

Science of Nanoscale Systems and their Device Applications

Harvard, MIT, UC Santa Barbara and Museum of Science Boston
Sandia, Oak Ridge and Brookhaven National Labs
TU Delft, Uni Basel, NEST, Lund Univ and Univ of Tokyo



R.M. Westervelt Director, **R. Graham** Asst Director
N. Brave Center Coordinator

Outline

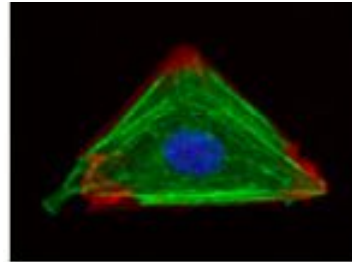
- **NSEC Research**
 - **Tools for Integrated Nanobiology** (Whitesides)
 - **Nano Building Blocks** (Bawendi & Park)
 - **Imaging at the Nanoscale** (Ashoori)
- **NSEC Infrastructure**
 - **Center for Nanoscale Systems (CNS)**
 - **Lab for Integrated Science and Engineering (LISE)**
 - **National Nanotech Infrastructure Network (NNIN)**
- **Industrial Innovation**
 - **Industrial Knowledge Transfer**
 - **Startup Companies from NSEC research**
 - **International Collaborations**

Center Research (2001-10)

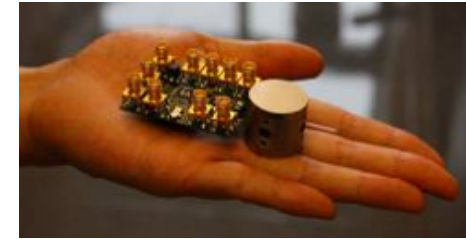
microfluidics



Magnetic bead 'flagella' (Stone)

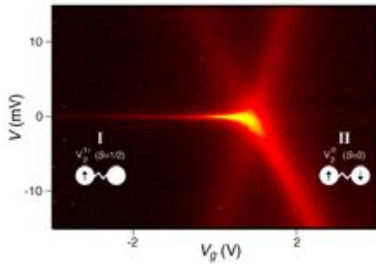


Engineer Cell Environment (Whitesides, Aizenberg)

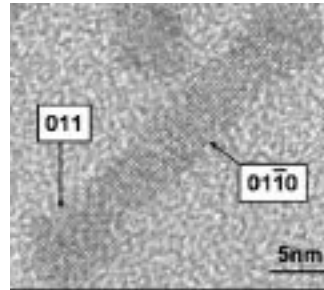


Handheld NMR system (Ham)

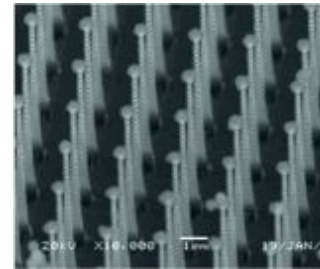
nanostructures



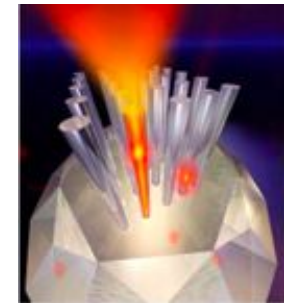
Single molecule SET (Park)



Nano barbell (Bawendi)



CaCO₃ grown on nanoposts (Aizenberg)

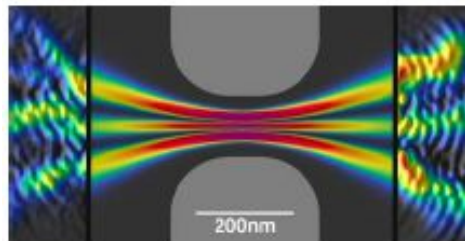


Diamond nanowire NV centers (Loncar)

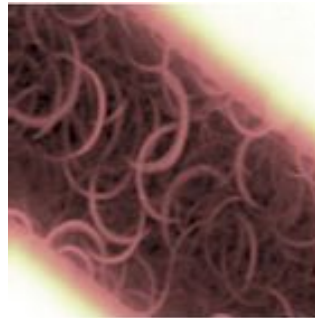
2001

2010

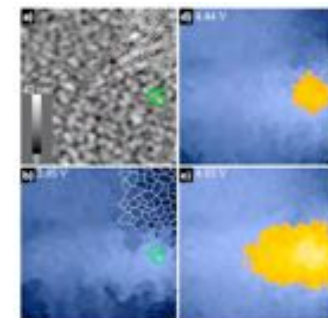
SPM imaging



SPM images of electron waves (Westervelt & Heller)



SPM images of QDs in QHE (Ashoori)

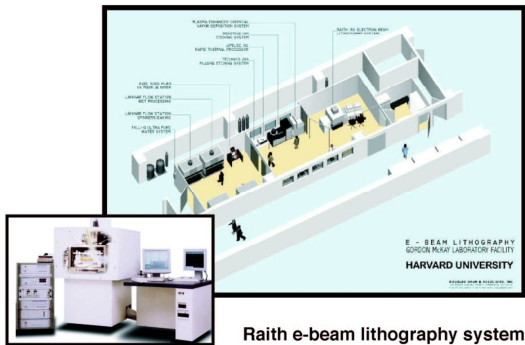


SPM images of metal-insulator transition in VO₂ thin film (Hoffman & Ramanathan)



NSEC Infrastructure (2001-2010)

New McKay Clean Room



Center for Nanoscale Systems (CNS) facilities inside the new Laboratory for Integrated Science and Engineering (LISE) (2007)

2001



2010



Museum of Science

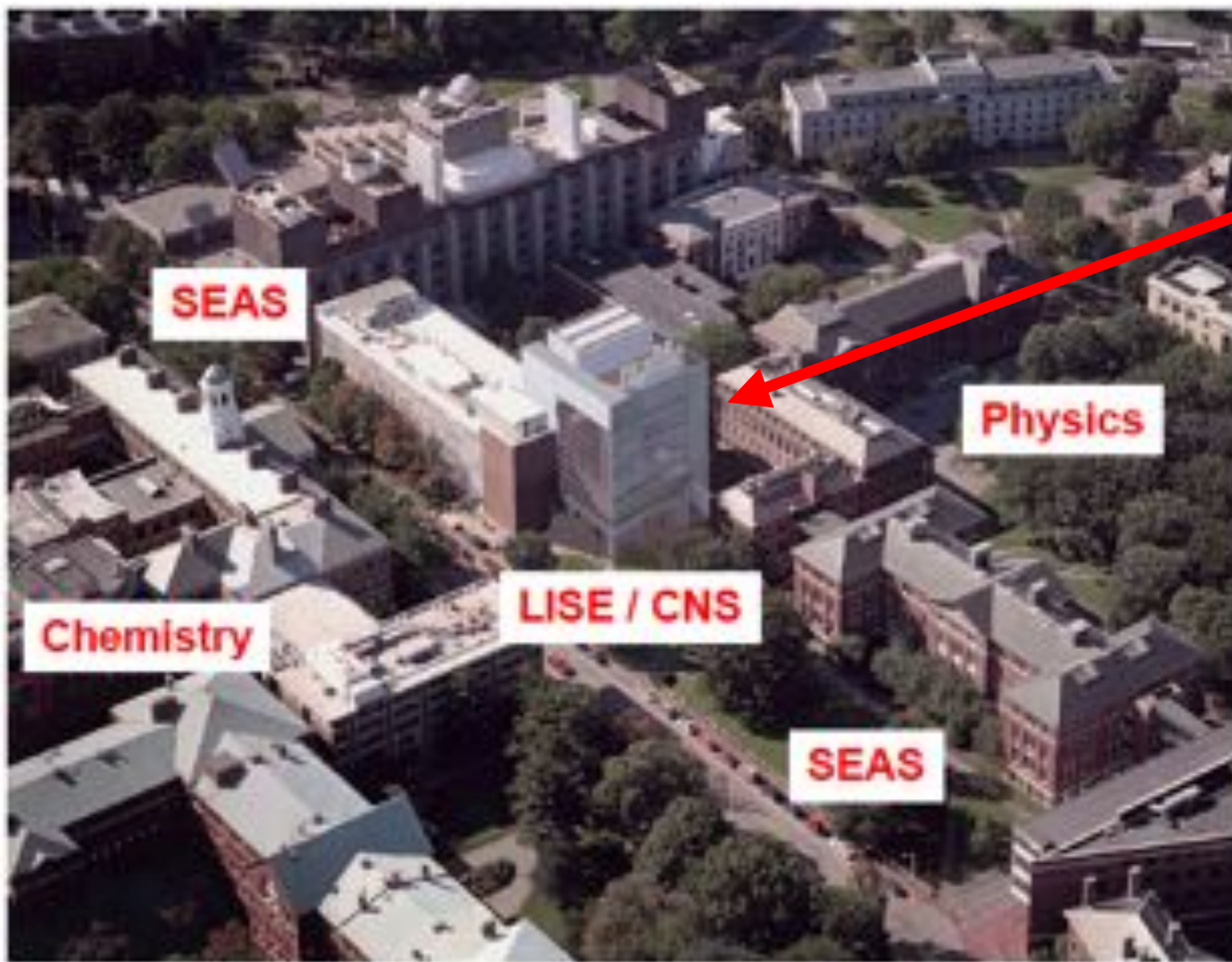


Talking Nano DVDs



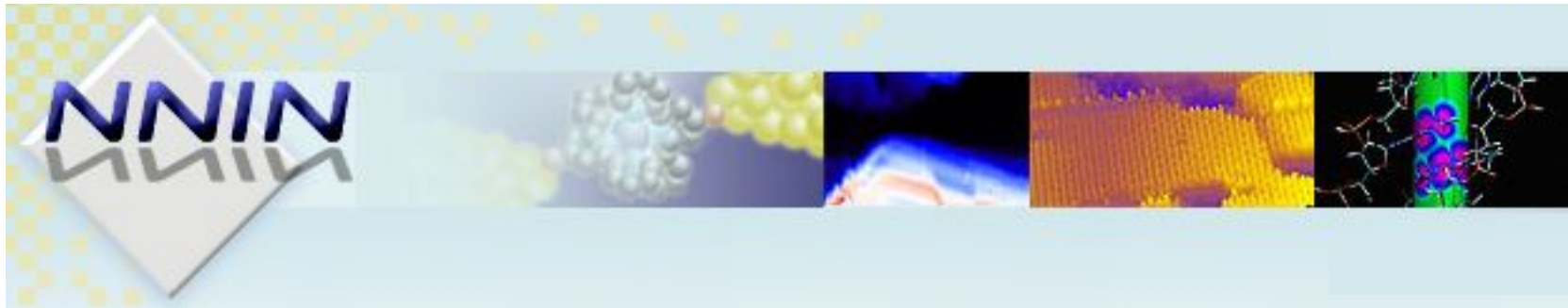
NISE Network

LISE / CNS connects Chemistry, Physics and School of Engineering & Applied Sciences



NSEC Site Visit 2010

National Nanotechnology Infrastructure Network



Center for Nanoscale Systems (CNS) at Harvard

One of 14 members

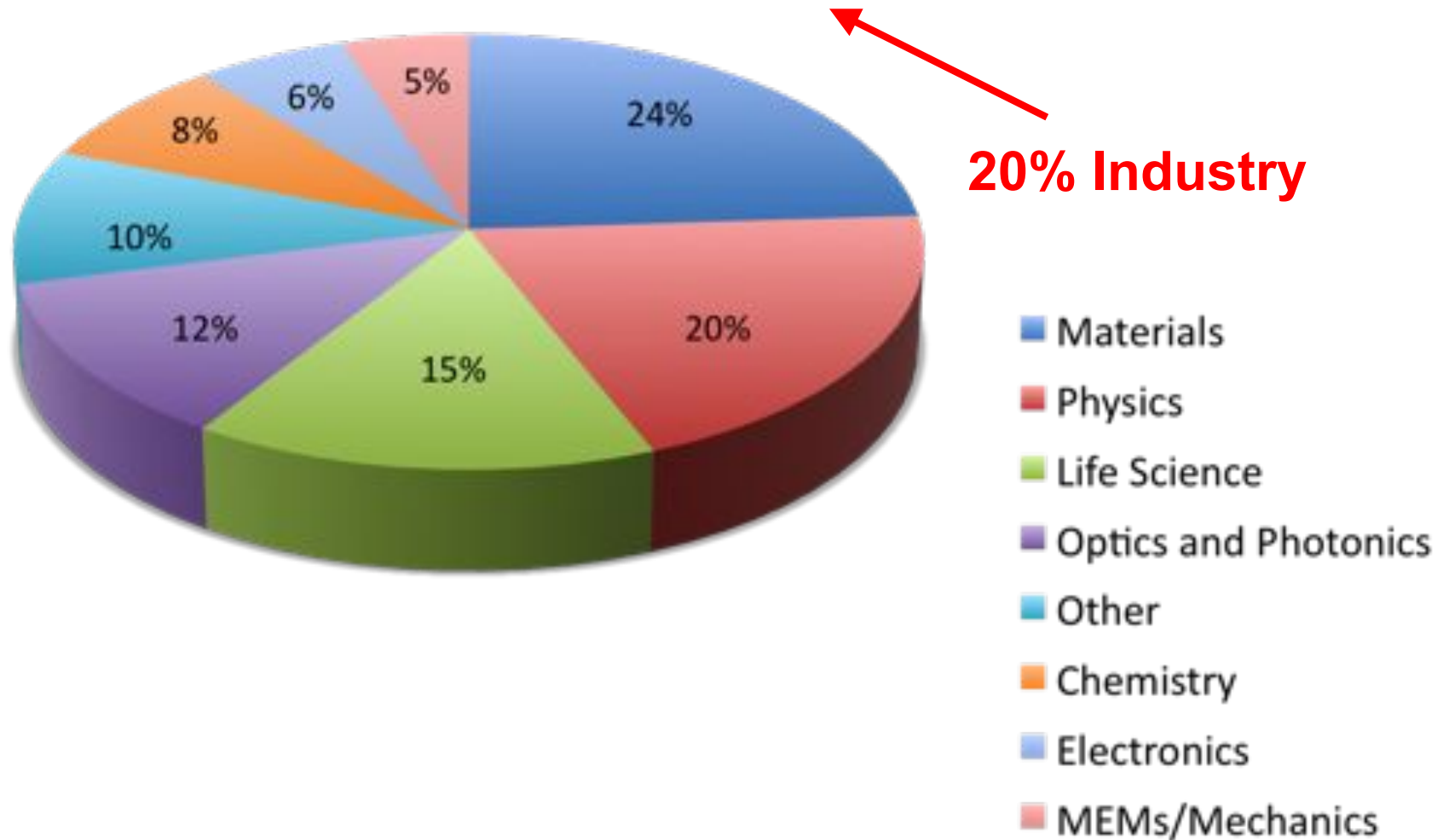


NSEC Site Visit 2010

CNS/NNIN Users

Over **1100** Users of Shared Facilities, FY 2009-10

440 Grad Students, **295** Postdocs, **215** Industry & other, **65** Undergrads



NSEC Site Visit 2010

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- ➔ • **Industrial Innovation**
 - **Industrial Knowledge Transfer**
 - **Startup Companies from NSEC research**
 - **International Collaborations**

Industrial Innovation

23 Startups by NSEC Faculty (2001-2010)

Arsenal Medical *to* Si Energy Systems

440+ High Tech jobs created

30 Companies Licensed NSEC Researcher Intellectual Property (2001-2010)

180+ Licenses on NSEC Researcher IP (2001-2010)

Agilent Technologies *to* Vista Therapeutics, includes licenses by NSEC startups

\$6.8M total licensing fees (2001-2010)

43 Industrial Collaborations

Advanced Energy Consortium *to* Zena Technologies

60 Connections with Industry & other Sectors

Advanced Diamond Technologies *to* Zena Technologies

Startup Companies from NSEC Research since 2001 - examples

- **Arsenal Medical** (Whitesides and Roberts)
 - Develops therapeutics based on "BioActive" composites to make elastic materials and locally dose drugs.
- **Claros** (Whitesides)
 - Claros builds portable instruments that move *in vitro* medical diagnostic tests from hospital labs to the point of care.
- **Diagnostics for All** (Whitesides)
 - Nonprofit organization that is producing paper microfluidic systems to diagnose disease.
- **Endolumina** (Westervelt and Thompson)
 - Wireless biosensors for the GI tract based on RFID technology.

Startup Companies (2)

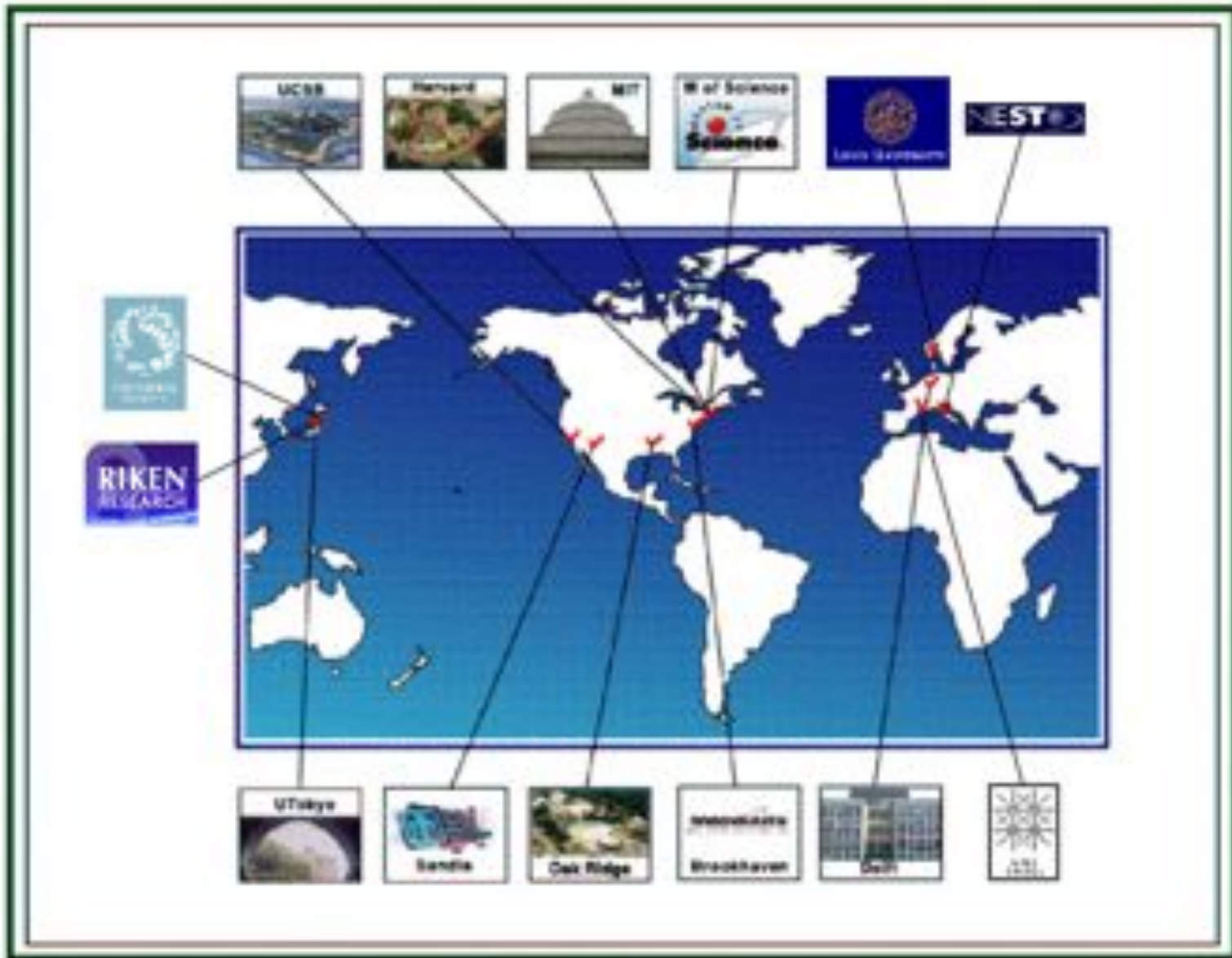
- **Enexra Inc** (2 postdocs, Pfeffer & Lichtensteiger)
 - Technology that reduces the cost by 30% for Si solar cells.
- **Nano Terra** (Whitesides and Roberts)
 - Soft lithography, self assembly, surface chemistry and microfluidics to make smart materials, flexible electronics and displays, fuel cells, batteries and solar cells.
- **Qd Vision** (Bawendi)
 - Manufactures lighting and display products based on semiconductor quantum dots.
- **Qu Nano** (Samuelson)
 - Develops nanowire LED solid state light sources with high efficiency, long life and low cost.
- **Si Energy Systems LLC** (Ramanathan)
 - Solid oxide fuel cell, directly on a Si chip, that generates power from gaseous hydrocarbon fuel at lower temperature.

High-Tech Job Formation from NSEC Startup Companies

440 Jobs Created

Company	Jobs	Company	Jobs
Arsenal Medical	30	Igen	18
Cambridge Nanotech	25	Minerva	20
Capsum	12	NanoTerra	25
Claros	10	Paper Diagnostics	1
CoolEdge Lighting	8	QdVision	60
Diagnostics for All	5	QuNano	17
Fluidigm	90	Raindance Tech	70
GnuBIO	2	SiOnyx	15
HabSel	2	Surface Logix	30

International Collaborations



NSEC Site Visit 2010

New Memos of Understanding to promote international collaboration

RIKEN (Japan) / Harvard

Nanoscience and Technology
Scanning probe microscopy
Computational Science

Tohoku University (Japan) / Harvard

Spintronics
Oxide Semiconductors



Frontiers in Nanoscale Science & Technology

*Nanoelectronics & Nanophotonics
Spintronics & Quantum Information*

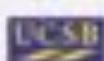
Nanoscale Science and Engineering Center (NSEC)

Harvard, MIT, UC Santa Barbara, Museum of Science, Boston
Univ of Basel, TU Delft, Lund Univ, RIKEN, Univ of Tokyo



January 5 - 7, 2011
RIKEN Wako campus
Saitama, Japan

www.nsec.harvard.edu/nst



Speakers:

Tsuneya Ando (Tokyo Inst Tech)
Hendric Bluhm (Harvard)
Jonathan Fan (Harvard)
Christian Glattli (CEA Saclay)
Tetsuro Hanaguri (RIKEN)
Pablo Jarillo-Herrero (MIT)
Gijs de Lange (TU Delft)
Heiner Linke (Lund Univ)
Daniel Loss (U Basel)
Fumihiro Matsukura (Tohoku Univ)
Masahiro Nomura (Univ Tokyo)
Konstantin Novoselov (Manchester)
Hajime Okamoto (NTT)
Hongkun Park (Harvard)
Lars Samuelson (Lund)
Axel Scherer (Caltech)
Paul Sheehan (Naval Research Lab)
Charles Smith (Cambridge)
Kota Tateno (NTT)
Robert Westervelt (Harvard)
Hongqi Xu (Lund Univ)
Michihisa Yamamoto (Univ Tokyo)

Broader Impact

- **Educate the next generation of scientists & engineers**
 - Multidisciplinary Nanoscale Science and Engineering
- **Major infrastructure investments by Harvard**
 - Center for Nanoscale Systems (CNS) (\$20M equipment)
 - Laboratory for Integrated Science & Engineering (LISE) (\$170M)
- **Industrial Innovations**
 - 23 Startup companies from NSEC researchers create 440+ jobs
 - 180 Licenses on NSEC Intellectual Property (\$6.8M fees)
 - Many industrial collaborations and connections
- **Partnership with Museum of Science, Boston**
 - Engage the public through presentations and forums
 - Nanoscale Informal Science Education (NISE) Network

NSEC

Overview Education Events Participants Highlights Research

Science of Nanoscale Systems and their Device Applications

Robert Westervelt, PI & Director and Bertrand Halperin, Co-PI

Our Nanoscale Science and Engineering Center (NSEC) is a collaboration among Harvard University, the Massachusetts Institute of Technology, the University of California—Santa Barbara, and the Museum of Science—Boston with participation by Delft University of Technology (Netherlands), the University of Basel (Switzerland), the University of Tokyo (Japan), and the Brookhaven, Oak Ridge, and the Sandia National Laboratories.

The NSEC combines “top down” and “bottom up” approaches to construct novel electronic and magnetic devices with nanoscale sizes and understand their behavior, including quantum phenomena. Through a close integration of research, education, and public outreach, the Center encourages and promotes the training of a diverse group of people to be leaders in this new interdisciplinary field.

NSEC at Harvard is supported by the National Science Foundation.

Harvard and UC Santa Barbara are two of an integrated partnership of thirteen user facilities, led by Cornell and Stanford, that provide opportunities for nanoscience and nanotechnology research.

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NSEC.Harvard.edu

CNS.fas.Harvard.edu

NNIN.org

MOS.org/nano

NISEnet.org

Thank You

NSEC Site Visit 2010