Science of Nanoscale Systems and their Device Applications

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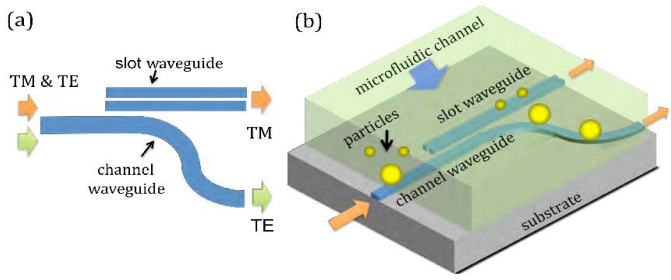
The Goals of our Center are to advance the fields of ***Nanoelectronics***, ***Nanophotonics*** and ***Nanobiology***. In ***Nanoelectronics*** and ***Nanophotonics*** we build, image, and test devices and systems from nanocrystals, nanowires and MBE-grown heterostructures, and understand them theoretically. For ***Nanobiology*** we develop microfluidic tools based on technology from the physical sciences to investigate and understand biological systems on the nanoscale.

Three Research Clusters address these goals to make fundamental contributions to nanoscale science and engineering:

Cluster I: Tools for Integrated Nanobiology – Biology and Medicine offer an enormous range of engaging problems in functional biological systems. This research cluster develops powerful new tools to manipulate and test cells and tissues, which are based on microfluidics and advanced technology from the Physical Sciences.

Cluster II: Nanoscale Building Blocks – New classes of nanoparticles and nanowires are grown and synthesized, with an emphasis on new materials and structures with unconventional shapes. Molecular Beam Epitaxy grown heterostructures provide new properties. These nanoscale building blocks open new approaches in nanoelectronics and nanophotonics, and provide new biosensors.

Cluster III: Imaging at the Nanoscale - The quantum behavior of electrons and photons inside nanostructures is imaged using custom-made cooled scanning probe microscopes. Imaging is an essential tool for the development of new nanoelectronic and nanophotonic devices.



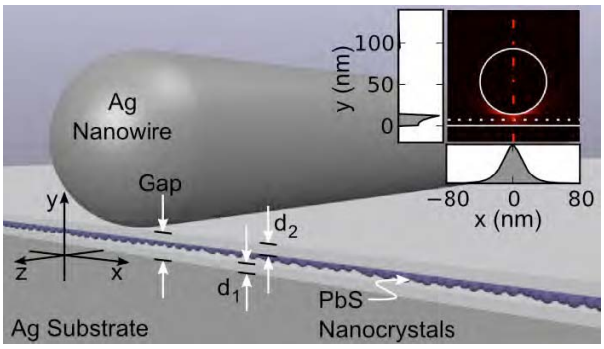
Cluster I: Ultra Compact Polarization Splitter. Slot-waveguide based on-chip polarization splitter and passive particle sorting (Ken Crozier)

The ***Center for Nanoscale Systems (CNS)*** is a major investment by Harvard to provide facilities needed to conduct research in nanoscience and engineering. The new ***Laboratory for Integrated Science and Engineering*** houses CNS facilities for imaging, nanofabrication, and materials growth. Harvard and UC Santa Barbara open these facilities to outside users as members of the NSF supported ***National Nanotechnology Infrastructure Network (NNIN)***.

Education – Led by Kathryn Hollar at Harvard, our Center promotes ***Education*** in nanoscale science and engineering and develops human resources at the pre-college, undergraduate, graduate, and postdoctoral levels through a range of activities including Research Experience for Undergraduates and Research Experience for Teachers programs, a Harvard course *Applied Physics 298r — Interdisciplinary Chemistry, Engineering and Physics* giving tutorial introductions to nanoscience and engineering and annual workshops including *Industry*

Partnership Program workshops and *Frontiers in Nanoscale Science and Technology* workshops held with our international collaborators.

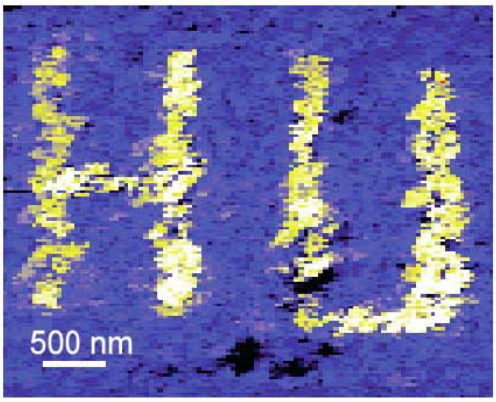
Diversity - Our Center aims to increase ***Diversity*** by recruiting a more diverse group of graduate students and postdocs, increasing the diversity of participating faculty, recruiting members of under-represented groups through our REU program, introducing public school students to science and engineering, and developing long-term partnerships with predominantly female and minority-serving institutions.



Cluster II: Plasmonic Optical Cavities. Schematic diagram of plasmonic nanocavity with coupled nanocrystal optical emitters not to scale). Cavity comprised of a silver nanowire coupled with a planar silver film (Evelyn Hu)

Museum of Science, Boston - Our Center has developed a strong partnership with the ***Museum of Science, Boston*** to inform the public about advances in nanoscience and technology in an entertaining and informative way through presentations, forums, displays, and student internships. Led by Larry Bell and Carol Lynn Alpert the Museum is a core member of the ***Nanoscale Informal Science Education (NISE)*** network. The NISE network provides a nationwide partnership to foster public awareness, engagement and understanding of nanoscale science, engineering and technology. Center faculty Hu, Mazur, Westervelt, and Whitesides are members of the NISE Net Scientific Advisory Board.

International Collaborations – Our Center has strong international collaborations with institutes in Europe and Japan, including Delft University of Technology, the University of Basel, Lund University, and Scuola Normale in Pisa, in Europe, and Tohoku University, University of Tokyo and RIKEN in Japan. Harvard University has signed Memos of Understanding with RIKEN and Tohoku University to promote collaborative research. Our Center promotes these collaborations through the annual Frontiers in Nanoscale Science and Technology Workshop series. The last FNST workshop was held on January 5-7, 2011 at RIKEN in Japan, and will include talks top speakers, including Konstantin Novoselov, 2010 Nobel Laureate in Physics.



Cluster III: High Spatial Resolution Magnetic and Electrostatic Force Microscope. High conductance regions written into a VO2 thin film by SPM tip via a field-induced metal-insulator transition (Jennifer Hoffman, Shriram Ramanthan)

Engaging the Public in Nanoscale Science and Engineering

As described above, our Center has conducted an active program to engage public school and university students in Nanoscale Science and Engineering, and to improve the diversity of our researchers and teachers. The Museum of Science, Boston played an essential role, by engaging the public in nanoscience and technology through engaging presentations and debates, and interesting displays. Our Center's early

success in forming a Museum / University partnership encouraged the creation of the new Nanoscale Informal Science Education (NISE) Network, which is building partnerships of this type nationwide. Developing effective ways to connect the public with new scientific discoveries and to discuss the possible benefits and concerns associated with new technology is an important part of our Center's activity.

Startups, Spinoffs and Industrial Collaborations

Our Center has encouraged connections with ***Industry***, working with Harvard's ***Office of Technology Development*** and the ***Industrial Outreach Program*** of the School of Engineering and Applied Sciences.

A supplement funded by the ***Nanoelectronics Research Initiative (NRI)*** of the ***Semiconductor Research Corporation*** supported the development of new vanadium oxide materials that undergo an electric field induced metal-to-insulator transition for future logic switches.

Our Center has developed strong connections with Industry.

- Over the past nine years, 23 startup companies have been created by our Center's faculty members; ranging from Arsenal Medical to Vista Therapeutics. These new companies have generated over 484 new, high tech jobs, an important contribution to our economy.
- Over the past nine years 30 companies have licensed intellectual property from our Center's researchers, totaling 180+ licenses with $6.5M in licensing fees.
- Center researchers have 43 collaborations with industrial colleagues as well as 60 connections with industry, national laboratories, and other sectors.

The scientific advances made by our Center's investigators as well as the community built through collaborative, multidisciplinary research played an important role in building these new companies and connections.

Additional Information

For further information, please see our website http://nsec.harvard.edu.