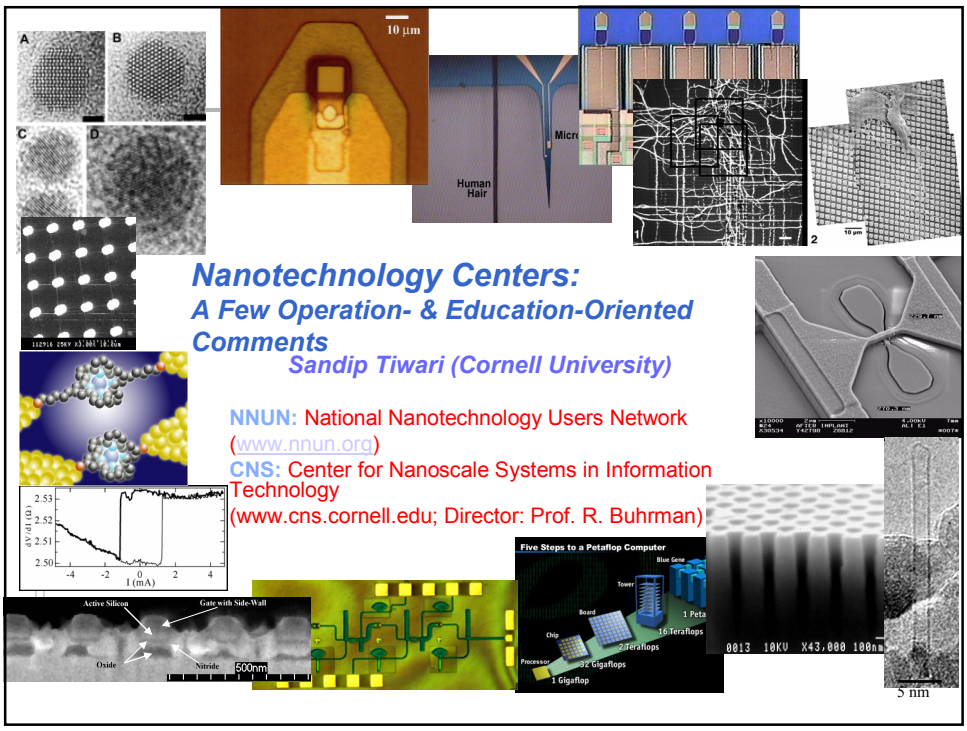
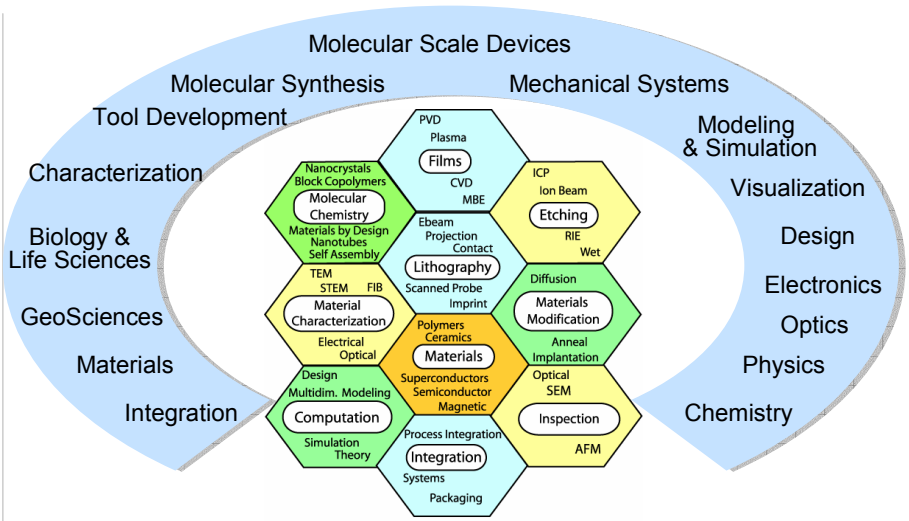


Research: Multi-Disciplinary with Diverse Needs



Departments have different cultures
Schools have different goals

Diverse faculty styles and different expectations with career-stage

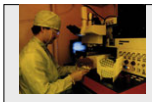
Infrastructure and Research Centers

- NNUN – an infrastructure for networked research service
- CNS – a research center`

- Infrastructure's mission is support of research and education & outreach
  - Multiple university laboratories/facilities
  - Funds support research service in a university environment
  - New area research initiation and outreach activities across the nation

- Research Centers' mission is research and education & outreach
  - Research groups and exploratory research seeds
  - Funds support research directions through student support, research expenses and specialized facility/instrumentation
  - Outreach and knowledge transfer as a center-wide activity
    - Education and outreach across age groups and community
    - Industrial impact through strong research-centered interactions and transfer

NNUN Users and Their Characteristics



Graduate Students
- Full time resident
- Provide significant baseline process support

Large Companies
- Dupont, Xerox, Corning, LSI, IBM, …
- Specialized NNUN facilities

Large Research Universities
- Often have clean room experience
- Require specialized NNUN facilities

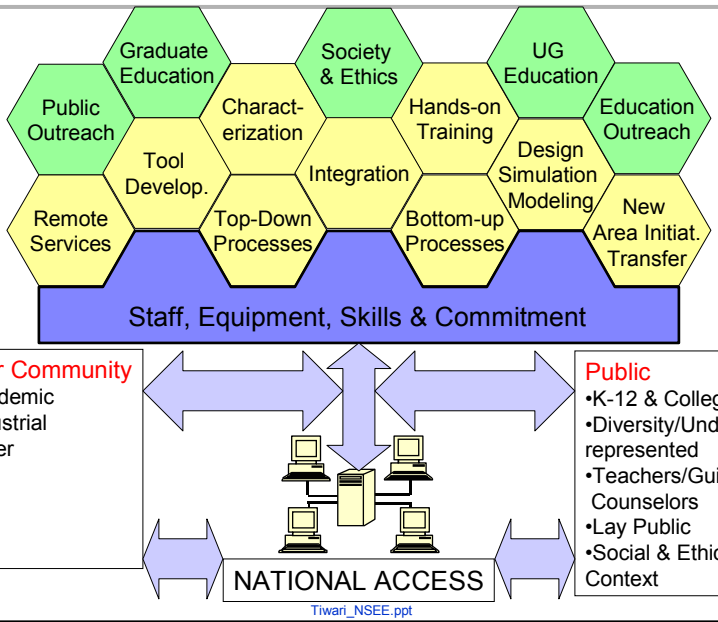
Small Companies
- Broad range of resources
- SBIRs, Start ups, etc
- Economical facilities for new ventures

Students From Smaller Universities
- New research programs
- May have few high technology resources
- Often require significant technical support

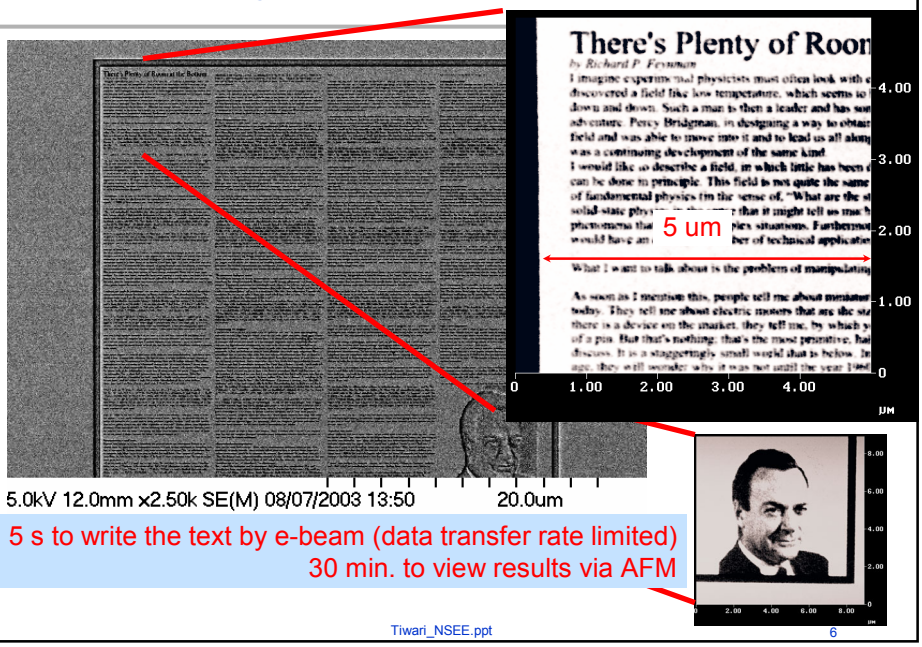
Undergraduates
- Local and outside including REU
- First exposure to nanotechnology and research

Long Term Visitors
- Students and Scientists
- Major investment of time and money, but necessary for complex projects

Infrastructure Network



Plenty of Room at the Bottom !



5 s to write the text by e-beam (data transfer rate limited)
30 min. to view results via AFM

Facility Users' Needs/Expectations

- First contact: phone, web or e-mail
- Discussion of project with staff experts
  - Redirection to alternative site if appropriate
- Web resources (process libraries)
- On line training
- *2 page maximum* technical description of proposed work
- Visit Site for hands on training and user support
  - Safety training and ethics tutorial
  - Consultation and support
  - Equipment training
  - Fabrication and characterization
- Evolve to independent user
- Local low-cost housing for users

From first contact to first visit: Two Weeks

Visit Duration: From 1 week to months

Low Barriers to Entry

Useful structures by the end of first visit

Facility's Imperatives: Hands-on Equipment and Safety Training

- >5 NEW users per week at large sites, 10-15 at peak times (summer), move projects between sites for tools
- Enormous logistical, educational, and compliance issues
- Extensive "training"
  - How to/practical rules and procedures from staff
  - General Lab, General Safety, Specific Equipment
  - 5-40 hours per user (some shared)
  - Common practices
- Extensive "technical support and training"
  - Scientific and engineering advice from staff
  - Integration support
  - Project specific support
- Focus on management of this process

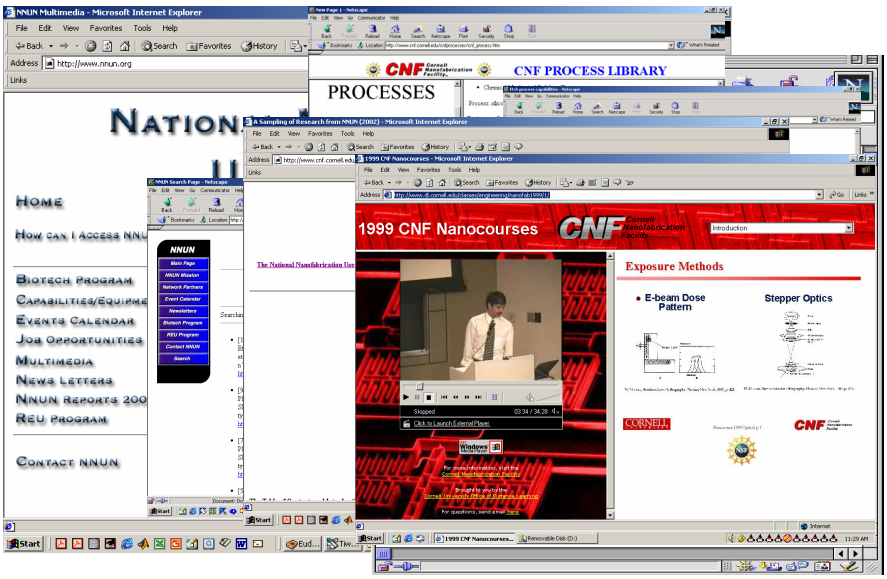
Commitments for Networked Service

For a network of university facilities to succeed in support of national research needs, the culture must provide

- Single-minded commitment to external user support
- Open and equal access to all
- Staff that finds satisfaction from research service and interdisciplinary research
- No Intellectual Property barriers
- Simple, efficient and quick procedures for bringing in users
- Facility ownership of equipment and resources
- High up-time
- Openness to new ideas, materials, techniques, disciplines, …
- Funding based on metrics that evaluate quality and quantity
- Network management focused on service

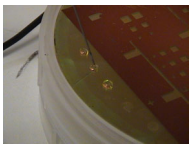
Local use provides critical mass and leverage through constant flow of new ideas and new technologies from local research

Culture: Openness to Technology Changes

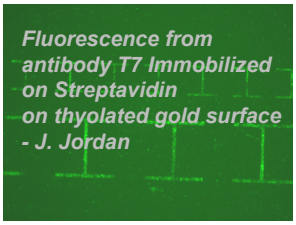


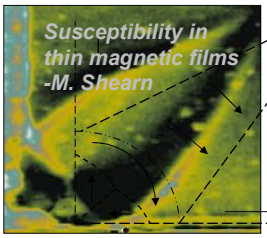
Openness: Remote User Access

- Remote User Demo
  - U. Michigan user fabricated actuators
  - Deep RIE etch step done remotely at NNUN
  - Made use of web video, whiteboard, and microscope
- NNUN REU lab projects between multiple sites

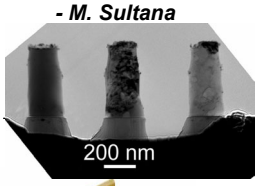


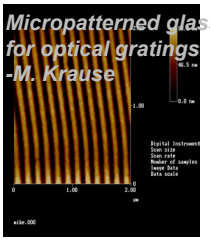
Openness: REU Intra-Network Involvement

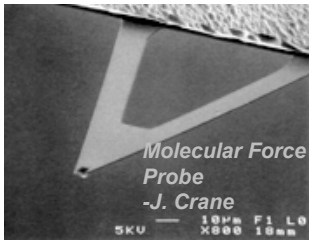


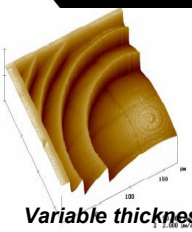


Stress effects on crystallization
- M. Sultana





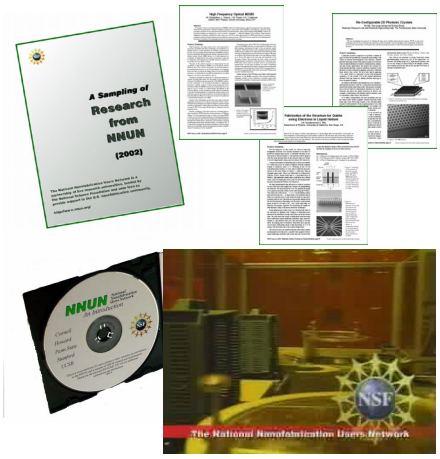




Variable thickness
HSQ Structures
- O. Negrete

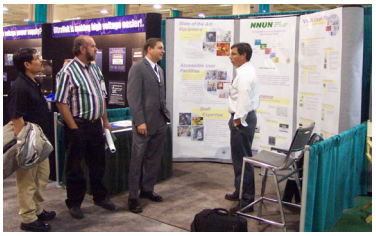
Networked National Outreach

Introductory Material and examples of successful projects in sufficient detail



Hands-on and In-Depth Workshops

Talks and presence at Conferences



Education and Learning

- Graduate
  - Advanced research and associated technical training for independent activity
  - Underlying rigorous technical course-work
- Undergraduate
  - Critical thinking
  - Underlying rigorous technical course-work
  - Opportunities in independent research that fosters interest
- K-12
  - Excitement and fostering and mentoring of scientific interest
  - Independent thinking skills

What Does Science/Engineering Education Mean?

Programmers have careers not much longer than pro-football players

Christian Science Monitor (Dec. 25-26, 2002)

For people who view this as a career, engineering is in worse shape now than it's been in years

Le Earl Bryant (President, IEEE, 2002)

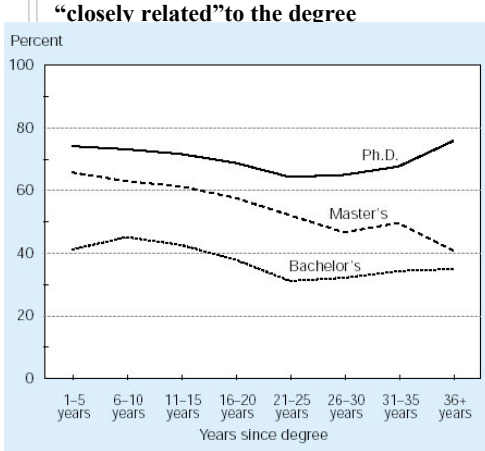
The half-life of engineering knowledge, the time it takes for something to become obsolete, is from seven to 2-1/2 years

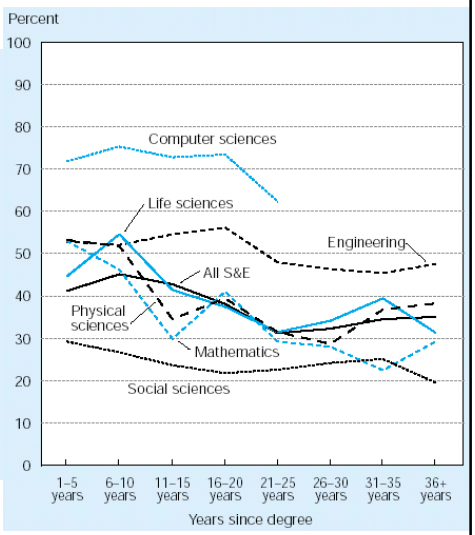
William Wulf (President, NAE, 2002)

Life-long learning is central in technical careers.
What makes it possible is critical thinking, ability to analyze and make technical connections, ability to continue to learn on one's own, ability to ask the right questions and to find the answers, and to apply these skills across the breadth of problems one faces in technical careers and in our life, is the goal of our education

Science & Engineering Jobs

Percentage of degree holders in jobs "closely related"to the degree





Science and Engineering Workforce Report from NSF/Division of Science Resources Statistics

CNS NSE Educational Program

An interdisciplinary UG and Graduate NSE curriculum

- Introduction to Nanoscience and Nanoengineering – **Freshman**-level
  - Introduction lectures to provide awareness and excitement for the discipline, small group demonstrations, hands-on laboratory team project
- Nanotechnology - **senior/ first-year-graduate** level course
  - Foundation-setting interdisciplinary course for NSE students
  - Hands-on laboratory in nanofabrication and nanoscale processing
  - Rigorous teaching lab
  - *To be followed up by field-specific NSE courses*
- Nanocharacterization - **senior/ first-year graduate** -level course
  - A critical introduction to scanned-probe and charged-particle tools
- Nanoscience and Nanoengineering – Advanced graduate course (under development)
  - Unification of ideas from across disciplines

ENGRI 130 (Prof. V.O. Kostroun)
Intro. to Nanoscience and Nanoengineering

Lecture/laboratory course designed to introduce freshmen to some of the ideas and concepts of nanoscience and nanotechnology(Ver.1)

Topics:

- nanoscience and nanotechnology
- behavior of light and material particles when confined to nanoscale dimensions; scanning tunneling microscopy (STM)
- atomic force microscopy (AFM)
- microelectromechanical systems (MEMS) design
- basic micromachining and chemical synthesis methods, i.e. “top-down” and “bottom-up” approaches to nanofabrication
- physical laws and limits they place on the nanoworld; some far out ideas.

In the laboratory:

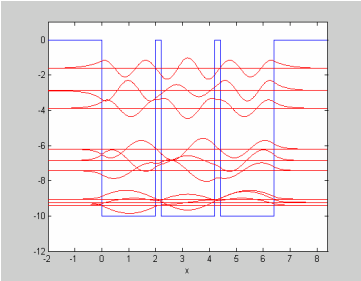
- students use an AFM to record atomic resolution images
- use a MEMS computer-aided design software package to model the entire manufacturing sequence of a simple MEMS device
- construct a simple STM and learn through hands on experience the basic workings of the device.

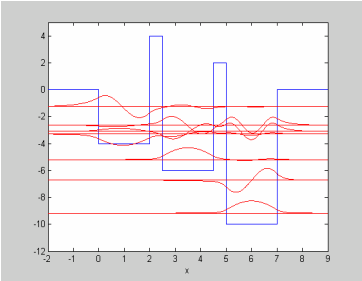
Engri 130 (Prof. V.O. Kostroun)
Introduction to Nanoscience and Nanoengineering

Wrote MATLAB program ***multi-well*** (one if a series) to illustrate pertinent quantum mechanical concepts

Input: Number of potentials, their depth and width

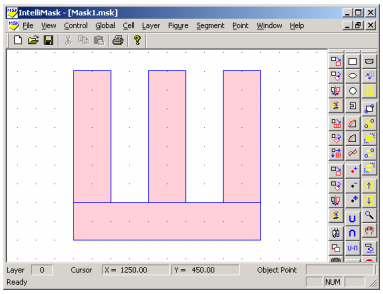
Output

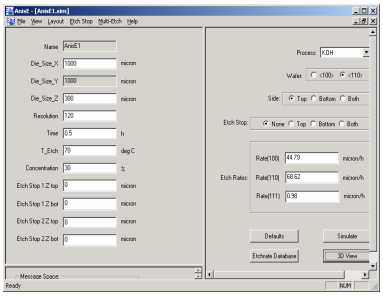




Engri 130 (Prof. V.O. Kostroun)
Intro. to Nanoscience and Nanoengineering

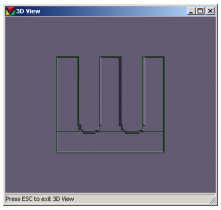
- IntellisuiteTM ** CAD for MEMS programs to illustrate fabrication



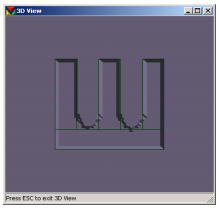


** Corning IntelliSense Corp. Boston, MA

Engri 130 (Prof. V.O. Kostroun)
Introduction to Nanoscience and Nanoengineering



<100> silicon, 0.3 hr dark-field



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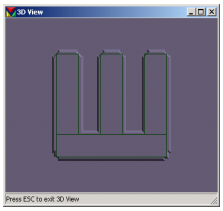

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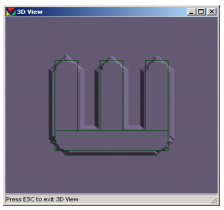
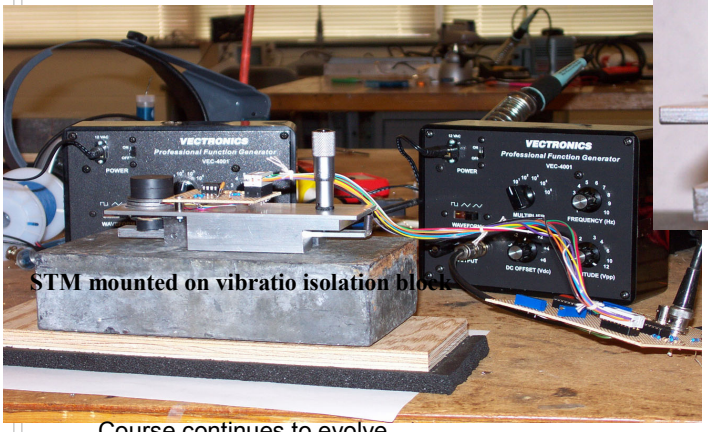


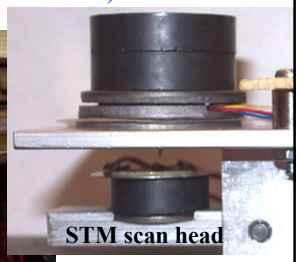
<100> silicon, 0.6 hr light-field

Engri 130 (Prof. V.O. Kostroun)
Intro. to Nanoscience & Nonoengineering

Simple STM constructed by pairs of students.* (17units/class)



STM mounted on vibratio isolation block



STM scan head

Course continues to evolve responding to feedback and broadening its scope.

**Design based on that of J. Alexander, www.geocities.com/spm_stm/Project.html*

CNS K-12 Education Focus

Teacher needs

- Intellectual community
  - Little interaction with colleagues
  - Little contact with institutions of higher learning
- Lab enhancement
  - Few resources for new experiments
  - New experiments should be inquiry-based and fit the curriculum
- Professional development
  - Need for resources to learn about cutting-edge technology
  - Update curriculum (> 50 years old)
  - Provide new teacher training due to large number of retirements expected in next 5 years
- Stimulation for best/brightest students
  - Provide connection to world of advanced science and engineering

Source: Conversations with HS physics teachers.

CNS K-12 Educational Goals

- Provide training to update teachers on recent advances in physical science including NSE
  - 3-week summer program (lecture and laboratory courses)
  - Workshops throughout the year
- Develop lab kits for classroom use
  - Teams of researchers and teachers design new labs
  - Lending library for equipment that is difficult to obtain
  - Commercial production of kits
- Promote interactions between teachers and researchers
  - CNS researchers lead workshops and courses for teachers
  - Researchers and teachers work closely together to develop new labs
  - Develop a strong web presence for communication

CNS Teacher Summer Courses & Workshops

July 13—25, 2003
PHYS 501 Contemporary Physics for Teachers
(2 graduate credits)
Course theme: nanoscale science and engineering. Topics include imaging, nanofabrication, light and optics, and electric circuits.

July 27—August 1, 2003
PHYS 502 Modern Mechanics for Teachers
(1 graduate credit)
Topics include MEMS and atomic force microscopy. Also an introduction to Modeling Instruction in mechanics (ASU program).

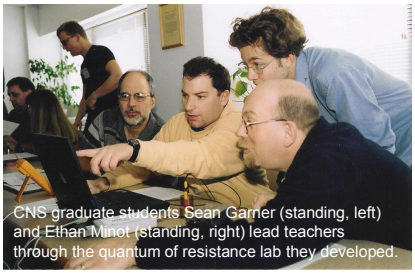
Workshop Title	Date(s)	Teachers	Overall Usefulness
1. First Workshop	3/23/02	48	**4.6**
2. NYS Science Mentor Workshop (with NYS Mentor Network)	7/9—7/11/02	30	**4.8**
3. Nanoworld (with U. Wisconsin MRSEC)	7/15—7/16/02	19	**4.2**
4. Particle Physics Workshop (with LEPP)	9/7/02	39	**4.9**
5. Physics Tools for the Molecular Biologist (with CIBT)	1/19/03	13	**4.5**
6. Pomona College Workshop	2/15/03	10	**4.9**
7. Brigham Young University Workshop	2/17/03	12	**4.6**
8. Physics with Single Molecules	3/22/03	38	**4.7**

scale: 1 = waste of time
5 = extremely useful

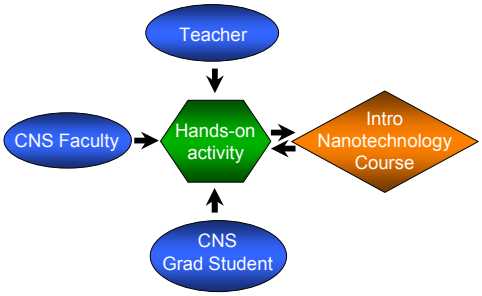
CNS Lab Development for Schools

- Suite of ~50 lab kits
  - Each team: CNS faculty, graduate student, classroom teacher
- Themes
  - Nanoscale science and engineering (NSE)
  - Electronics, optics, magnetics, physics underlying NSE
- Targets
  - High-school and middle-school curriculum
  - Introductory college courses including *AEP 130 Introduction to NSE*

Dr. Monica Plisch
Education Director

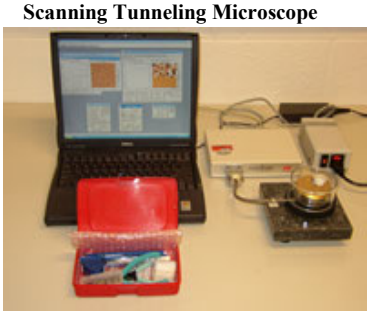


CNS graduate students Sean Garner (standing, left) and Ethan Minot (standing, right) lead teachers through the quantum of resistance lab they developed.

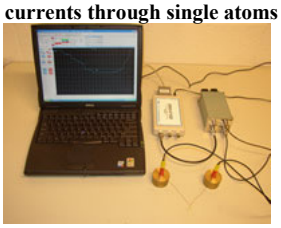


Laboratory Modules

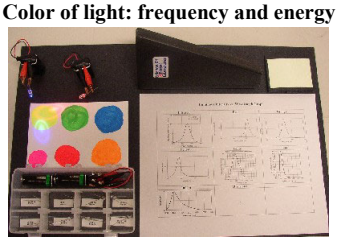
Scanning Tunneling Microscope



Quantum of Resistance:
Electrical currents through single atoms



Color of light: frequency and energy



Thank you