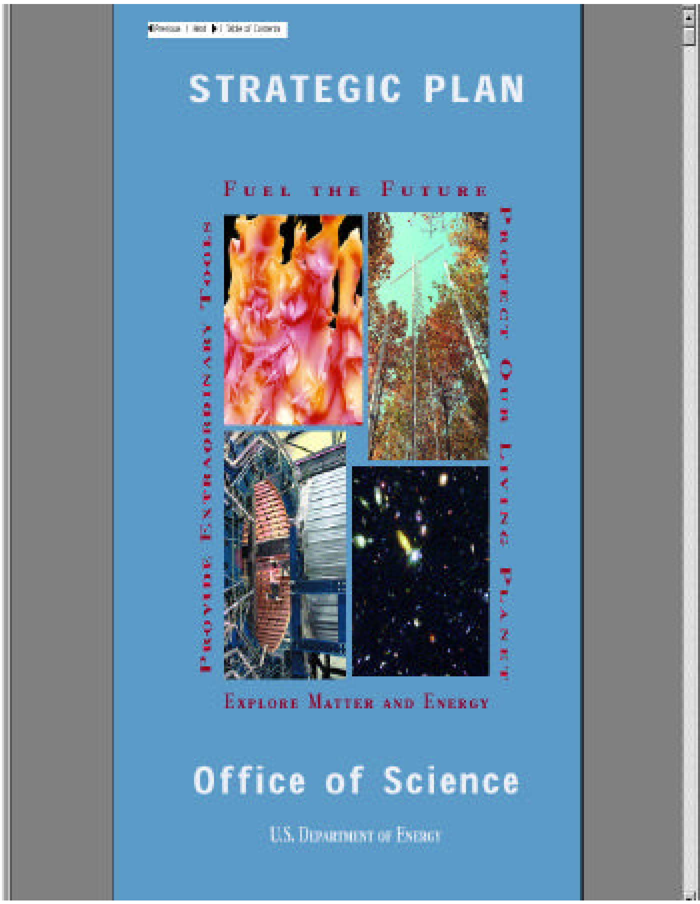
- An intense, coherent, ~1Å X-ray source will provide an enormously exciting and diverse science program — one that will open up new vistas of inquiry and discovery
  - Capitalizing on this opportunity is being aggressively pursued by groups in the U.S., Europe and Japan

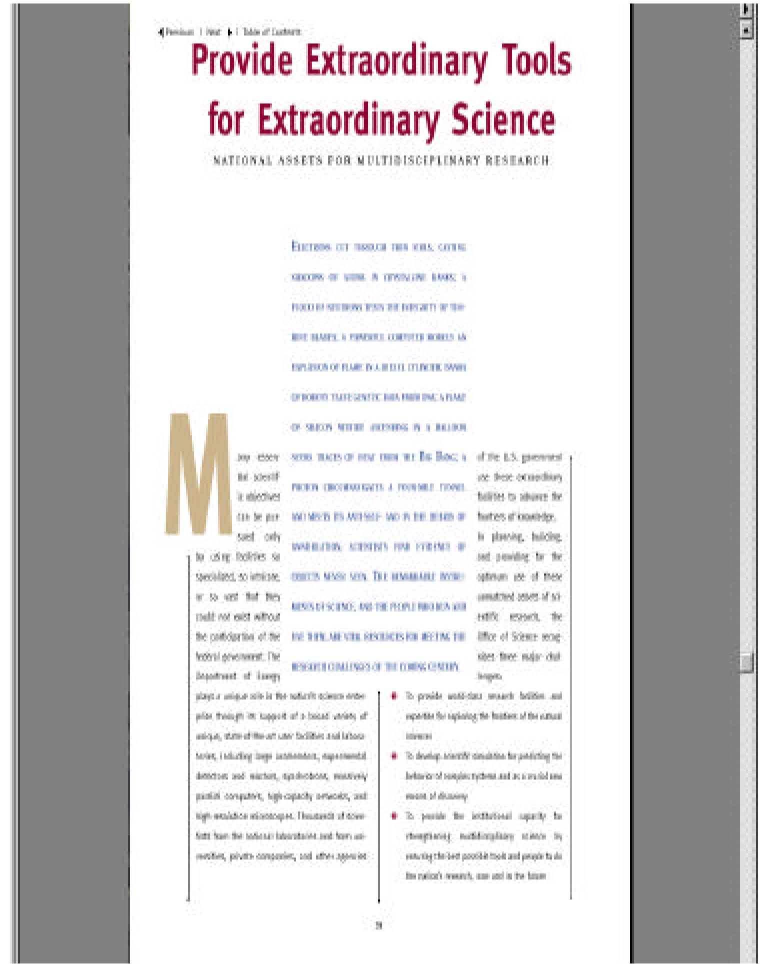
- The U.S. is well positioned to establish the first source of this kind world-wide — the unique infrastructure at SLAC provides many of the key elements for a rapid, risk-averse implementation

- SLAC has a long tradition of successfully developing novel accelerator-based facilities. SLAC welcomes the opportunity to join with its National partners to host this exciting scientific adventure
  - Ø SLAC will give the LCLS its highest priority in developing a conceptual design and during construction

- Our most recent construction project — the *B* Factory — was completed ahead of schedule and within budget
  - The *B* Factory machine comprised a $200M upgrade of an existing facility, to build a pair of energy asymmetric storage rings to produce unprecedentedly high integrated luminosities. Both the conceptual design and the construction were done in collaboration with LBNL and LLNL
  - The *B* Factory detector comprised a $120M device build as a collaboration of 600 scientists from 9 nations
    - SLAC has a proven record of successfully managing major design and construction projects involving major partnerships
    - Within one year of first collisions, the *B* Factory was producing design performance integrated luminosity
- SPEAR3 is proceeding very well. The recent Lehman Review was extremely complimentary about the progress of this upgrade

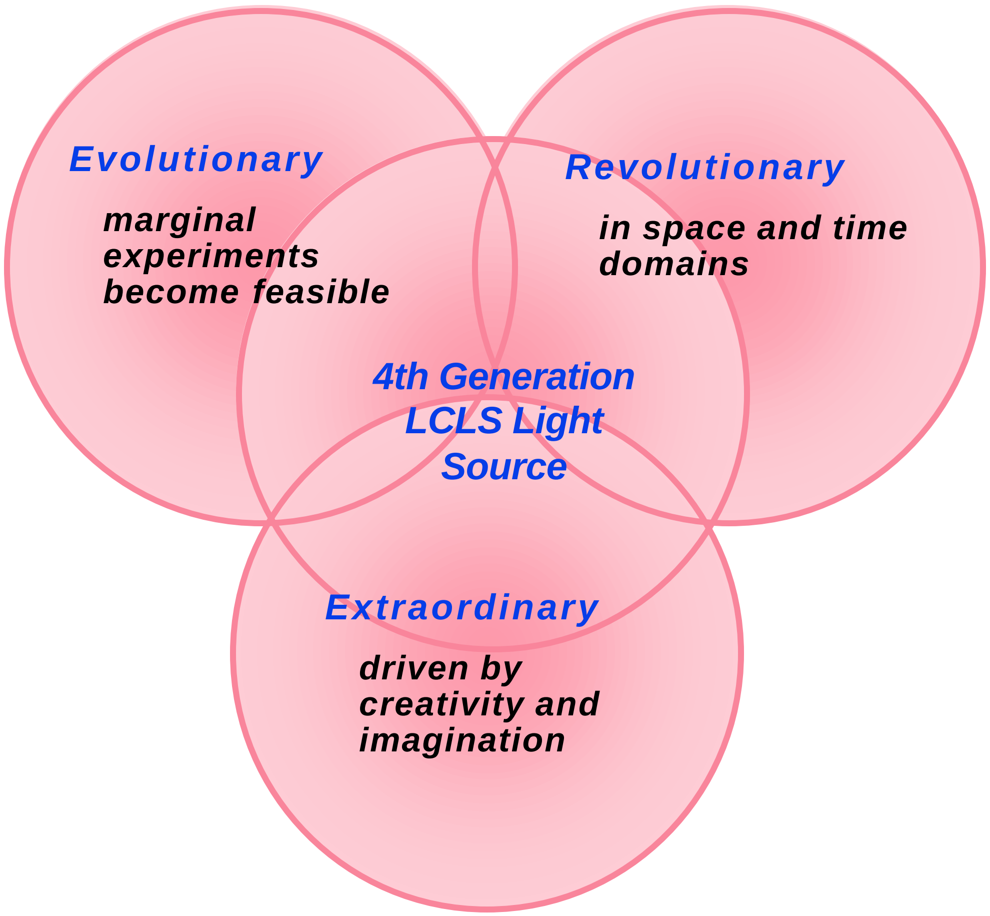
- As we have done with the construction of SPEAR3 and the LCLS R&D program, SLAC will deploy its premier engineers and technical staff to ensure the success of LCLS
  - The Vacuum and RF engineering teams on SPEAR3 came directly from the *B* Factory team
  - The lead engineer on LCLS R&D was the Chief Engineer of the *B* Factory
- We have made the decision at SLAC to dedicate the last 1/3 of the Linac to the LCLS. We have committed to ensuring a minimum of at least 75% of the annual operating time of this section of the Linac to dedicated LCLS operation. One should assume that all but the 2 months set aside for annual maintenance and experiment reconfiguration constitute the available operating time
- We seek BESAC's strong endorsement to proceed to the conceptual design phase of this exciting project
  - Given the go-ahead late this Fall, we can complete the CDR and undergo a Lehman Review in time for a FY2003 construction start


STRATEGIC PLAN
Fuel the Future
Provide Extraordinary Tools
Protect Our Living Planet
Explore Matter and Energy
Office of Science
U.S. Department of Energy


Provide Extraordinary Tools for Extraordinary Science
NATIONAL ASSETS FOR MULTIDISCIPLINARY RESEARCH

Defining the 4th generation x-ray light source as having:

ultrahigh brightness - coherence - sub-psec pulses - wavelengths of ~1 Å



- **Peak brightness** exceeds existing x-ray sources by > 10^9
- **Time resolution** exceeds 3rd gen. synchrotron sources by a factor 10^3
- **Coherence**: degeneracy parameter exceeds present sources > 10^9

- **A Broad Scientific Case Document Being Coordinated and Edited by APS under the Leadership of Gopal Shenoy**
- Meetings held and being planned by specialized working groups
- The current goal is to complete the document by late 2000 or early 2001

1.0 Executive Summary

2.0 X-ray FEL Radiation

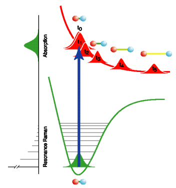
2.1 Introduction
2.2 The Physics of SASE Process
2.3 Role of Laser Technology in X-ray FEL Development
2.4 The X-ray FEL User Facility and Characteristics
2.5 FEL Performance: User Requirements
2.6 Center for Laser Development
2.7 Conclusions

3.0 Science and Technology

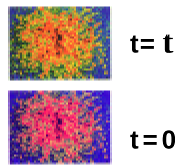
3.1 Introduction
3.2 Experimental Opportunities for Science and Technology
3.2.1 Peak Brilliance Methods
3.2.2 Time Resolved Techniques and High Intensity Lasers
3.2.3 Multi-Photon Methods
3.2.4 Radiation Damage
3.2.5 X-ray FEL Optics
3.2.6 Detectors for X-ray FEL Science
3.3 Science and Technology Applications
3.3.1 Life Sciences
3.3.2 Condensed Matter/Material Science and Technology
3.3.3 Chemical Science and Technology, and Femtosecond Chemistry
3.3.4 Atomic and Plasma Physics
3.3.5 Fundamental Physics
3.3.6 X-ray Quantum Optics

APPENDICES

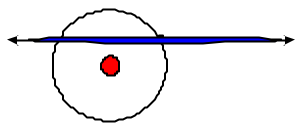
A. The Process Used in Generating the Document
B. Contributors to the Document
C. Background Workshops
D. Concept for X-ray FEL Facility and Center for Laser Development
E. Limitations of Third Generation X-ray Sources
F. Development of Science-Driven Goals
G. Proposed Scientific R&D Program at the LCLS
H. LCLS R&D Funding Needs in Support of Coherent X-ray Facility Science
• Other R&D Projects in Support of Coherent X-ray Facility (Laser Development, etc.)
K. User Community



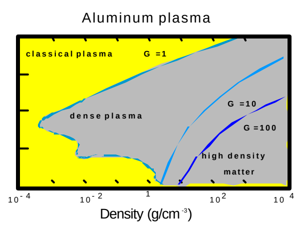
Femtochemistry — Dan Imre, BNL



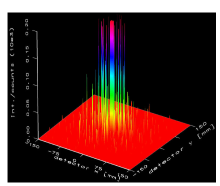
Nanoscale Dynamics in Condensed Matter — Brian Stephenson, APS



Atomic Physics — Phil Bucksbaum, Univ. of Michigan



Plasma and Warm Dense Matter — Richard Lee, LLNL



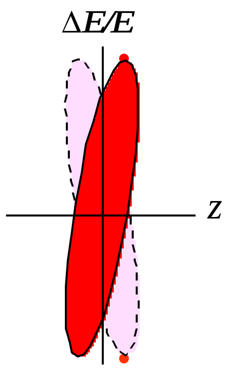
Structural Studies on Single Particles and Biomolecules — Janos Hajdu, Uppsala Univ.

Program developed by international team of ~45 scientists working with Accelerator and Laser Physics communities

X-ray Laser Physics

The "sixth" experiment - LCLS parameters will evolve in time with advances in accelerator and optics R&D

- **The flexibility of the LCLS design opens the possibility of operating it with ultra short bunches (< 50 fs). This can be obtained by:**

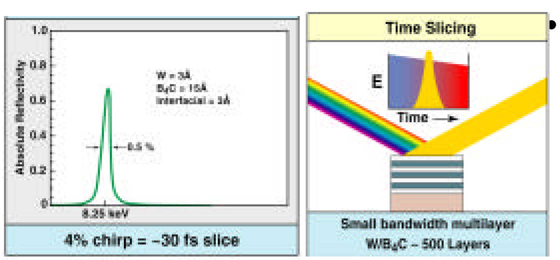


Stronger compression of the electron bunch

- No new hardware is required

Photon bunch compression or slicing

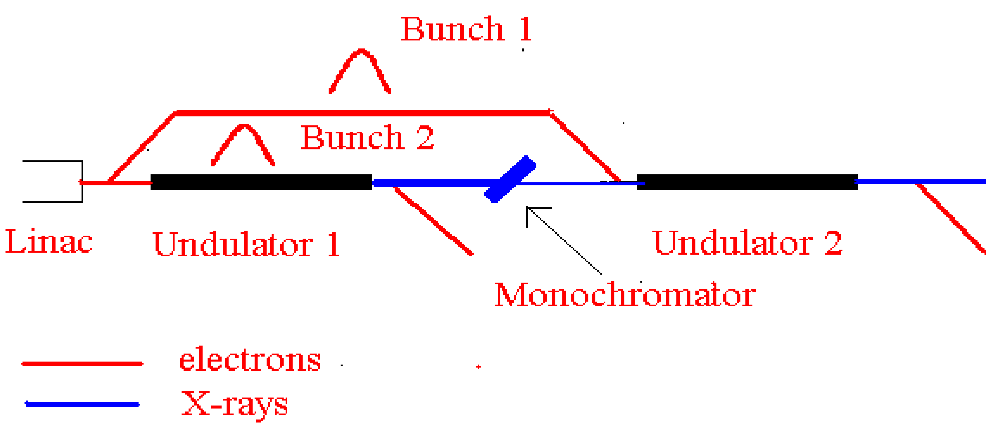
- Principle: *spread the electron and photon pulses in energy; recombine optically or select a slice in frequency*



- Study indicates concepts appear sound and simulations will continue, but ultimately require experimental verification. *Operation will begin at the nominal (230 fs) bunch length and R&D to reduce it to <50 fs within 1-2 years can be anticipated*

The "sixth" experiment - LCLS parameters will evolve in time with advances in accelerator and optics R&D

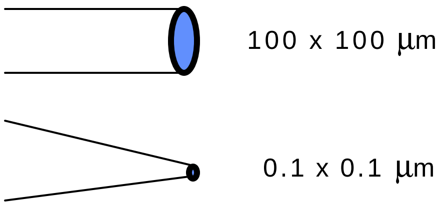
- **Reduction, with seeding, of the line-width corresponding to the bunch length Fourier transform limit. Two methods:**
  - Filtering spontaneous radiation to produce a seed
  - Cascade scheme: seeding the FEL at longer wavelengths, followed by harmonic generation
    - Bandwidth could be reduced from 2×10^{-4} to 10^{-6}
    - Baseline design is compatible with this upgrade



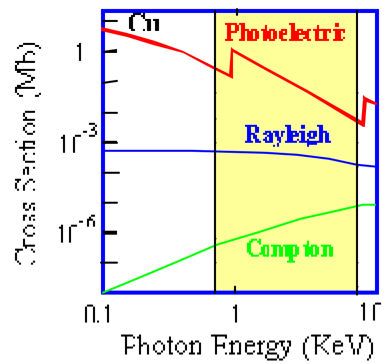
The two bunch linewidth reduction scheme

LCLS Beam can Probe or Manipulate Matter

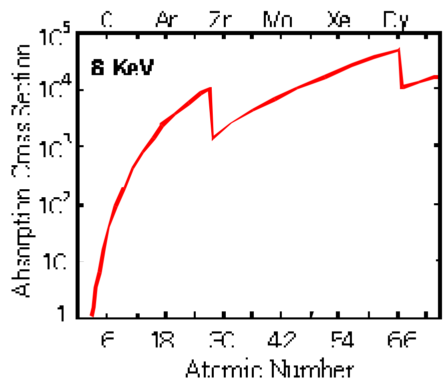
- **Flux density can be varied by focussing: factor 10^6**



- **X-ray absorption can be varied by tuning energy: factor 10 - 10^2**

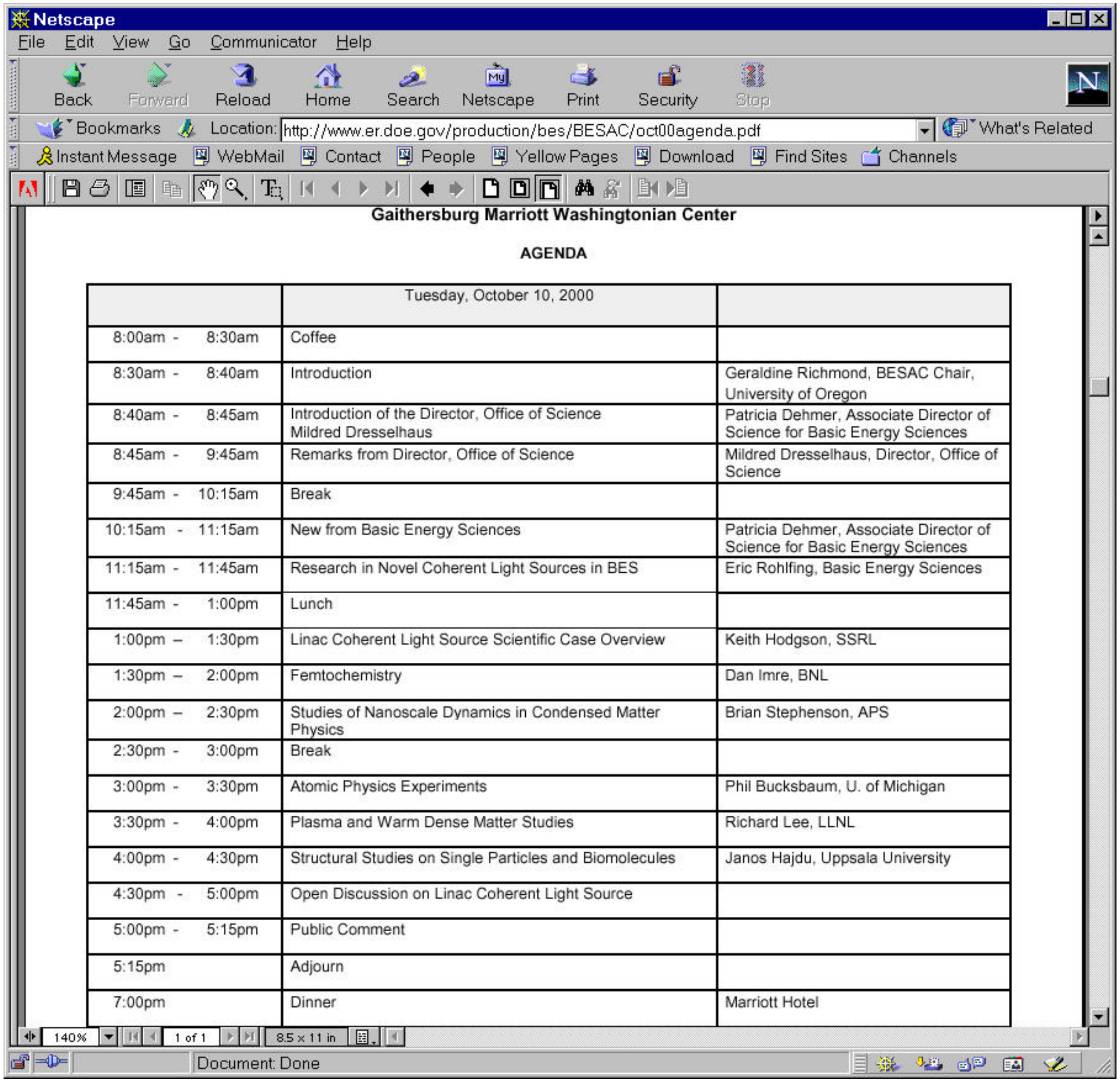


- **X-ray absorption depends on atomic number: factor 10^5**



LCLS - The First Experiments - BESAC Agenda

LCLS



Gaithersburg Marriott Washingtonian Center

AGENDA

	Tuesday, October 10, 2000	
8:00am - 8:30am	Coffee	
8:30am - 8:40am	Introduction	Geraldine Richmond, BESAC Chair, University of Oregon
8:40am - 8:45am	Introduction of the Director, Office of Science Mildred Dresselhaus	Patricia Dehmer, Associate Director of Science for Basic Energy Sciences
8:45am - 9:45am	Remarks from Director, Office of Science	Mildred Dresselhaus, Director, Office of Science
9:45am - 10:15am	Break	
10:15am - 11:15am	New from Basic Energy Sciences	Patricia Dehmer, Associate Director of Science for Basic Energy Sciences
11:15am - 11:45am	Research in Novel Coherent Light Sources in BES	Eric Rohlfing, Basic Energy Sciences
11:45am - 1:00pm	Lunch	
1:00pm – 1:30pm	Linac Coherent Light Source Scientific Case Overview	Keith Hodgson, SSRL
1:30pm – 2:00pm	Femtochemistry	Dan Imre, BNL
2:00pm – 2:30pm	Studies of Nanoscale Dynamics in Condensed Matter Physics	Brian Stephenson, APS
2:30pm - 3:00pm	Break	
3:00pm - 3:30pm	Atomic Physics Experiments	Phil Bucksbaum, U. of Michigan
3:30pm - 4:00pm	Plasma and Warm Dense Matter Studies	Richard Lee, LLNL
4:00pm - 4:30pm	Structural Studies on Single Particles and Biomolecules	Janos Hajdu, Uppsala University
4:30pm - 5:00pm	Open Discussion on Linac Coherent Light Source	
5:00pm - 5:15pm	Public Comment	
5:15pm	Adjourn	
7:00pm	Dinner	Marriott Hotel