NSF SMART LIGHTING Engineering Research Center

Rensselaer Polytechnic Institute (lead institution)

Engineering light for the benefit of humanity

A National Science Foundation Engineering Research Center since 2008

Partner Institutions:

- *Boston University*
- *The University of New Mexico*

Outreach Institutions

- *Howard University*
- *Morgan State University*
- *Rose-Hulman Institute of Technology*

The NSF SMART LIGHTING Engineering Research Center (ERC) will develop new technologies and applications to change the way society uses lighting. To realize the full potential of light, the ERC will enable efficient, full spectrum lighting, novel modes of communication with unlimited bandwidth, brighter and more efficient displays – to improve our health, safety and productivity and improve energy efficiency.

The newest generation of efficient yet highly controllable light can be accomplished with light-emitting diodes (LEDs), which are capable of generating white light with 20 times greater efficiency than conventional light bulbs. Deployed on a global scale to replace conventional sources, solid-state light sources will result in enormous environmental and energy benefits. Smart Lighting will generate comfortable, efficient illumination while simultaneously providing high speed data access, scan for biological and biochemical hazards and impact our daily lives from the way we communicate to the way we communicate to the way we practice medicine.

Smart Spaces Test Bed
Systems comprised of full-spectrum LED sources, distributed light sensors and adaptive control are being designed to record the lighting fingerprint of an illuminated space. The ERC is developing this technology to deliver superior quality lighting with reduced electrical energy consumption.

The right light, when and where it is needed

The future of smart lighting might include:

- Brilliant, highly efficient, full color displays enabled by polarized emitters. Virtual windows that can be placed in windowless environments
- Indoor air quality sensing and maintenance with efficient, controlled UV exposure systems
- Increased safety in transportation systems through the implementation of ambient intelligence
- Unlimited bandwidth for data
- Reduced pollution and global warming through energy-conserving, mercury-free lighting
- Reduced dependency on sleep-inducing pharmaceuticals, reduced risk of cancer, heart disease, and support of the natural circadian rhythm

The Center's Mission

- Engage in research leading to smart lighting systems with adaptive and controllable properties
- Develop a culture of innovation and engage industry to help shape the center's research and commercialize its results
- Educate a diverse, world-class workforce that will be needed to grow the business of Smart Lighting

Research

Sources, Sensors and Controls

Through the holistic integration of advanced, solid-state light sources, sensors, and adaptive control architectures, the ERC will provide revolutionary new approaches to lighting design and energy efficiency. The **sources** developed will enable the integrated control of lighting parameters such as intensity, spectral properties, fast switching, adaptive illumination, polarization and efficiency. The **sensors** created will be inexpensive, power efficient, and will be able to measure

the properties of light to support higher sensitivity, higher response speed, high resolution, and adaptive parameter control. feedback from the sensors will allow the ERC to develop **controls** needed to illuminate and provide energy-efficient, healthy indoor lighting environments.

Research Objectives

Efficient Full Spectrum Lighting Systems

- High efficiency, low droop LEDs for all visible and UV wavelengths
- Efficient light extraction optics for chips and fixtures
- Spectrally selective ambient light detectors
- Improved performance and reduced cost through integration

Display Illumination Fusion System

- High brightness, full spectrum lighting panels with added functionality for BLU operation

Healthy Lighting Systems

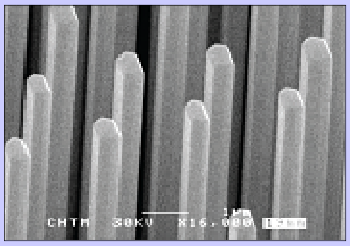
- High performance UV LEDs
- High sensitivity, hazard-specific sensors
- Biological and biochemical mitigation strategies
- Circadian entrainment

Lighting for Data Communication

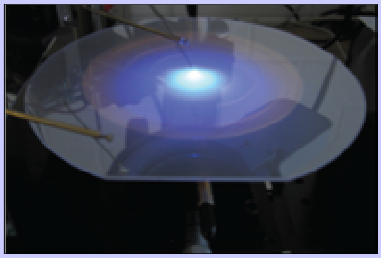
- Very fast LED lighting fixtures
- Spectrally selective fast detectors
- High speed photodiode arrays for mobility and tracking
- High speed LED arrays
- Duplex system configuration

Adaptive Lighting Control Systems

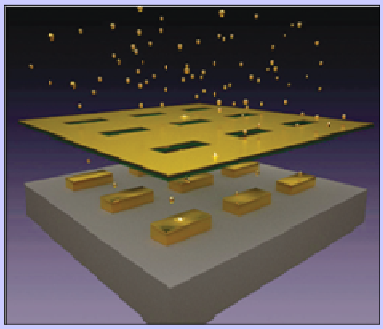
- Source sensor communications
- Occupancy sensing
- Energy minimization protocol



Nanowire LEDs: *Nanowire LEDs grown in the ERC offer many possibilities for improved LED operation, including reduced defect density when compared to planar wafer structures and better light extraction for higher efficiency operation.*



Blue LED Wafer: *Probe test of a high efficiency, blue LED wafer. The ERC is developing technologies to improve the efficiency of all wavelengths – from UV to deep red for efficient, full spectrum lighting systems.*



Nanostencil lithography: *ERC researchers have developed a new way to make large numbers of plasmonic nanorod antenna arrays using nanostencil lithography. The arrays have the same optical properties as those engineered by conventional electron lithography and could revolutionize light sensing.*

Education

To support the Center's vision, the ERC education program seeks to prepare an interdisciplinary community of students for successful competition in the global economy. ERC students engage in hands-on and minds-on learning in a rigorous and challenging academic environment, with problem-based learning experiences that connect fundamental engineering knowledge from a variety of disciplines; best practices in design, product development, and entrepreneurship; and contemporary engineering tools. A systems approach to framing and solving problems is followed, integrating sound technical fundamentals, business considerations, understanding of social and environmental impacts, and the needs of a technical workforce prepared to make difficult systems-level tradeoffs.

The SMART LIGHTING Education, Outreach, and Diversity program plans are highly interconnected within our educational culture, which features: (1) exceptional research based on strong fundamental science; (2) active, regular engagement with industry, research labs, domestic and international universities, K-14 schools, and museums; and (3) commitment to an ever more diverse student body and workforce.

Our ERC education and outreach programs have five basic components, listed below:

Science you can see builds on the suitability of light for a fully engaging visual experience with strong societal impact. Because of the visual accessibility of the science and engineering of light, students will be attracted to the promise of smart lighting and become enthusiastic advocates working with the communities of potential future students, engineers, scientists, and other ERC partners.

Learn by teaching builds on the principle that teaching educates educators. All graduate students and researchers will be involved in developing and delivering education to a wide variety of formal and informal venues to enhance their learning and to develop the skills necessary to work in other educational cultures.

Beyond research offers education in innovation in a global economy through training in and a practical appreciation for effective communications, intellectual property, entrepreneurship, working and living cultures, and the rudiments of effective teaching and educational assessment.

Courses in smart lighting and related fundamental disciplines will fully prepare our undergraduate and graduate students to pursue their research and careers. Mod-

ules will be developed for introductory and core courses in the engineering and science programs in which Center faculty teach.

Special educational opportunities will include summer programs as part of Beyond Research, internships, student and faculty exchanges, Chautauqua, REU, and RET programs that engage ERC students, potential students, and their teachers.

All partner universities monitor existing outreach activities at their institutions to identify opportunities for participation by SMART LIGHTING students and investigators.

ERC research facilities will be used by undergraduate and graduate students at all levels who are directly involved in SMART LIGHTING research. Participants in REU, RET, and Young Scholars programs will also work in these facilities, under the guidance of graduate students or staff.

Industrial Collaboration & Innovation

The SMART LIGHTING ERC's industrial collaboration and innovation program has been strategically designed to speed the commercialization of discoveries made by the Center. Strong and close working relationships are fostered among SMART LIGHTING faculty and student researchers, university and local and state government innovation partners, and our industrial collaborators. Each participant represents a critical component of the innovation bridge. In addition to generating new discoveries, a number of our faculty are using their prior experiences in starting companies to help other faculty and students with new start-up firms. Each of our core university partners has a campus Incubation center that provides physical space for start-up companies. Several state and local agencies that focus on economic development are providing access to market analysis, industrial contacts, venture capitalists, and financial support.

The ERC's industrial partners comprise a diverse group of small, medium, and large companies with business interests across all the ERC thrusts. The Center's industrial partnership is governed by an intellectual property (IP) management policy that encourages collaborations among academic, industrial members, and strategic partners. Industrial membership offers both a full and affiliate level. Full members enjoy generous IP licensing provisions and a seat on the Industrial Advisory Board. The Center supports small firms in exploiting opportunities offered by the federal and state Small Business Innovation Research (SBIR)/Small Business Technology Transfer Research (STTR)-type programs during the translational research stages.

Our industry partners provide guidance on strategic planning, collaborate on joint research opportunities, assist with test bed design, and support both formal and informal education of our undergraduate and graduate students. Summer internship, co-ops, and job opportunities at the member companies will be available to students at various stages for leveraging the ERC research activities and creating stronger ties between the ERC and its industrial members. In addition to the industrial membership privileges, companies can fund research projects on any specific topic with ERC participants to accelerate product development using ERC synergistic technologies. To further enable rapid commercialization of new discoveries made by the ERC participants, venture capital firms and angel investors frequently are invited to the ERC for presentations on our inventions and technology development activities.

Facilities

Rensselaer, the University of New Mexico (UNM), and BU facilities together provide a vertically integrated array of fabrication, processing, characterization, and system assessment tools that is unparalleled. Facilities for conducting SMART LIGHTING research include the 5,000 sq. ft. ERC Central Laboratories, located in RPI's George M. Low building, which include a wide array of semiconductor material growth, device fabrication and characterization tools, as well as instruments for systems research and testbed implementation. These facilities are complemented by the nano-growth and nano-fabrication capabilities at UNM, along with the optical communication system design and characterization at BU.

Center Configuration

The SMART LIGHTING ERC is a partnership of Rensselaer Polytechnic Institute, the lead university, with core research partner universities Boston University and the University of New Mexico. The ERC partners with three outreach universities: Howard University, Morgan State University, and Rose-Hulman Institute of Technology.

More than 40 faculty members from multiple institutions with diverse backgrounds and disciplines work together in teams on the Center's research programs in our world class facilities.

Center Headquarters

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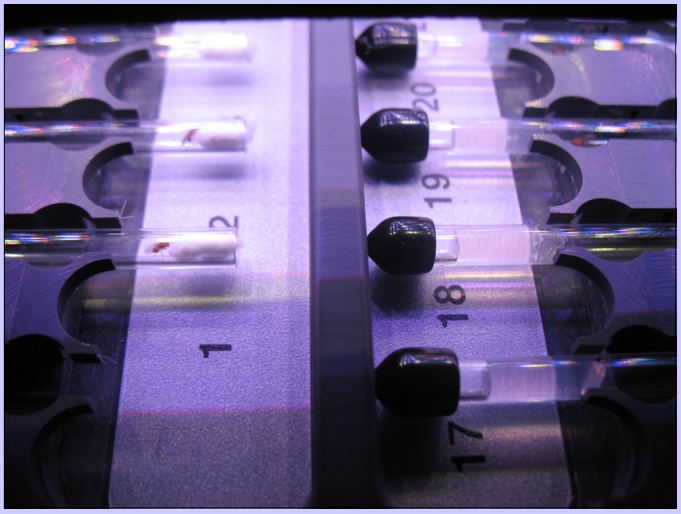

Complex biological control mechanisms that correlate light exposure to circadian rhythm control is being studied in fruit flies. Such studies can inform the optimal design of advanced lighting systems to help regulate circadian function for improved human health and well-being.

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