AMO Physics at NSF

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NSF AMO Program Director

CAMOS Meeting

April 6, 2010

Outline

- **Where is AMO at NSF?**
- **CAMOS current Issues: QIS & Energy/Environment**
- **AMOP funding trends**
- **Some NSF/AMO issues for discussion**

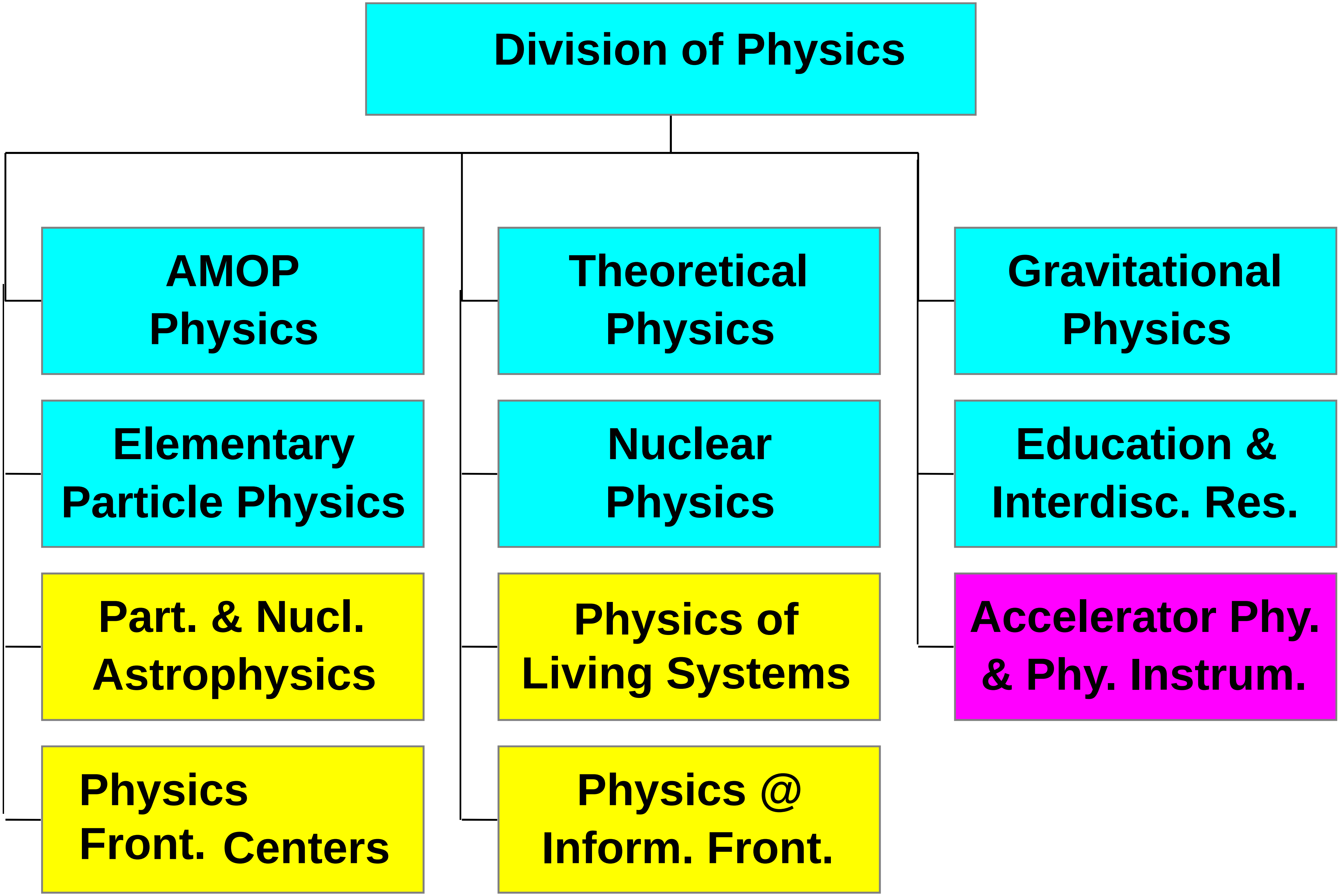
Where is AMO in NSF?

NSF Directorates

- Biology
- Computer,Info.Sci.,Eng.
- Crosscutting, NSF wide
- Cyberstructure
- Education
- Engineering
- Environmental Research
- Geosciences
- Math, Physical Sciences (MPS)
- Polar Research
- Soc.,Behav.,Econ. Sci.

MPS Divisions

- Astronomical Sciences
- Chemistry
- Materials Research
- Mathematical Sciences
- Physics (PHY)
- Office of Multidisciplinary Activities


Division of Physics
AMOP Physics
Elementary Particle Physics
Part. & Nucl. Astrophysics
Physics Front. Centers
Theoretical Physics
Nuclear Physics
Physics of Living Systems
Physics @ Inform. Front.
Gravitational Physics
Education & Interdisc. Res.
Accelerator Phy. & Phy. Instrum.

AMO Programs

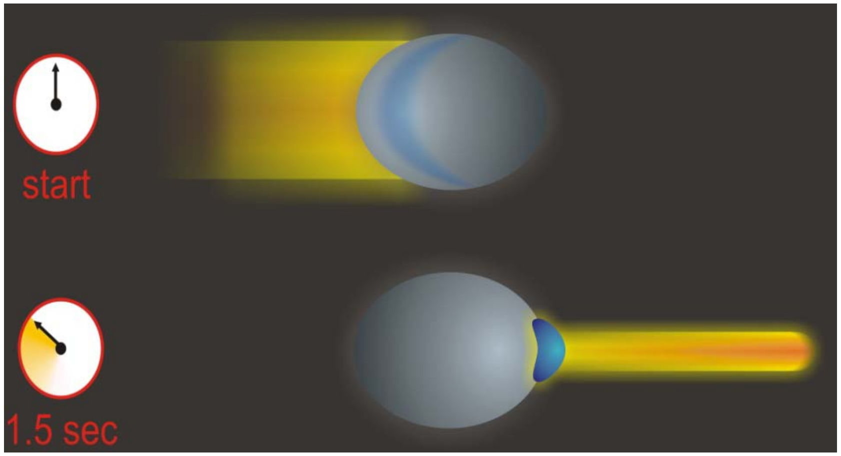
- **Precision Measurements**
  - QED tests
  - Fundamental constants
  - Fundamental symmetries
- **Optical Physics**
  - Nonlinear optics
  - Quantum optics
  - Quantum information science
- **Atomic and Molecular Dynamics**
  - Coherent Processes
  - Collisions
  - Cooling and trapping
  - Ultracold collisions and ultracold molecules
  - Collective Phenomena
- **Atomic and Molecular Structure**

Long sought EDM stays hidden

Norval Fortson and his colleagues at the University of Washington have made the most sensitive test to date for the existence of an EDM, in an experiment using mercury atoms. Their results show no evidence for an EDM, but they have improved the limit on their own earlier measurement of the EDM of the mercury atom (199Hg) by a factor of seven. In this experiment, mercury vapor cells (see figure) are illuminated by laser beams that line up the nuclear spins of the mercury atoms and detect the change in spin direction when the putative EDM is acted on by an applied electric field

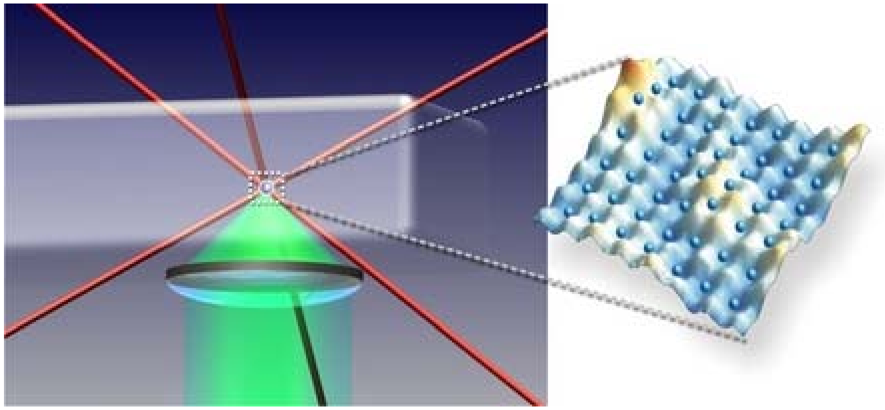
New Record For Light Storage

Lene Hau and her group at Harvard University smashed the record for how long light can be trapped in a cloud of cold atoms; having stored a pulse of light for a period of 1.5 seconds. This is a remarkable achievement, as prior to this result, light could only be stored for a few milliseconds (thousandths of a second) in such systems.



Yellow light was stored for more than 1 second in an imprint (dark blue) on ultra-cold sodium atoms (bluish-gray). The beam that emerges (bottom) is weaker but has the same polarization and frequency as the original beam (top).

Progress on Quantum Simulation



An atom gas is trapped in an optical lattice formed from three intersecting laser beams (shown in red on the left). Controllable disorder is added using a green laser beam focused through a holographic diffuser (gray disk), which produces a random array of bright and dark spots. The atoms are confined in the disordered potential (right), which can be completely measured and characterized, unlike the materials being simulated.

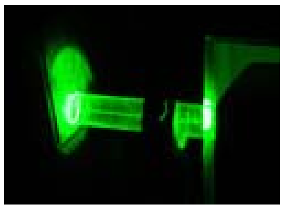
Brian DeMarco, University of Illinois

Centers

- Subject of special emphasis by 2006 COV
- Over life of program, 12 awarded, 3 phased out
- Subject to strategic portfolio balance
- Diverse frontier topics across PHY sub disciplines
- Talent magnet
- Next competition in FY 2011
- Exhibit interagency participation+-

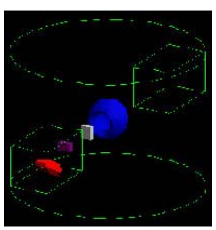
Physics Frontiers Centers (Cont'd)

Center for Magnetic Self-Organization in Laboratory and Astrophysical Plasmas – Wisconsin – Prager (Joint NSF/DOE)



Joint Quantum Institute – Maryland/NIST – Phillips

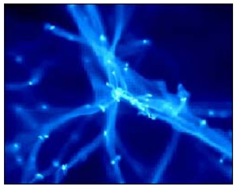
Center for the Physics of Living Cells – U Illinois – Ha (Joint NSF/PHY/CHE/DMR and BIO)

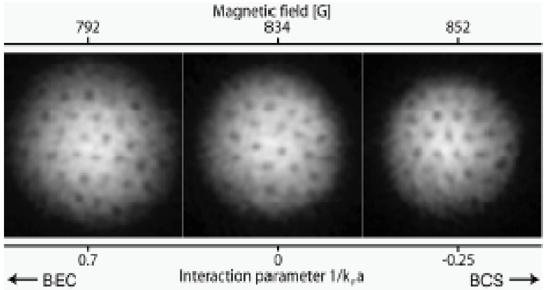


Center for the Study of the Origin and Structure of Matter
Hampton - McFarlane

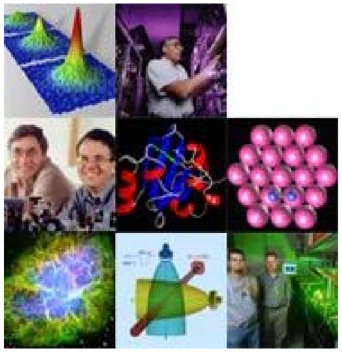
Physics Frontiers Centers

Kavli Institute for Cosmological Physics – Chicago - Meyer





Center for Ultracold Atoms – MIT/Harvard - Ketterle



JILA – Colorado – Cornell

Kavli Institute for Theoretical Physics – UCSB – Gross

Center for Theoretical Biological Physics – UCSD – Onuchic (Joint NSF/PHY/DMR and BIO)

Joint Institute for Nuclear Astrophysics – Notre Dame - Wiescher

QIS & Energy/Environment

- **SEBML - Science and Engineering beyond Moore's Law (AMOP, PIF, TAMOP) – NSF Wide Program**
- **Quantum Information Science (AMOP, PIF,TAMOP)**
- **SEES - Science Engineering and Education for Sustainability**

PIF Programs

Physics at the Information Frontier

- **Computational Physics**
- **Grid Computing**
- **Quantum Information Science**

Quantum Information Science

- AMO + PIF/QIS + PFC’s – about $10 M in FY09
- Recovery Act showed in AMO and PIF/QIS, a doubling of support for QIS would be appropriate
- SEBML – Foundation-wide program – includes QIS and other future computation paradigms
- Increasing budget for QIS is a PHY Division priority
- In the short term guidance for the NSF supplied by:

  NSTC – “A Federal Vision for QIS”

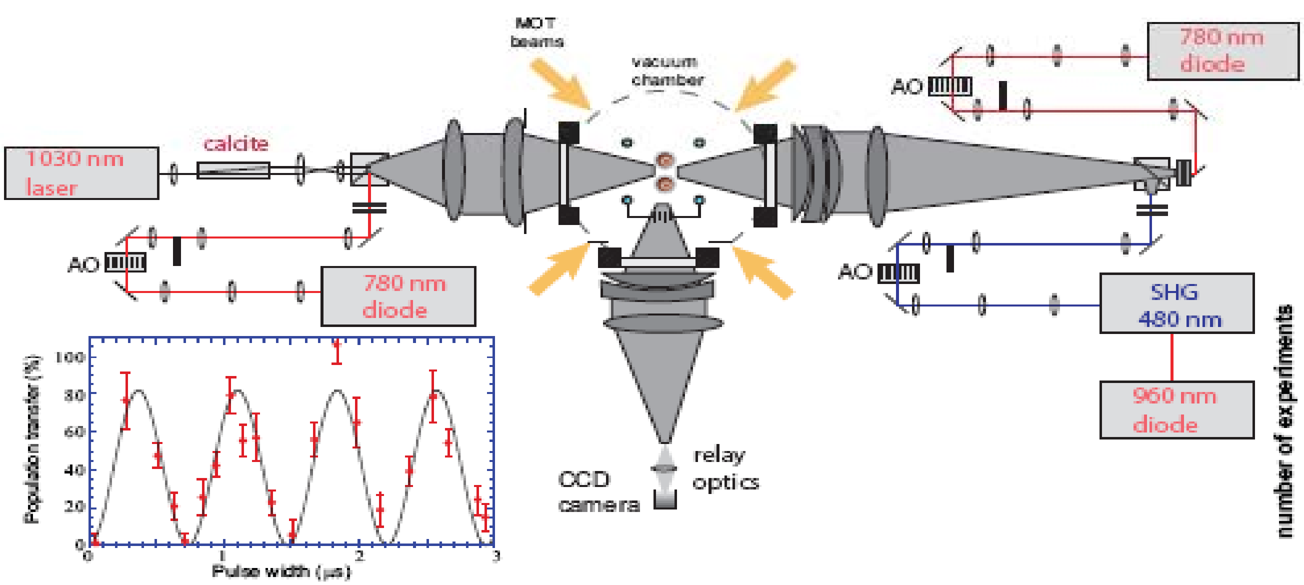
  Workshop on QIS, Vienna, VA, April, 2009

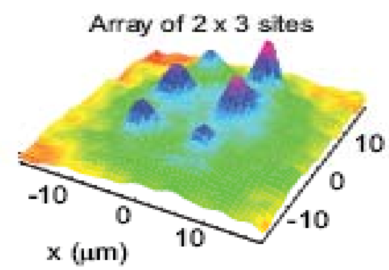
PIF/QIS: Neutral Atom Qubit

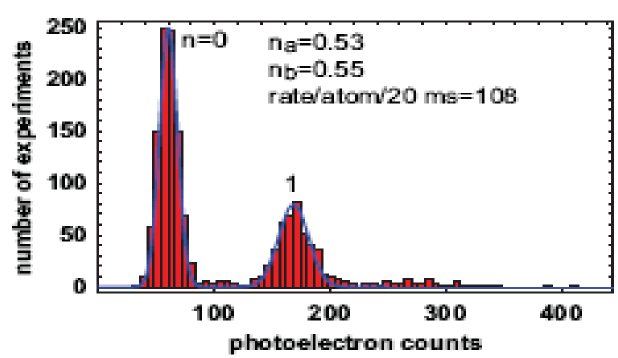
M. Saffman, PHY-0653408

Goal: Generation of two-qubit conditional logic gates based on optically trapped neutral atoms. Dipole-dipole interactions of Rydberg states will provide the mechanism for fast, high fidelity gates.

Atoms trapped in a small array of optical traps. Single qubit rotations have been performed on single atoms loaded into a single site. Atoms in two sites can be entangled through long-range interactions when excited to Rydberg state.







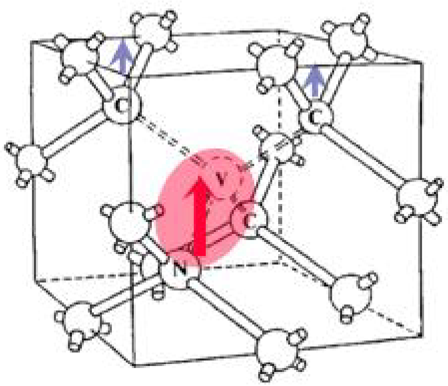
PIF/QIS: Extending Quantum Memory

Quantum information requires the ability to store, retrieve and manipulate information in quantum memories

Problem: Quantum Information is fragile, and susceptible to loss during readout – for example, spins in NV centers in diamond – promising quantum memory …. but fragile

Recent Progress: control the interactions of the spin with nearby nuclear spins of the carbon network, making the electron spin quantum memory more robust

Diamond with Nitrogen Vacancy Center (NV)



Jiang et al.,
Science 326, 267 (2009)
PHY-0653555
PI: Mikhail Lukin, Harvard

Energy and Environment

- MPS Working groups on Energy and Environment
- New NSF wide program SEES

  Science Engineering and Education for Sustainability

  There will be money. See 'Dear Colleague Letter on Climate' on NSF Web site (NSF 10-040)
- Chemistry and Materials Science Divisions more heavily involved than Physics – Solar, new materials, etc.
- Issue for NSF/Physics: Basic Research vs Targeted Research

Interagency Cooperation

NSF/DOE Partnership in Basic Plasma Science and Engineering

NSF: Engineering, Geosciences, and Mathematical and Physical Sciences directorates

DOE: Office of Science/Office of Fusion Energy Sciences

"Enhance plasma research and education by coordinating efforts and combining resources of the two agencies. The initiative will address fundamental issues in plasma science and engineering .."

Energy Research in Physics

Low Energy Nuclear Physics

NSF supported nuclear laboratories provide beam-time on a competitive basis. Some of the experiments provide data of benefit to R&D on Nuclear Reactors, Waste Disposal, etc.

PHY-0606007 NSCL Nuclear Lab at Michigan State University

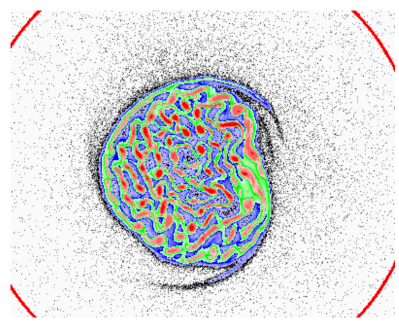
PHY-0754674 Nuclear Lab at Florida State University

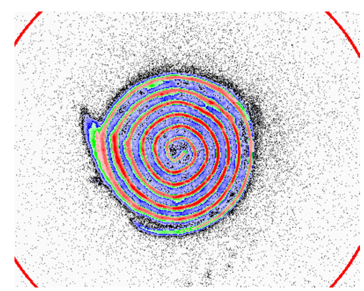
Plasma Physics

The Plasma Physics program supports fundamental studies of the physics of plasmas. Some of this work provides information of interest to the Fission Energy community.

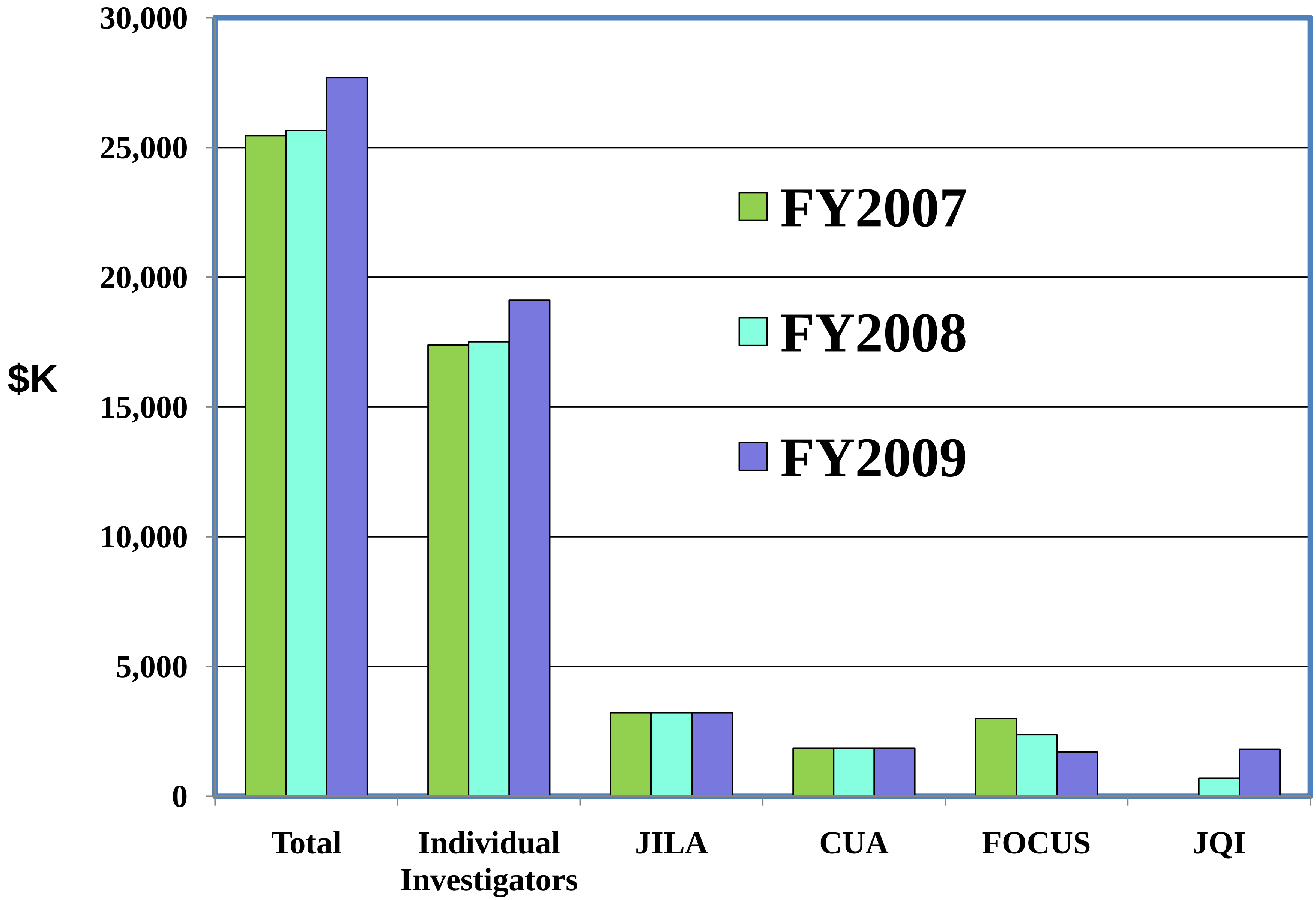
PHY-0903877 "Fundamental Processes in Plasmas" UC San Diego

The Experimental Nuclear Physics Group at FSU





AMOP Funding History



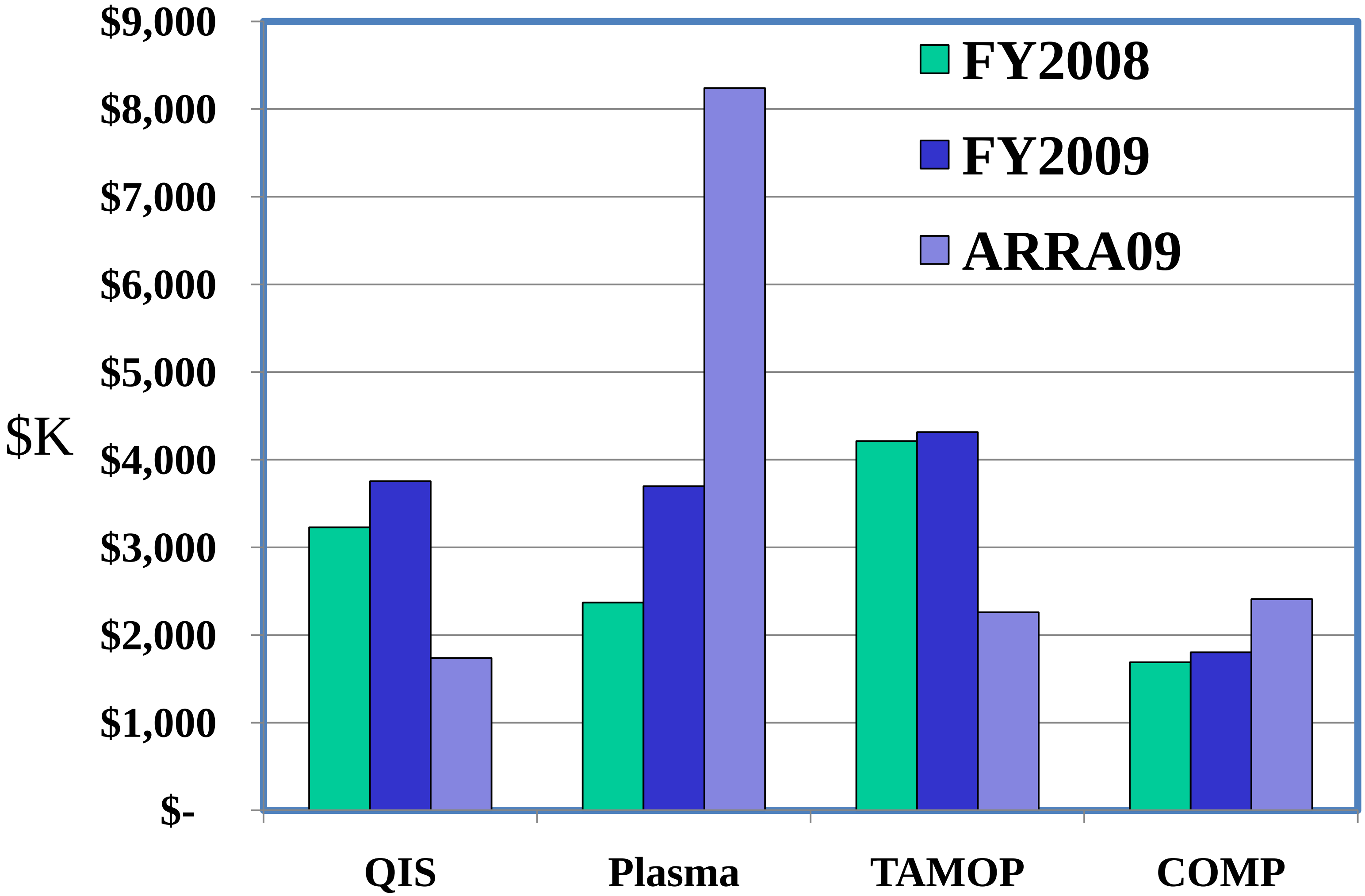
FY09 Stimulus (ARRA)

- Model is near term increases with stimulus spike, followed by flat budgets with inflation.
- Stimulus used so as not to incur mortgages, i.e., instrumentation, standard grants, supplements.
- 2009 appropriations used for normal funding, but with bias to reduce out-year commitments.

ARRA Funding FY09

- AMO - $9,616K
- QIS - $1,740K
- TAMOP - $2,260K
- Plasma Physics- $8,240K

Related Programs



Award Success Rate in AMO

- **100 Total proposals submitted in FY08**
  (102 in FY07, 93 in FY09, 99 in FY10)
  - **31 Total awards made**
  - **31% success rate for all proposals submitted**
- **27 Renewal proposals submitted**
  - **21 Renewal awards made**
  - **78% success rate for renewal proposals**
- **73 "New" proposals submitted**
  - **10 New awards made (8 to junior faculty)**
  - **14% success rate for new proposals**

Active Awards (FY 09)

'Individual' Investigator Awards

• AMO	139
• Plasma (including DOE)	70
• QIS	47
• TAMOP	73
• REU – (# Undergrads)	60

Context of Decisions

- We decline worthy proposals
- Must be considered in context
  - What else is on the table
  - Reviewers comments and panel summary
  - Overlap with communities' priorities
  - Eye on future health of the field
  - Eye on commitment implications
- COV (Committee of Visitors) examines this process

INVESTMENT GOALS

- Dramatic scientific advances that alter the course of AMO physics and other fields
- International leadership/cooperation across the intellectual frontiers of science
- Recruitment of exceptional talent into science (education, outreach, and early inspiration)
- Production of highly trained professionals for the nation’s workforce
- Significantly increase diversity in science

Education

- Graduate students and Postdocs, and Undergraduates

- REUs and RETs- Research Experiences for Undergraduates and High School Teachers
  58 undergraduates, 1teacher in 2009

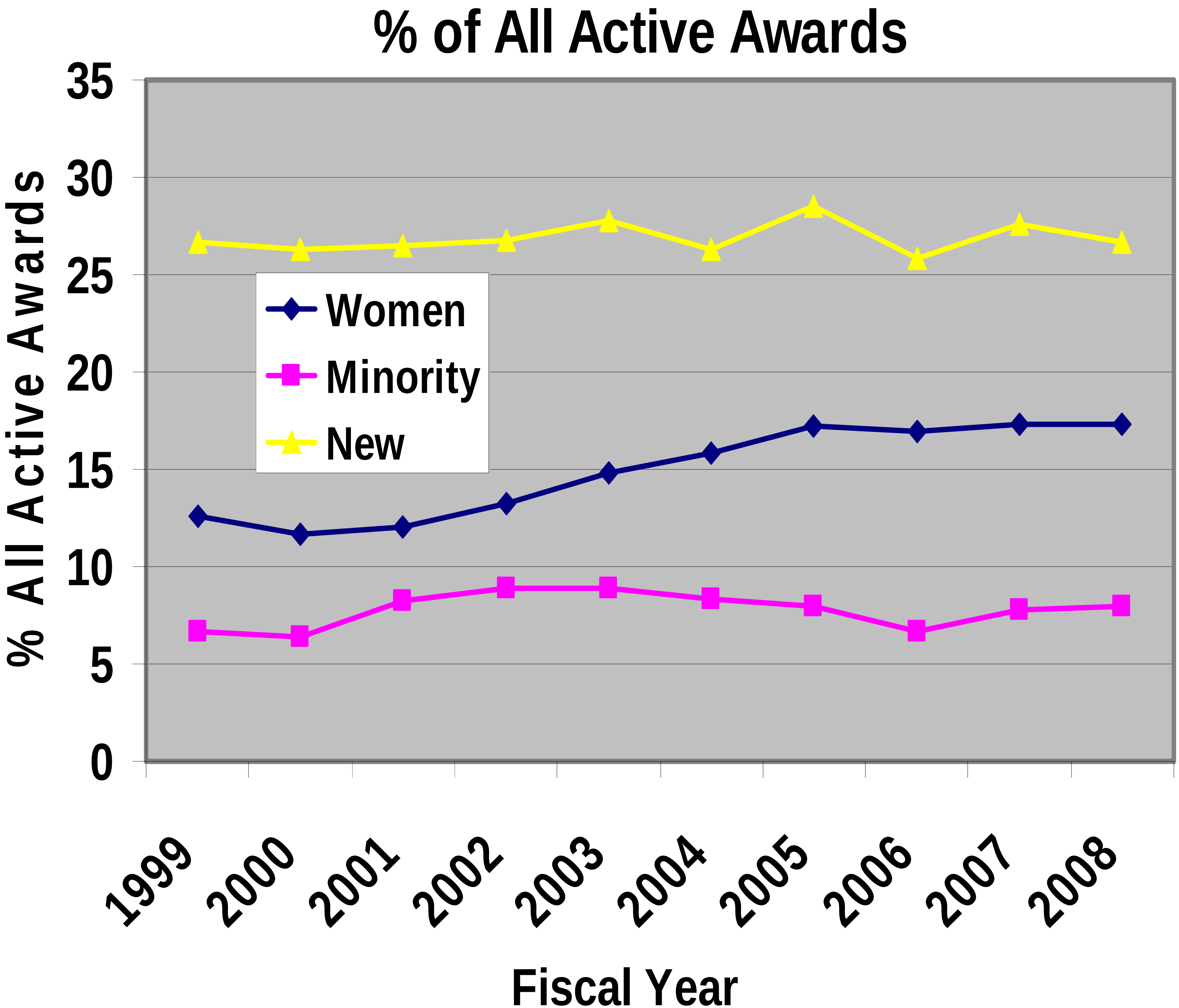
- Education/Outreach activities of facilities and centers

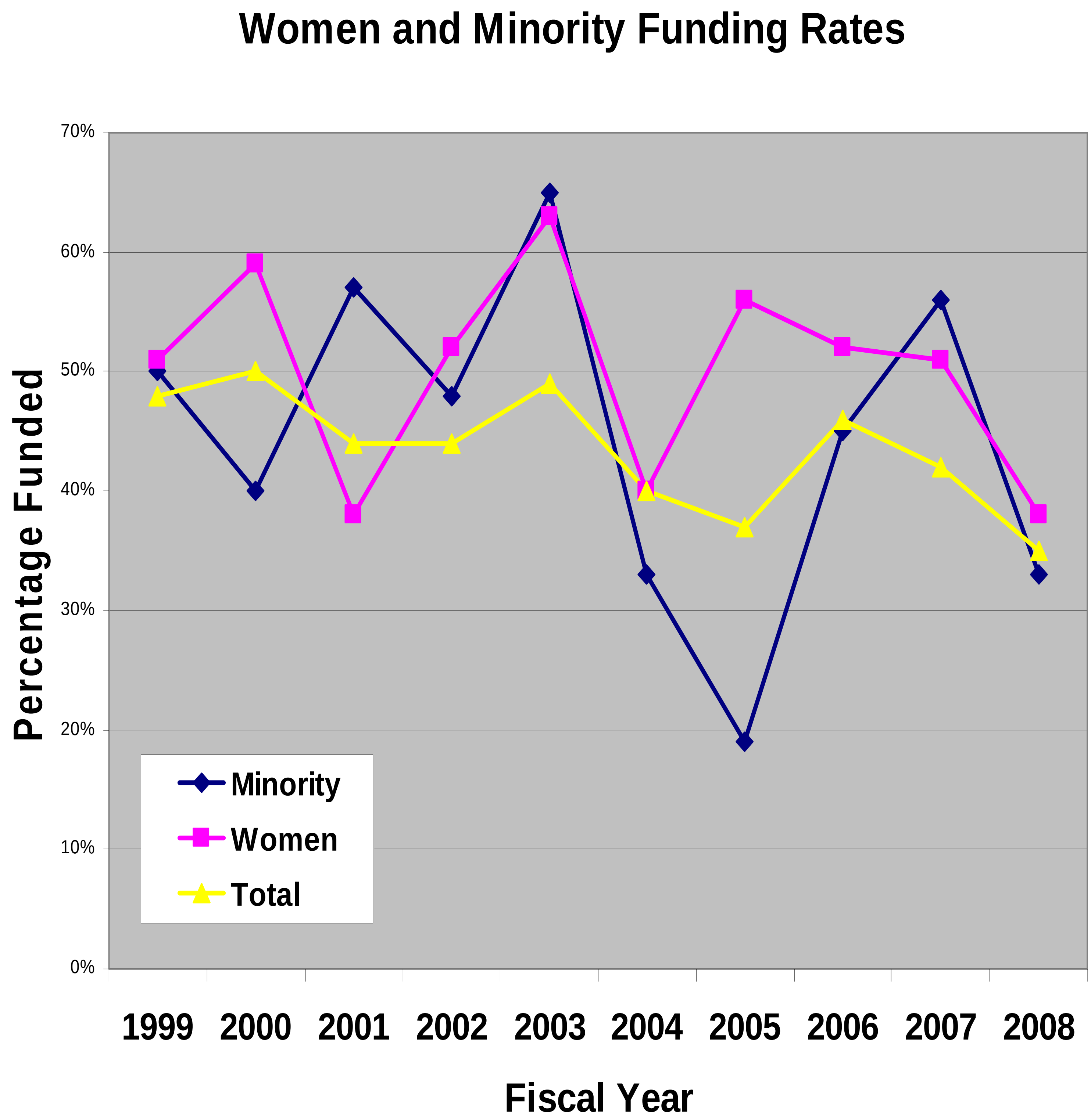
- CAREER – Faculty Early Career Development - 11 active awards, in 2008: 2 CAREER of 11 funded

- RUI – Research at Undergraduate Institutions – 17 Active Awards, in 2008: 5 RUI of 14 funded

PROGRAM BALANCE

- Large/Small
- Facilities/PIs
- Basic/Applied
- Risk/Caution
- Youth/Experience
- White Males/ Underrepresented
- Hot/Not
- Have/Have-Nots
- Different Subfields
- Disciplines/National Initiatives
- Geographic Dist.
- Research/Education
- Theory/Experiment
- Institutional Dist.


% of All Active Awards
% All Active Awards
0
5
10
15
20
25
30
35
Women
Minority
New
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Fiscal Year


Women and Minority Funding Rates
Percentage Funded
70%
60%
50%
40%
30%
20%
10%
0%
Minority
Women
Total
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Fiscal Year

COOPERATION WITH OTHER SPONSORS

Within NSF

DMR, CHM, AST, DMS, CISE, ENG

Interagency

DOE: OHEP, ONP, OFES, OBES, NNSA; DOD, NIH, NASA, DOC (NIST), SI

International

Australia, Japan, China, Russia, Argentina, Brazil, Chile, Antarctica, Canada, Sweden, Germany, Italy, France, England, Scotland, Africa, Mexico, Belgium, Finland, India, Israel, Netherlands, Korea, Ecuador, Czech Rep., Columbia, Armenia, plus many more.

Innovation: PHY Role

- Innovation involves the answers to two questions: "What is possible," and "What is needed."
- Not a linear process, involving at least three stages: pushing the intellectual frontiers, making connections between what is possible and what is needed, and inventing a new deployable capability.
- Best viewed as an innovation "ecosystem," with multiple keystone species.
- PHY role has three components:
  - Advance intellectual frontiers opening up new possibilities
  - Develop the intellectual capital to populate the ecosystem
  - Seize opportunities to apply new knowledge to practical needs
- This ecosystem perspective matters because planning horizons shorten when funding is short, and this tends to emphasize incremental steps, not disruptively transformational events, which are usually not at all related to perceived needs, e.g., GPS system, which depends on fundamental developments made decades apart over a century for other reasons.