

NSF SMART LIGHTING Engineering Research Center

Rensselaer Polytechnic Institute (lead institution)

Engineering light for a brighter, sustainable future

A National Science Foundation Engineering Research Center since 2008

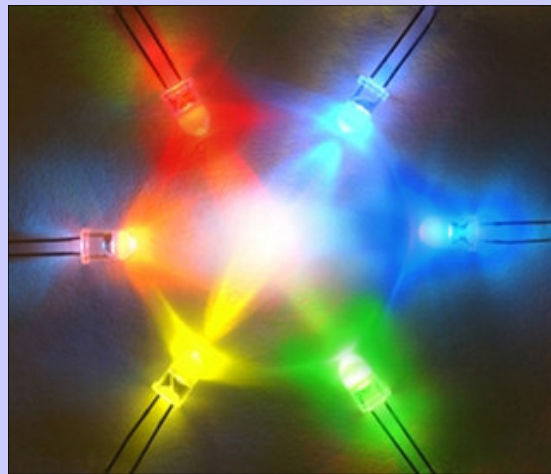
Partner Institutions:

- 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 seeks to revolutionize our ability to utilize solid-state light sources to increase our collective health, happiness, and safety. In 1998, the National Academies published a report on *Harnessing Light: Optical Science and Engineering for the 21st Century*, in which they described the world we live in as bathed in light. We see with light; plants draw energy from light; and light is at the core of technologies in many fields. To realize the full potential of light, the SMART LIGHTING ERC aims to create new solid-state lighting technologies to enable rapid biological imaging, novel modes of communication, efficient displays, and safer transportation, all with significant savings in energy use. These new lighting technologies will enable a revolution in communications, the practice of medicine, national defense, exploration of the frontiers of science, and much more.



Multiple LEDs make bright white light.

The 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, such solid-state light sources will result in enormous environmental and energy benefits.

Solid-state light sources can go beyond the replacement of existing sources by providing new capabilities not shared by any other light source, including the control of spectrum, color, temperature, polarization, temporal modulation, and spatial emission pattern. These future smart light sources can harness the huge potential of LEDs by offering multi-dimensional controllability in a wide range of applications, including optical microscopy, imaging, display technologies, communications, networking, and transportation systems.

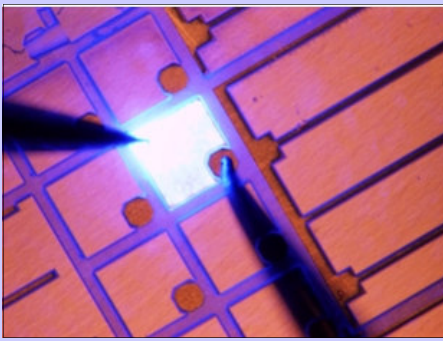
Smart light sources and advanced lighting systems will result in tremendous benefits to society. Examples include:

- Fundamental advances in disease understanding and treatment through long duration multi-color live cell observation for drug discovery.
- Brilliant displays with high efficiency and large color gamut enabled by polarized emitters
- Increased safety in transportation systems through the implementation of ambient intelligence
- Novel modes of communication, networking, and sensing
- Reduced pollution and global warming through energy-conserving, mercury-free lighting
- Reduced dependency on sleep-inducing pharmaceuticals, reduced risk of cancer, and support of the natural circadian rhythm, thereby enabling higher productivity and a better quality of life.

We envision a new world of photonics technology, which will multiply the benefits of solid-state lighting technology and make smart lighting products and benefits available worldwide.

Research

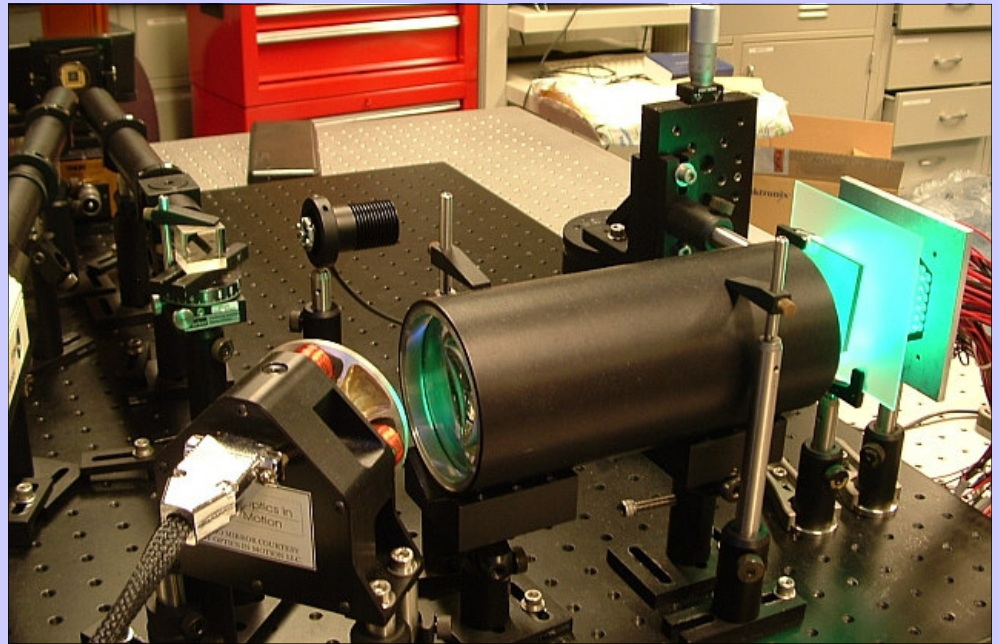
SMART LIGHTING research is organized in three major Research Thrusts: (1) System Applications (2) Device Technology and (3) Novel Materials.



Measurement and characterization stations provide rapid prototyping and testing capabilities.

Core components of the Systems Applications Thrust are three testbeds that concern bio-imaging systems, indoor and outdoor communication systems, and energy-aware lighting and display systems. The systems applications will demonstrate unprecedented functionalities and capabilities that are not feasible with conventional light sources. The functionality of the systems testbeds is enabled by the unique controllability of the SMART LIGHTING devices that are being developed under the Device Technology Thrust. Accordingly, the Device Thrust focuses on the controllability and efficiency of smart lighting devices. The Novel Materials Thrust, through innovation in nanotechnology and metamaterials, supports the Device and Systems thrusts.

An example of the Systems thrust is a new way to observe live cell mitosis with multiple-color fluorophores over long periods to gain an unprecedented amount of information on cellular processes under various environmental conditions. This is achieved by optimally adjusting the light spectra and dosage based on the cell image feedback to avoid photo-damage of the cells and photo-bleaching of the fluorophores. An example of the Device thrust is the focus on efficiency droop, which is the single most important problem in solid-state lighting technology. New approaches have made the SMART LIGHTING ERC team the leading force in low-droop devices. Finally, an example of the Materials thrust is a nano-column emitter which promises low defect densities as well as high light-extraction efficiency.



Adaptive scanning optical microscope (ASOM) used for bioimaging with smart lighting in reflected and transmission illumination modes

The RPI Lighting Research Center (LRC) is a close partner of the SMART LIGHTING ERC. It provides unique resources and capabilities in lighting research, education, and industrial outreach. The LRC participates in the ERC's research related to lighting and health and supports the ERC in technology innovation and commercialization.

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 con-

nect 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. Based on the Mobile Studio and other educational materials, we are developing a portfolio of learning modules that can be utilized at all educational levels in all educational venues and that incorporate significant experimentation and numerical modeling in addition to traditional paper-and-pencil problem solving.



State of the art fabrication and characterization facilities used for research and education

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 be developed to fully prepare our undergraduate and graduate students to pursue their research and careers. Modules 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 investiga-

tors. For smart lighting to achieve its promise, a new generation of engineers that better reflects the demographic makeup of the US population as a whole will be required to develop and transfer this technology into the marketplace. As a new ERC, we will focus initially on engaging the various elements of our educational program in mature existing outreach activities at our six institutions, including Rensselaer Polytechnic Institute's (RPI's) Black Family Technology Awareness Day, Boston University's (BU's) Summer Challenge Program for High School Students, the Black Engineer of the Year Awards Council of ECE Chairs' Meeting in Baltimore, and Morgan State University's Maryland Junior Science & Humanities Symposium and Regional High School Feeder Program.

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. In addition, each partner university will develop and maintain attractive and accessible facilities that are part of at least one of the research testbeds, the use of which will be integrated into smart lighting-relevant courses. These facilities will be updated continuously and will serve as an introductory experience and venue for outreach activities at all partner schools. It will be possible to participate in some activities in these facilities at a distance through the ERC's website.

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 three ERC thrusts—materials, devices, and systems applications. 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 is tiered, with two levels: Full Member and Affiliate Member. Full members enjoy generous IP licensing provisions and a seat on the Industrial Advisory Board. Special focus is given to small firms in translating research within the ERC's research program to commercial products. For this purpose, 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 pres-

entations on our inventions and technology development activities.

Facilities

The RPI, 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 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 nanofabrication capabilities at UNM, along with the optical communication system design and characterization at BU. In addition, a bio-imaging testbed is available at the Wadsworth Institute, in Albany, NY, for LED-based absorption and fluorescence microscopy applications.

The operation of the shared ERC Central Laboratories at RPI will be guided by:

- (1) Rapid access to facilities and equipment by academic, government, and industrial partners, enabled by expedited training schedules;
- (2) Initial supervised usage of equipment by visiting personnel until they are fully cleared;
- (3) Stringent maintenance and high availability of equipment by skilled technical support personnel, including a laboratory manager; and
- (4) The further development of our shared technical capabilities.

Center Configuration, Leadership, Team Structure

The SMART LIGHTING ERC is a partnership of Rensselaer Polytechnic Institute, the lead university, with two core research partner universities—Boston University and the University of New Mexico—and three outreach universities: Howard University, Morgan State University, and Rose-Hulman Institute of Technology. Whereas RPI has substantial expertise and a record of accomplishments in all three research thrusts, BU and UNM have particular emphases in the trans-

portation/ communications testbeds and nanotechnology, respectively. The ERC faculty team is composed of a variety of disciplines that include Electrical Engineering, Materials Engineering, Chemical Engineering, Physics, and Economics/Management, illustrating the strongly interdisciplinary nature of the SMART LIGHTING research and team.

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