Adventures on Science

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August 9, 2010
SC/BES Facilities for X-ray Scattering

- Advanced Light Source
- Advanced Photon Source
- National Synchrotron Light Source
- Stanford Synchrotron Radiation Laboratory
- Linac Coherent Light Source
- National Synchrotron Light Source - II

SC-1 Briefing to OSTP
BES provides complete support for the operations of the facilities as well as being the dominant supporter of light source research, including funds for beamlines, instruments, and PI support. Many other agencies, industries, and private sponsors provide support for instrumental research.

Number of Users by Discipline at SC/BES Light Sources

FY 2008

Number of Users by Discipline:
- Life Sciences
- Chemical Sciences
- Geosciences & Ecology
- Applied Science/Engineering
- Optical/General Physics
- Materials Sciences
- Other

Percent of Users:
- APS 40%
- NSLS 28%
- SSRL 14%
- ALS 21%

Total Number of Users:
9,500
8,500
8,000
7,500
7,000
6,500
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500

Fiscal Year:
- '90
- '91
- '92
- '93
- '94
- '95
- '96
- '97
- '98
- '99
- '00
- '01
- '02
- '03
- '04
- '05
- '06
- '07
- '08
- '09

SC-1 Briefing to OSTP
Three molecular biologists who mapped the structure and inner workings of the ribosome — the cell's machinery for churning out proteins from the genetic code — have won the Nobel Prize in Chemistry in 2009.

Venkatraman Ramakrishnan, who works at the Medical Research Council's Laboratory of Molecular Biology in Cambridge, UK; Ada Yonath of the Weizmann Institute of Science in Rehovot, Israel, and Thomas Steitz at Yale University in New Haven, Connecticut, share the prize equally.
Linac Coherent Light Source or “LCLS” at SLAC
The World’s First X-ray Laser

LCLS uses 1/3 of linac

First X-rays: ~ 1 PM PDT 4/15/2009
Detection of X-ray at Far Hall ~ 1 PM PDT 4/22/2010

SC-1 Briefing to OSTP
Early Studies at LCLS: Nanocrystals in Water Microjet

Spokesperson: Henry Chapman et al.
collaboration of
Center for Free Electron Laser Science DESY
Arizona State University, Max Planck CFEL ASG,
SLAC, LLNL, CBST, Uppsala University

John Spence et al. ASU

Liquid jet

8 cm

1.8 keV
60 - 300 fs pulses
$10^{13}$ photons / pulse

x-rays: 7 µm
liquid jet: 4 µm

front detector at 7cm

back detector at 55cm

8 SC-1 Briefing to OSTP
Modern CO₂ Concentrations are Increasing

The current concentration is the highest in 800,000 years, as determined by ice core data.

Concentration prior to 1800 was ~280 ppm.

Concentration now ~388 ppm.

Atmospheric CO₂ at Mauna Loa Observatory

Concentration prior to 1800 was ~280 ppm.
Greenland Ice Mass Loss
2002 to 2009

Increasing rates of ice mass loss from the Greenland and Antarctic ice sheets revealed by GRACE (Gravity Recovery and Climate Experiment) satellite:

- In Greenland, the mass loss increased from 137 Gt/yr in 2002–2003 to 286 Gt/yr in 2007–2009
- In Antarctica, the mass loss increased from 104 Gt/yr in 2002–2006 to 246 Gt/yr in 2006–2009

Figure 1. Time series of ice mass changes for the Greenland ice sheet estimated from GRACE monthly mass solutions for the period from April 2002 to February 2009. Unfiltered data are blue crosses. Data filtered for the seasonal dependence using a 13-month window are shown as red crosses. The best-fitting quadratic trend is shown (green line). The GRACE data have been corrected for leakage and GIA.

I. Velicogna, Geophysical Research Letters, VOL. 36, L19503, 2009
Reducing uncertainties in climate predictions

Atmospheric System Research

Global Atmosphere Models

Regional Atmosphere Models

Cloud Property and Process Models
Lab Experiments

Aerosol Property and Process Models
Field Studies

Lab Experiments
Terrestrial Ecosystem Research (Carbon Cycle)

• Advances the fundamental science concerning the effects of climate change on terrestrial ecosystems and the role of terrestrial ecosystems in global carbon cycling.

• Plans are proceeding for the next generation ecosystem experiment (arctic tundra warming) with infrastructure prototype development underway.
## DOE Genomic Science Program

### Technologies and Methods for Systems Biology
- Microbe genomics, plant genomics, metagenomics
- Analysis of global changes in gene expression and metabolite profiles
- Molecular imaging
- Structure determinations
- Modeling and simulation
- Prediction and design
- Synthetic biology

### Fundamental Research Needs
- **Energy**
  - Gain a predictive understanding of how cells work in communities, tissues, plants, and, ultimately, global ecosystems
  - Tools and concepts for designing and engineering bioenergy plant and microbial systems, including the mechanistic bases.
- **Carbon Cycle**
  - Explore the functioning and regulation of pathways and dynamic networks in cells
  - Tools and concepts to determine the carbon cycling and biosequestration processes of ocean and terrestrial ecosystems.
- **Environmental Remediation**
  - Understand how proteins function individually and in interactions with other cellular components
  - Microbial and plant modeling and experiments to predict and control contaminant fate and transport.

### Mission Grand Challenges for Biology
- **Payoffs for the Nation**
  - Sustainable and Viable Biofuel Technologies
  - Earth System Modeling and Biosequestration Strategies
  - Improved Strategies for Environmental Remediation and Long-Term Stewardship
The DOE Bioenergy Research Centers

• New paradigm for research—single focus, multi-disciplinary, team-based transformational science

• BioEnergy Science Center (ORNL)
  – Multi-institutional partnership with strategic focus on overcoming biomass “recalcitrance” as route to cost-effective cellulosic biofuels
  – Goal of “Consolidated Bioprocessing” – one-microbe or microbial community approach going from plants to fuel

• Great Lakes Bioenergy Research Center (U. W.-Madison, Mich State U)
  – Goal of re-engineering plants to produce more starches and oils
  – Using HTP technologies to optimize chem/bio process for biomass deconstruction
  – Major research thrust on sustainability of biofuels

• Joint BioEnergy Institute (led by LBNL)
  – Experimenting with new pretreatment process using room temperature ionic liquids
  – Beyond cellulosic ethanol: re-engineering E.coli and yeast to produce hydrocarbons – goal of “green” gasoline, diesel, jet fuel
The DOE Joint Genome Institute
A User Resource for the Biological Sciences

• Using high throughput tools, technologies and comparative analysis, the JGI serves as a discovery platform to understand the organization and function of complex genomes for bioenergy, carbon cycle, and bioremediation.

• Genome and metagenome expression and sequencing of microbes, plants, and other complex systems, such as microbial communities or the rhizosphere.

• Genome annotation, functional analysis and verification of genome-scale biological system models. Systems-level integration and validation of genomic data from multiple sequencing and functional analyses.

• Sequencing more than 4 Terabases per year (more than 1300 human genome equivalents)
Leadership Computing: Scientific Advances

**Turbulence**
Understanding the statistical geometry of turbulent dispersion of pollutants in the environment.

**Energy Storage**
Understanding the storage and flow of energy in next-generation nanostructured carbon tube supercapacitors.

**Biofuels**
A comprehensive simulation model of lignocellulosic biomass to understand the bottleneck to sustainable and economical ethanol production.

**Nuclear Energy**
High-fidelity predictive simulation tools for the design of next-generation nuclear reactors to safely increase operating margins.

**Fusion Energy**
Substantial progress in the understanding of anomalous electron energy loss in the National Spherical Torus Experiment (NSTX).

**Nano Science**
Understanding the atomic and electronic properties of nanostructures in next-generation photovoltaic solar cell materials.
ITER

- ITER (Latin for “the way”) is a first of a kind major international research collaboration on fusion energy.
- U.S. is a 9.09% partner.
- ITER Goals
  - Designed to produce 500 MW of fusion power (Q > 10) for at least 300-500 seconds
  - *Burning plasma* dynamics and control
    - U.S. emphasizes the value of ITER, its flexibility, and its diagnostics as a scientific instrument: develop a predictive capability of the burning plasma state
  - Will optimize physics and integrate many of key technologies needed for future fusion power plants

ITER Tokamak – Cross Sectional View
The search for the Higgs
Gamma ray view of the sky

NASA’s Fermi telescope reveals best-ever view of the gamma-ray sky

Credit: NASA/DOE/Fermi LAT Collaboration
Einstein said “The most incomprehensible thing about the world is that it is comprehensible”

This comprehensibility is true beauty of science, it is what we scientist most admire