SMART LIGHTING ERC - OVERVIEW

The Smart Lighting Engineering Research Center

Year 3

THE 20TH CENTURY: BATHED IN ELECTRIC LIGHT

SMART LIGHTING

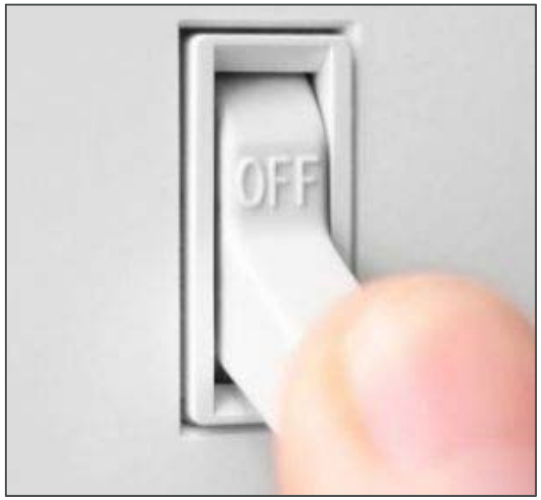
Bulbs, Tubes and Fixtures

- Easy off and easy on
- Light Quality: White
  - Hot Filaments
  - Plasmas

Controls: On/Off/Dim – Human Operator

Sensors: Limited or not used

Controls



Sensors

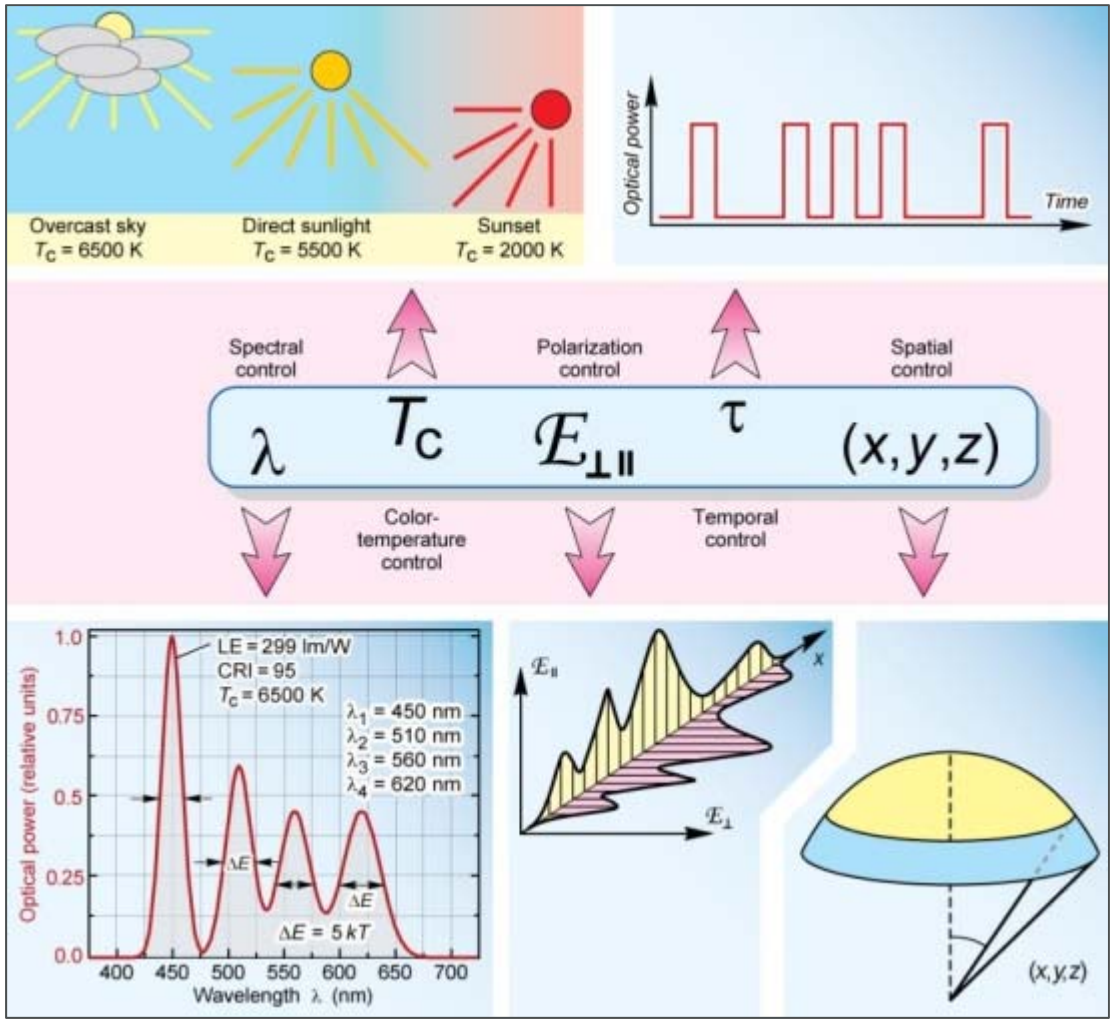
Everyone is a Lighting User

ANOTHER REVOLUTION IN LIGHTING IS COMING

First Wave

- Globally, over 3000 companies making LED bulbs
- Much more efficient, even than CFLs
- Adequate white light, but that is about it

BUT LIGHT CAN DO SO MUCH MORE…



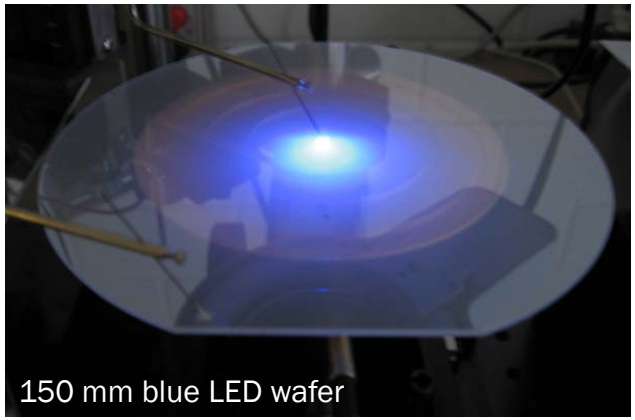
- Color
- High Speed Switching
- Spatial Control
- Polarization Selectivity

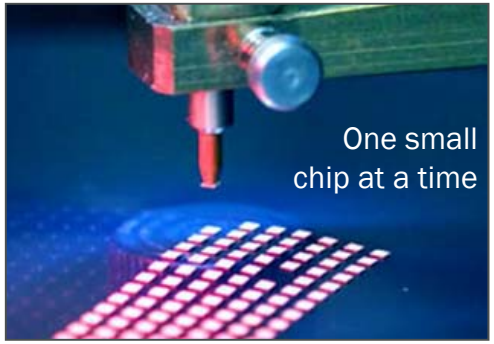
Electric Lighting barely taps the full power of Photons

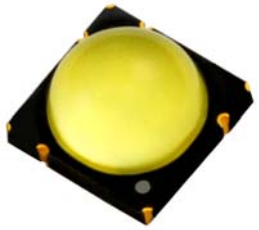
Square Source in a Round Lighting Hole?

- DC device in an AC Powered World
- Cool light source with thermal issues
- High Efficacy – High Lm/W (selected λ only)
  ….But low Lumens per part
- Cost high but dropping ($50 per 1000 Lm)

<u>Can Semiconductor “Thinking” do the job?</u>

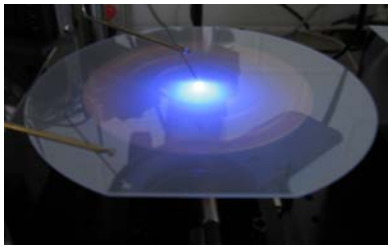
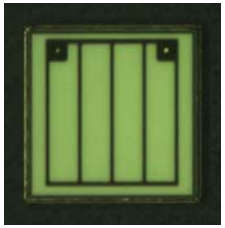
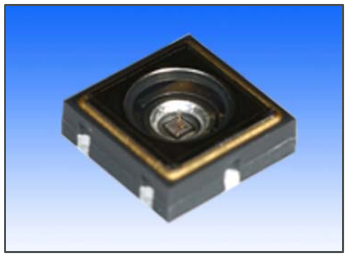






The Traditional LED Supply Chain

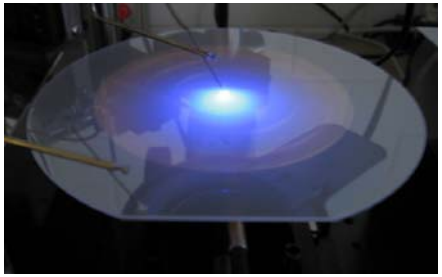
SMART LIGHTING

Materials Processes Devices	Materials & Subsystems	Materials & Subsystems Integration	Full Systems Integration
			
• Still an Art	• Low Lumen per chip	• Many styles to choose	• Few Design Standards
• Evolving Technology	• Evolving Technology	• Evolving Technology	• Evolving Technology
• High Cost of Entry	• Rapidly Dropping Cost	• Becoming cost bottleneck	• Lots of Suppliers

In the Future

New Chip Concepts

New Materials and Methods

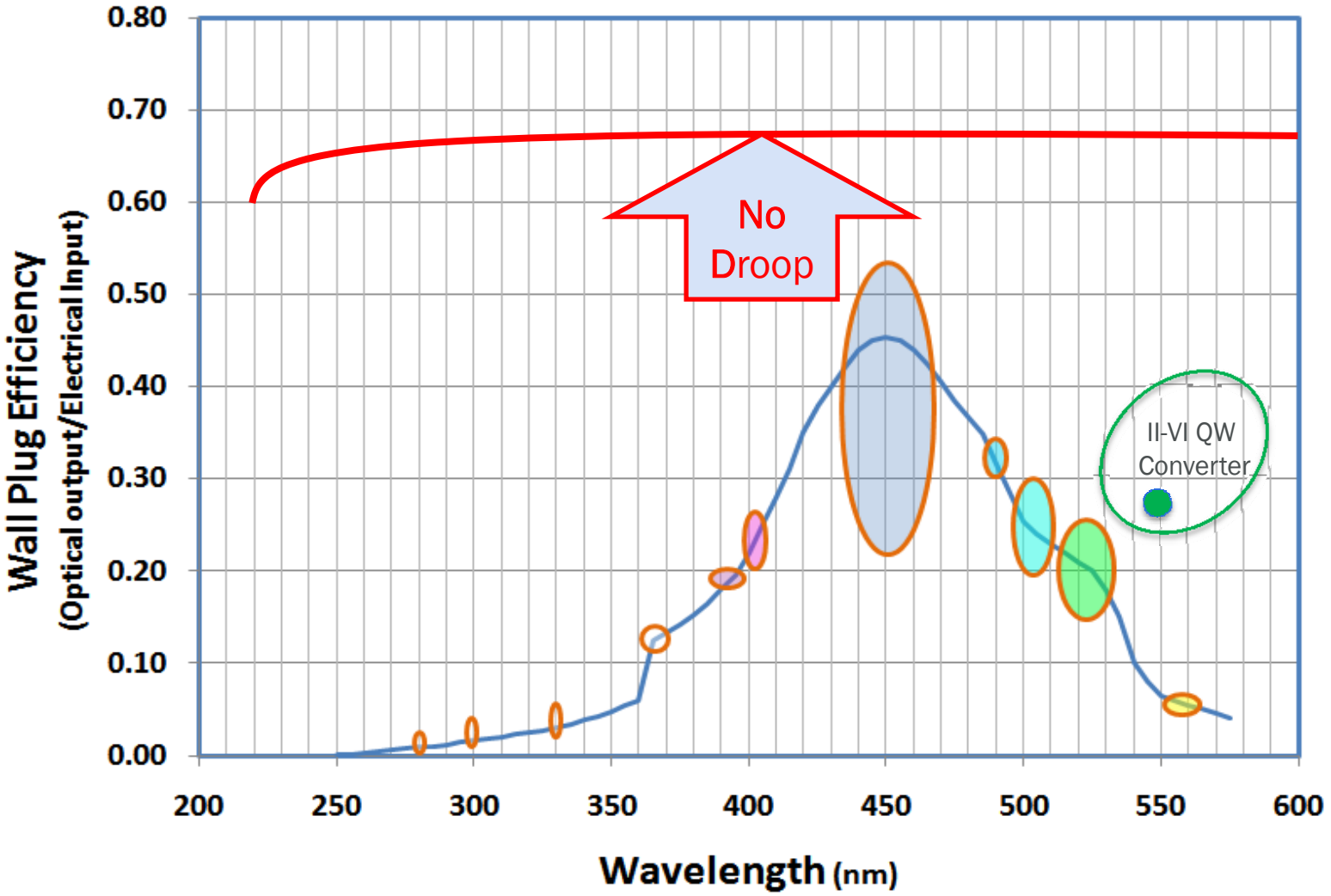


- Efficient full spectrum LEDs without droop
- Versatile, low cost light sensors
- OLED thinking applied to inorganic LEDs
- Opto-electronic Integration

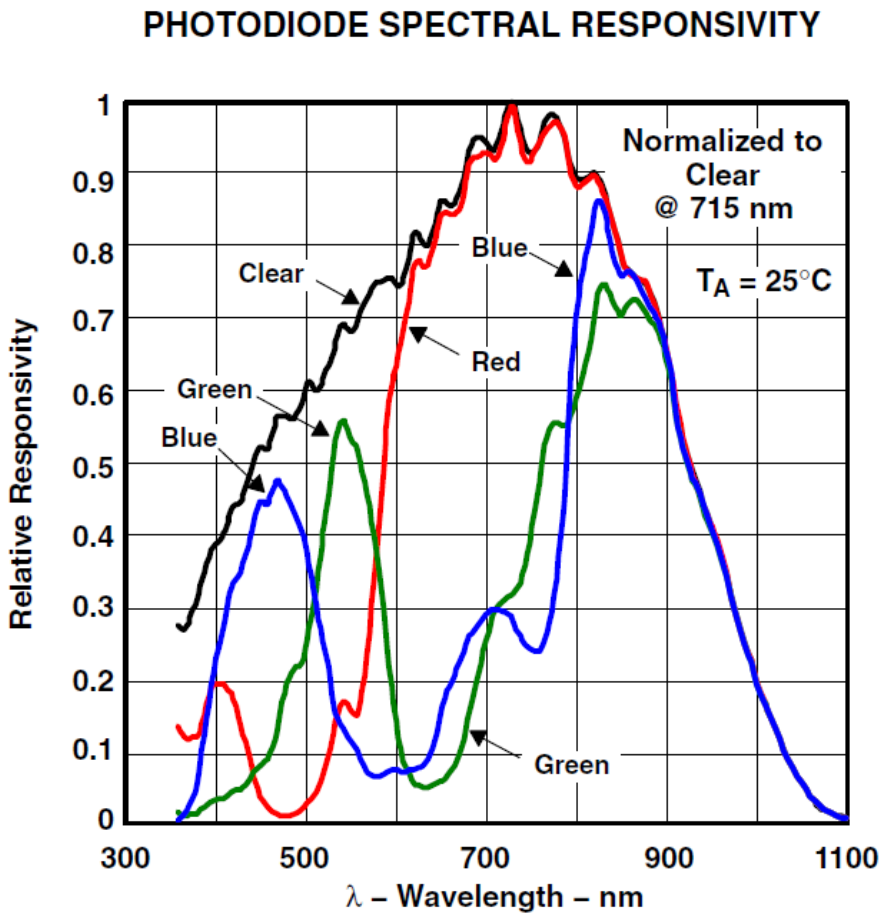
- Chip to Fixture Thinking
- Leverage Optoelectronic Integration for lower costs
- Novel integrated controls, optics and thermal management
- Flexibility for Artistic Expression

- Lighting Systems as capital equipment
- Adaptive, self- commissioning installations
- No Light Switches
- Smart Building & Grid Interfaces

Room for Improvement in LEDs



Real Need for New Light Sensors

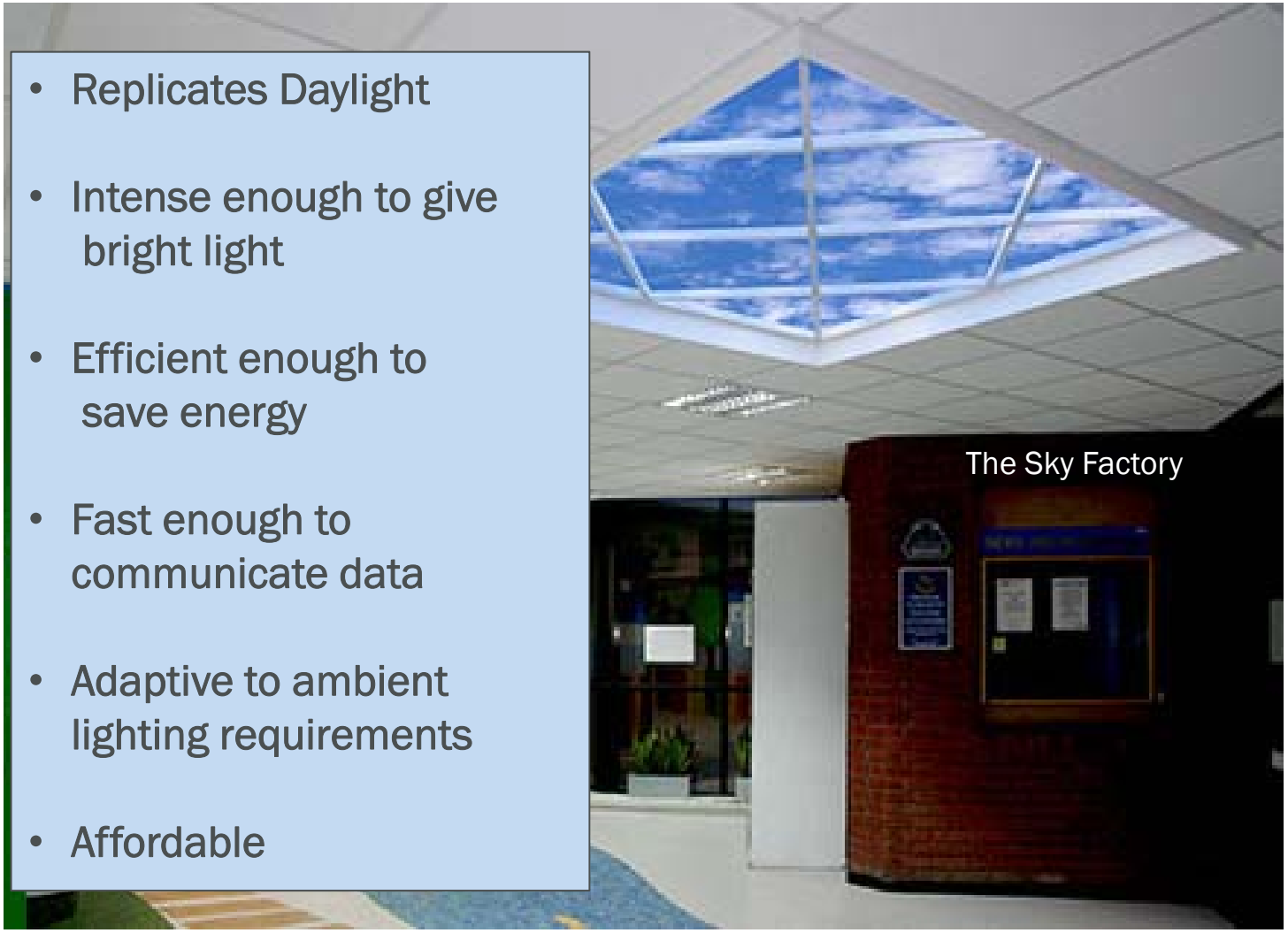


Opportunities

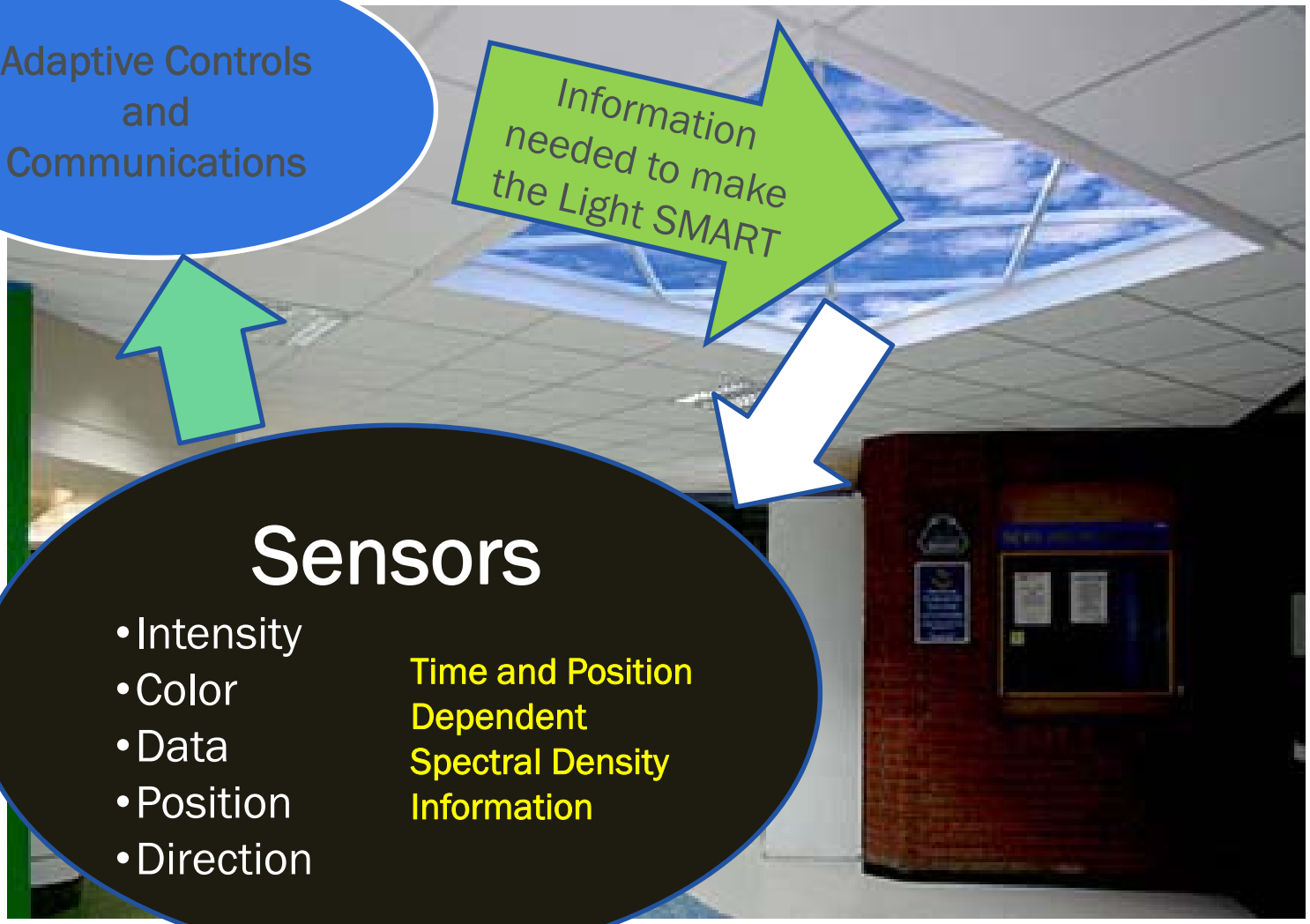
- Better spectral resolution
- Larger Dynamic Range
- Energy Harvesting
- RFID-like in size, cost and communication

Smart Lighting – The Second Wave

- Replicates Daylight
- Intense enough to give bright light
- Efficient enough to save energy
- Fast enough to communicate data
- Adaptive to ambient lighting requirements
- Affordable

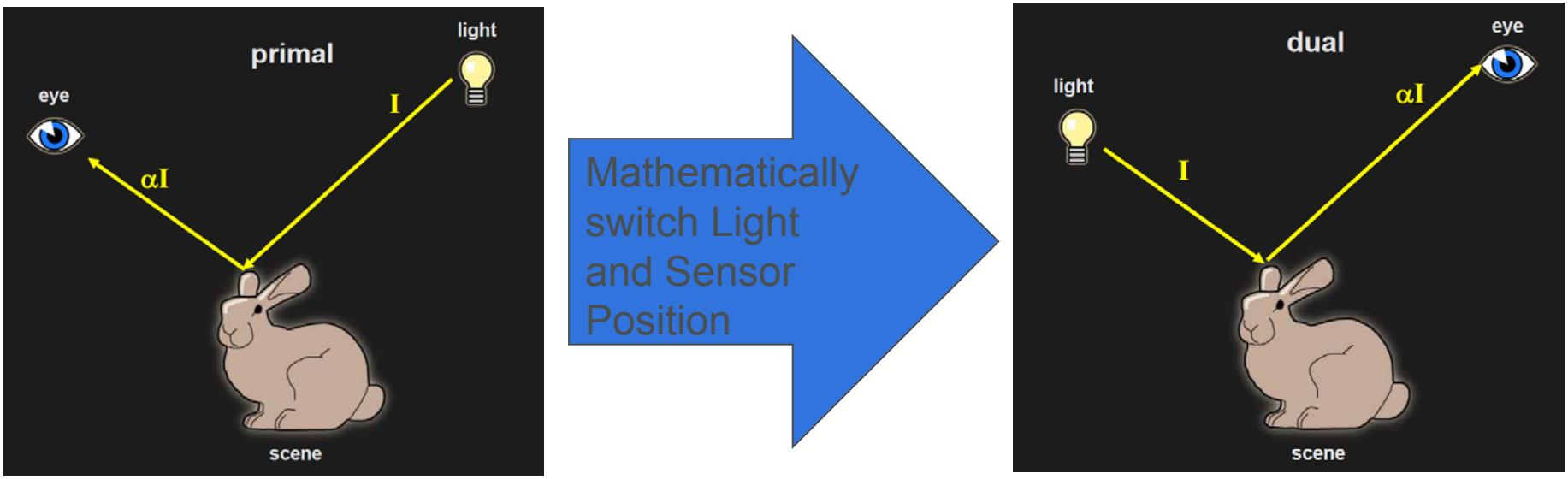


Smart Lighting - The Second Wave



Light Flow – Information in Light

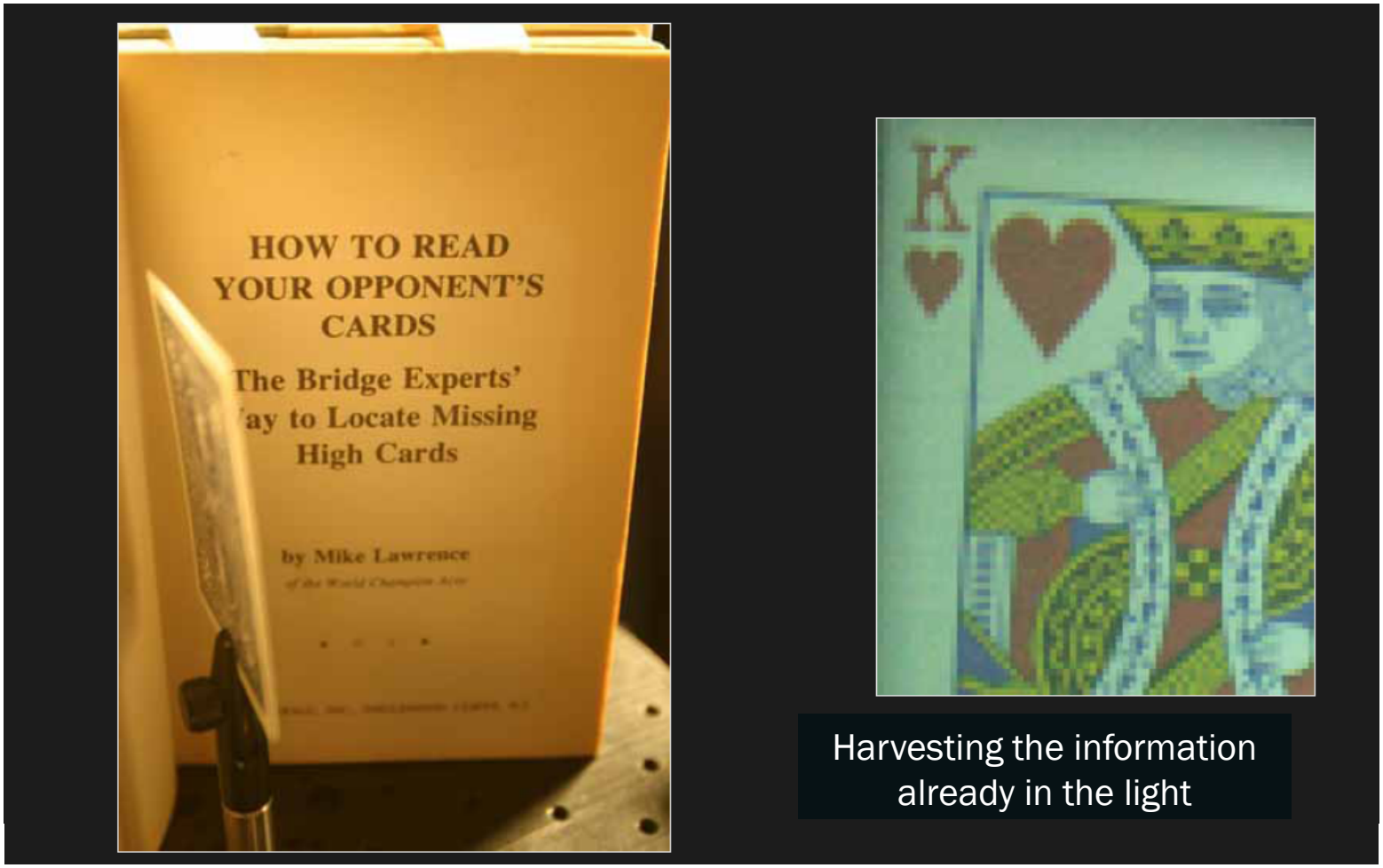
Helmholtz Reciprocity One tool for advanced lighting system control



- Concept used in “relighting” in film making
- Is also used for adaptive projection correction

Courtesy of P. Sen, University of New Mexico

The Information You Need is in the LIGHT

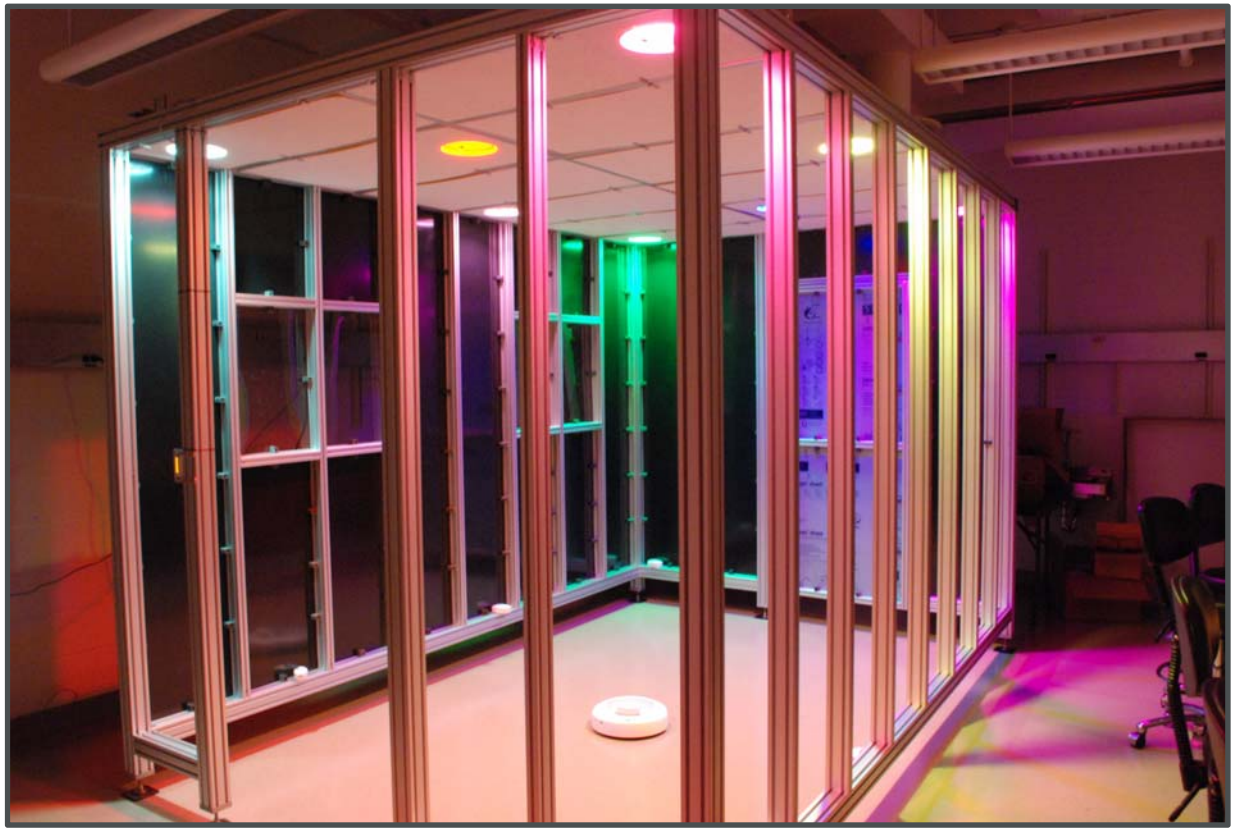


Harvesting the information already in the light

Detect the information already in light to create smart lighting systems

Courtesy of P. Sen, University of New Mexico

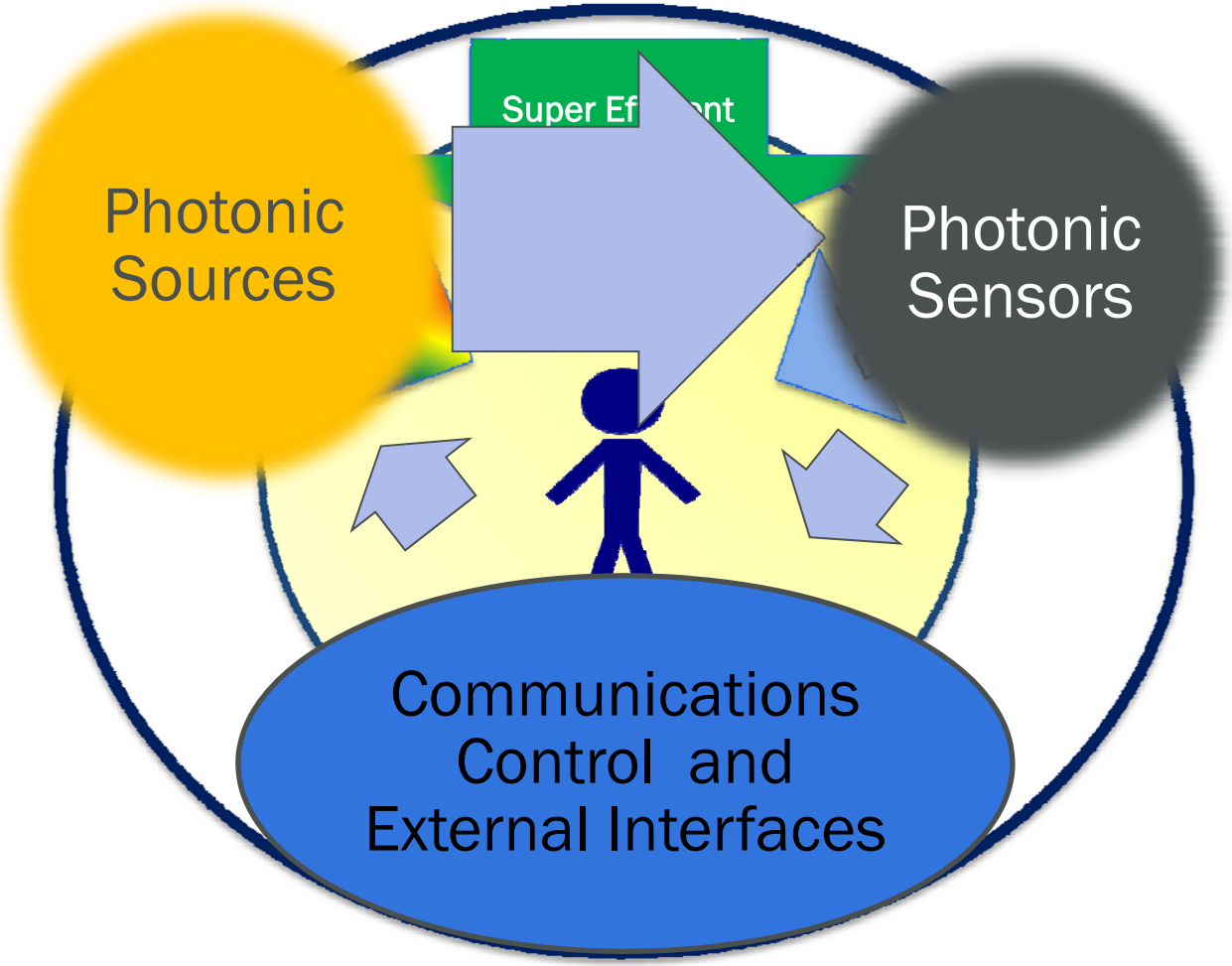
Test Bed for Adaptive Lighting Control



- Measure spectral and temporal Illumination "Fingerprint"
- System Level Integration of Fixture, Sensor Networks
- Control Algorithms for:
  - Adaptive Lighting
  - Occupancy Sensing
  - Energy Use Minimization
  - Visible Light Communications

Integration of smart fixtures, networked sensors and control systems for Smart Lighting Systems

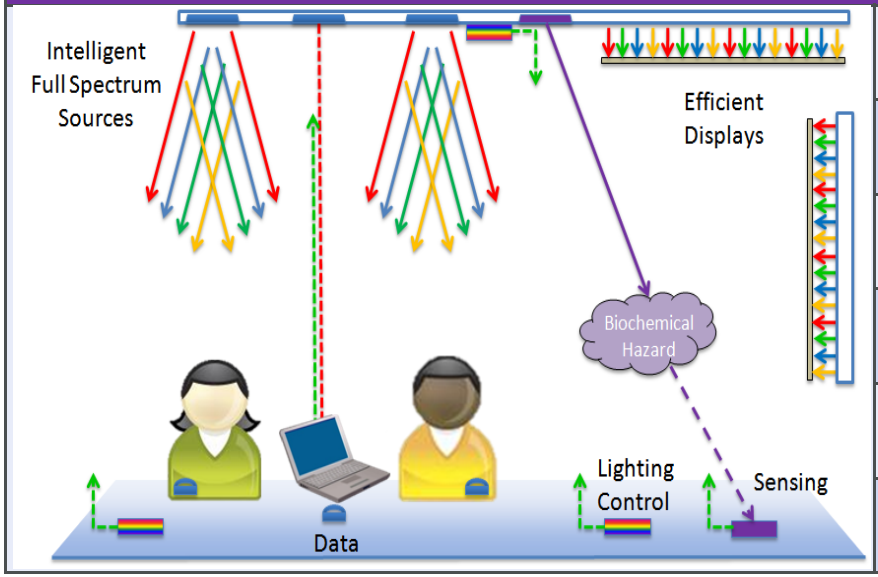
Synthetic Light for Health, Sustainability and Productivity



THE SECOND WAVE: SMART LIGHTING

Electric Lighting	Electronic Lighting
Luminaires with Components	Novel Integrated Systems
Bulbs, Sockets, Ballasts (commodity)	Semi-permanent (Durable Goods)
Limited control: on/off/dim	Fully Integrated Sensors, Controls
Different Shades of White	Any Color, any time

Complete New Capabilities and Features with Smart Lighting Systems

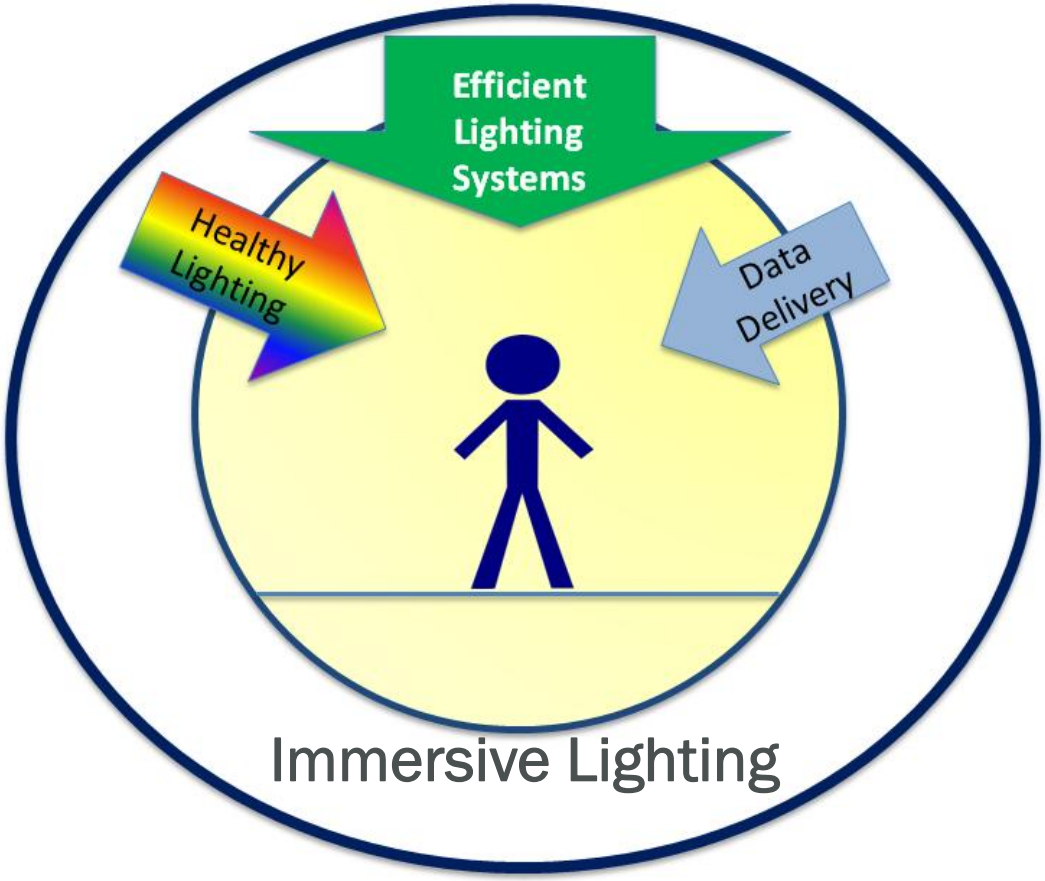


- Data with Illumination
- Illumination with Video Content
- Visible Light Communications
- Biochemical Sensing and Mitigation
- Circadian Corrected Lighting
- Self Commissioning Lighting Systems

SMART LIGHTING ERC VISION

Synthesizing Light for the Benefit of Humanity

Engineered light for energy efficiency, health, productivity

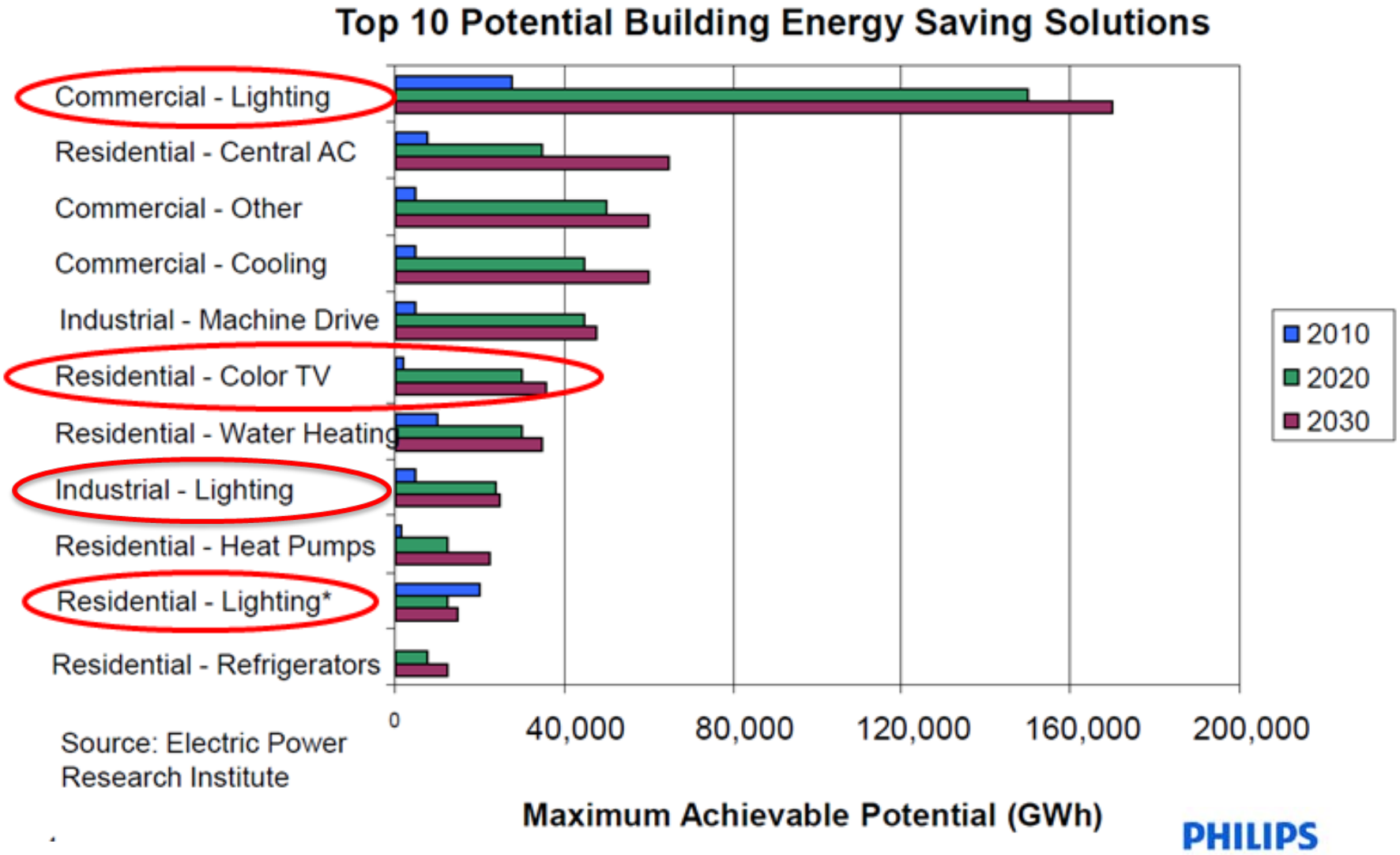


SMART LIGHTING SOCIETAL BENEFITS

Center Goals	Societal Benefits
Center Goal 1 Energy Savings at 2X the current DOE roadmap for Solid-State Lighting	 **Energy Sustainability**
Center Goal 2 Reduce Health Care Costs by 20% with Smart Lighting	 **Health, Safety and Well-Being**
Center Goal 3 Use Smart Lighting to improve workplace productivity by 10%	 **Productivity**

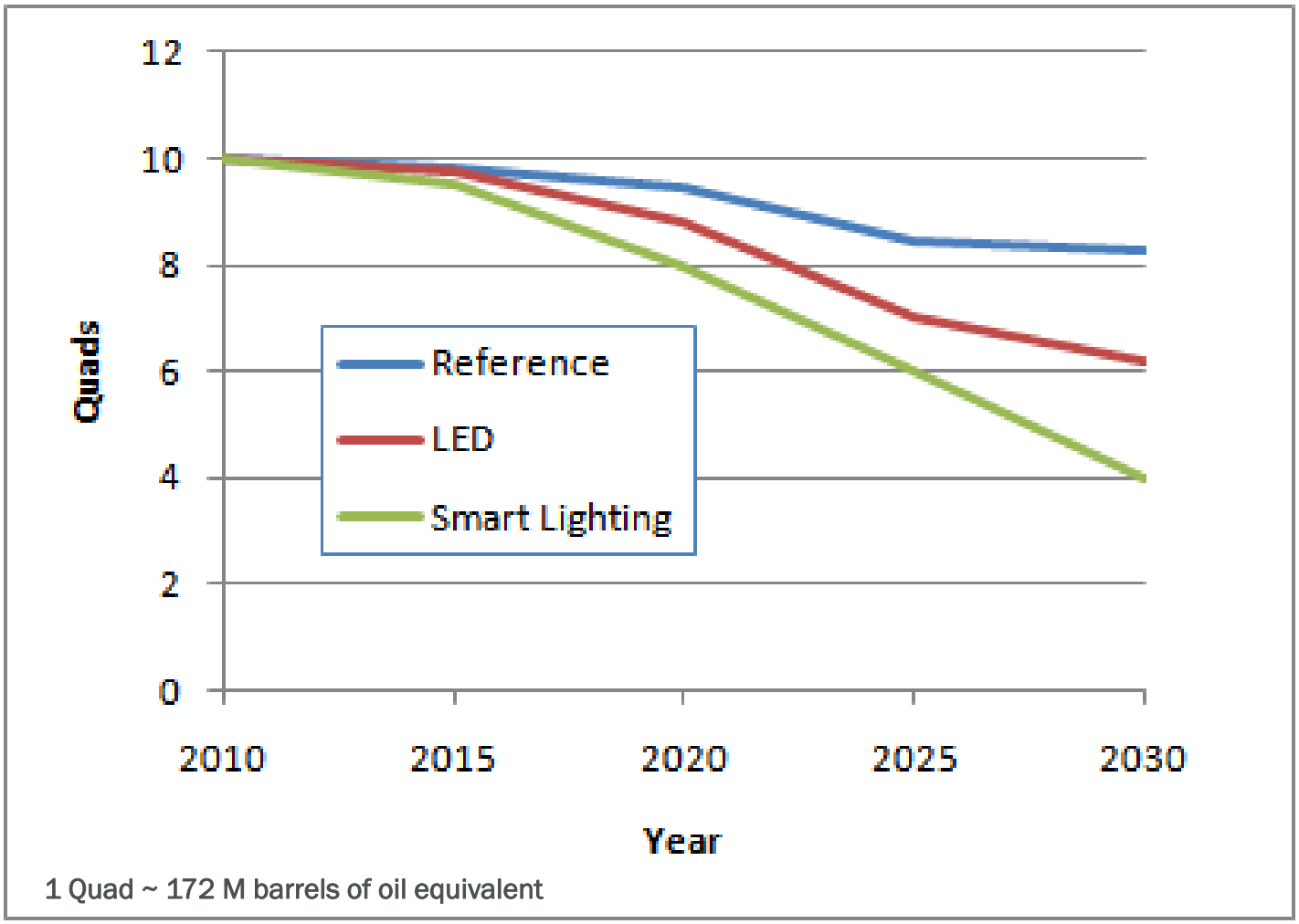
SMART LIGHTING

Lighting Opportunity



PHILIPS

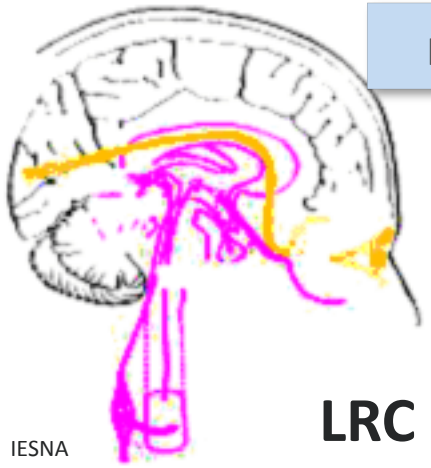
ENERGY SAVINGS POTENTIAL



- RGBY Lighting
- Controls
- Sensors provide key information

Adapted from the DOE SSL Report, February 2010

LIGHTING IMPACTS HEALTH



IESNA

Intensity | Spectrum | Distribution | Timing | Duration

Visual System

LRC Collaboration
(Figueiro, Rea, Wen)

Performance, Well-being, Satisfaction, and HEALTH

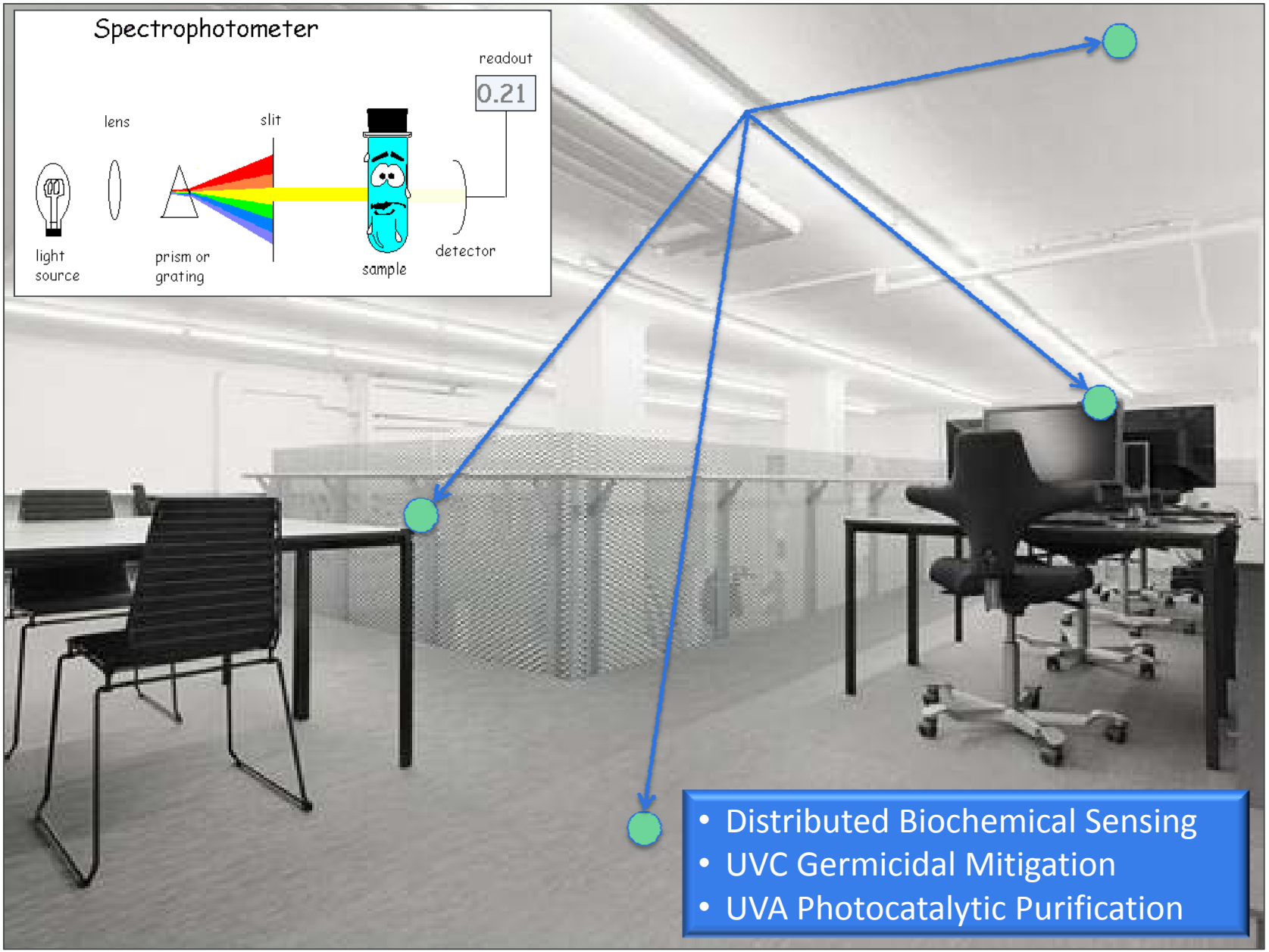
Circadian Disruption:
- Cancer
- Heart Disease
- Diabetes
- Obesity

What Else?
- Cognition
- Memory
- Recovery

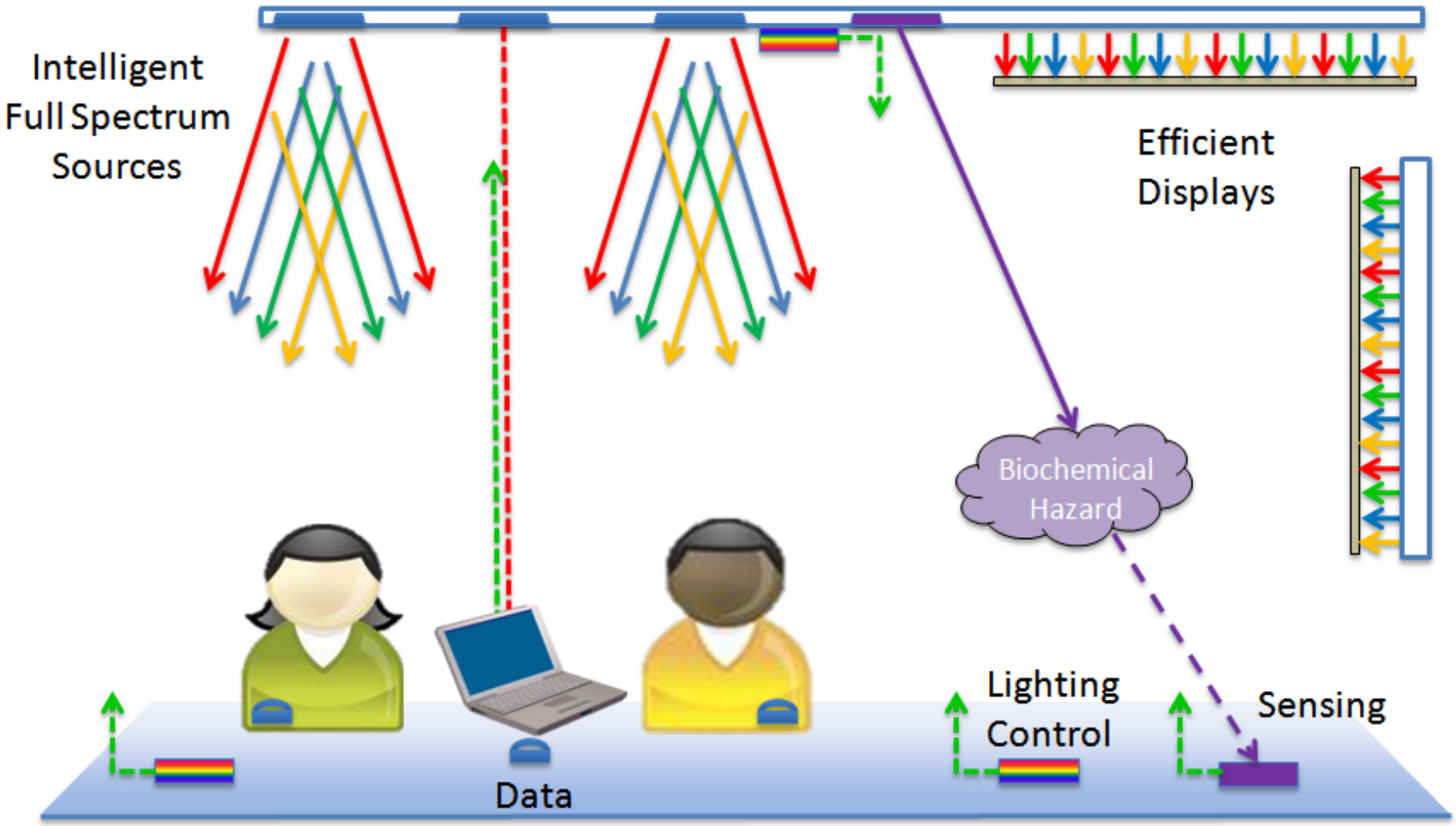
Circadian System

Intensity | Spectrum | Distribution | Timing | Duration

BIOCHEMICAL SENSING AND MITIGATION



LIGHTING – CHANGES ARE COMING



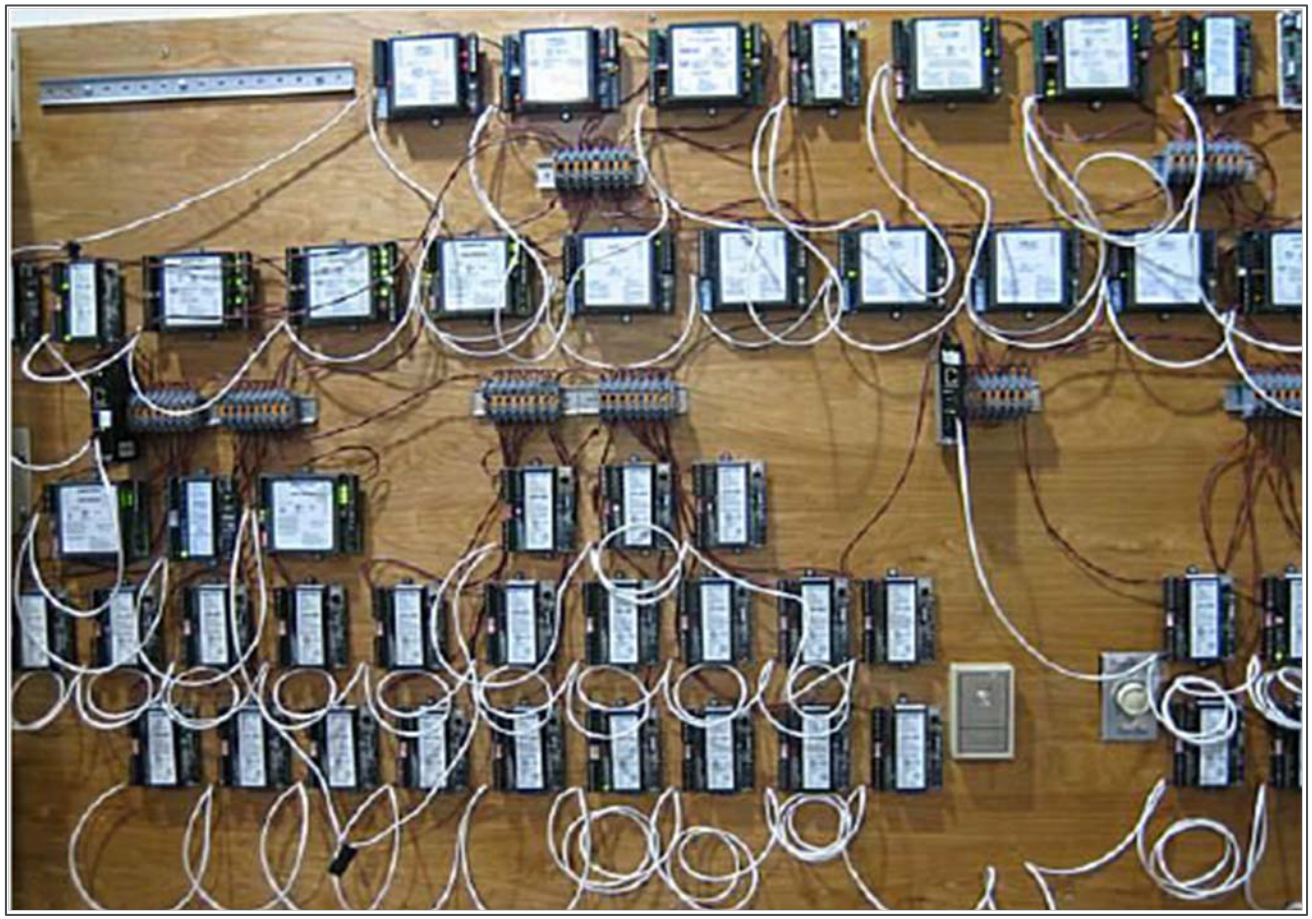
The Right Light, Where and When You Need It

WHAT INDUSTRY IS SAYING…

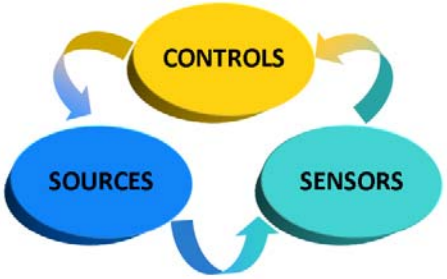
SMART LIGHTING

Future optimization direction: Intelligence Improving performance in General Illumination

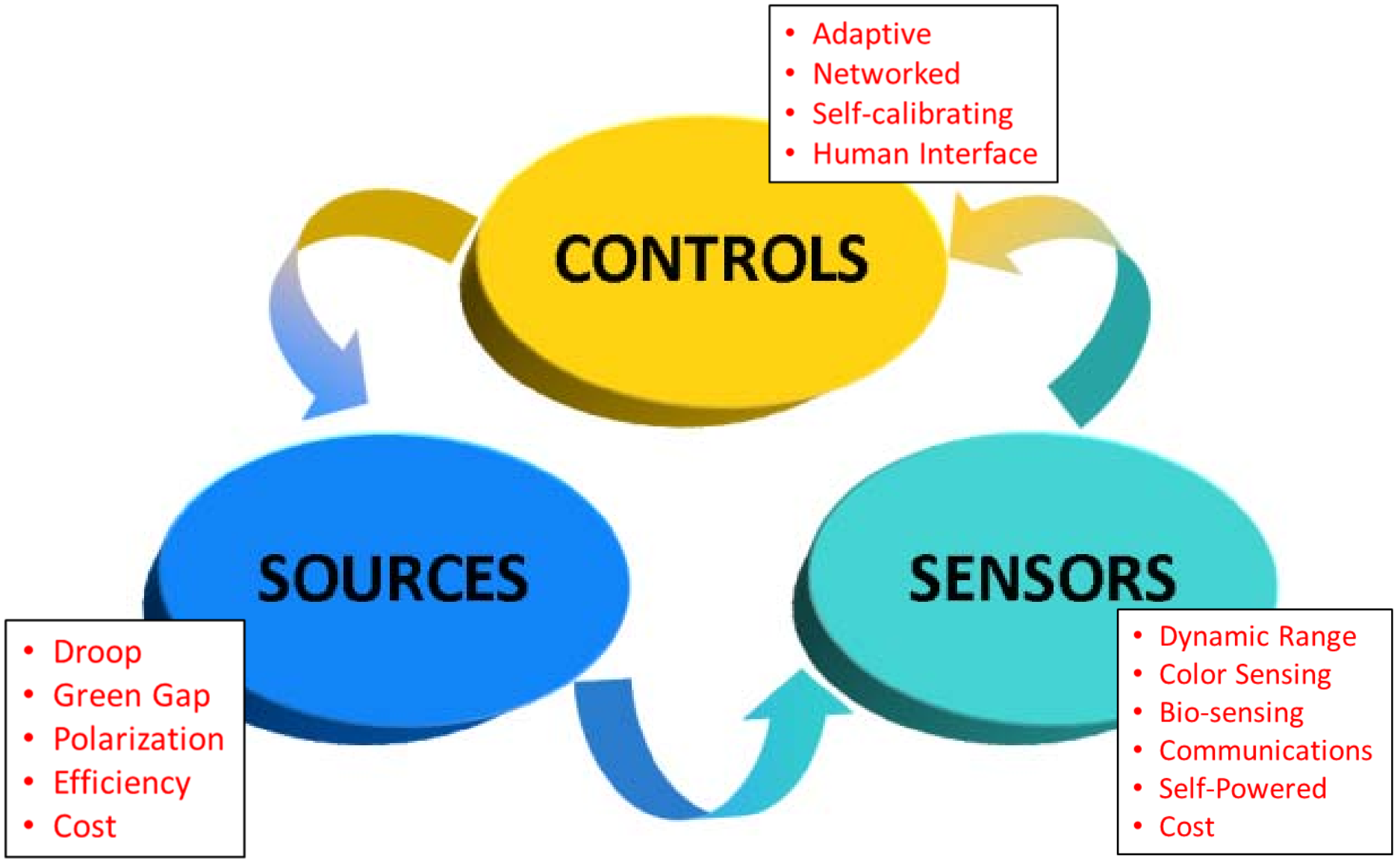
Intelligent sensor data fusion will allow for completely new lighting solutions which utilize full potential of LED (efficacy, instant-on, reliability, ..)



- Adaptive
- Color
- Video
- Data
- Biosensing
- Cleansing



PROJECT PLANS



VLC DRIVES ENTREPRENEURSHIP

SMART LIGHTING CHALLENGE — BUEnergyClub

April 9, 2011

Help optimize the design, manufacturing process, and product strategy for emerging solid state lighting technologies!

Solve Real Business Challenges

- Devise strategies for emerging lighting technologies currently under development and present them to industry professionals.
- Ideal for students with an interest in energy, entrepreneurship, operations, engineering design and technology.

Learn Problem Solving and Entrepreneurial Skills

Cross functional teams across different schools are strongly encouraged to produce fully rounded solutions. Participants will have the opportunity to learn from new methods while applying their skills in a new area.

Judges

- Boston University: Thomas Little, Professor and SL Challenge case author
- Chevron Energy Solutions: John Dotson, Vice President & General Counsel
- Constellation Energy (NYSE:CEG): Brett Feldman, Director
- Nexamp: Elijah Ercolino, Energy Engineer
- Northeastern University: Dr. Chad Joshi, Adjunct Faculty, College of Professional Studies
- Osram Sylvania: Roy Harvey, Manager, Industry Standards and Regulatory Affairs
- Philips Color Kinetics: Tracey Estabrook, Product Manager
- Smart Lighting Engineering Research Center (ERC): Robert F. Karlicek, PhD, ERC Director and Professor, RPI
- Wikoff Color: Veda Ferlazzo Clark, member, Board of Directors

Agenda

Student teams and judges only:

3:00-5:00 pm Preliminary judging round

Public event, RSVP required

5:00-6:00 pm Dinner

6:00-7:00 pm Welcome, Introduction of judges:
Eric Power, BU Energy Club President, BU MBA, 2011
Keynote speaker: Dr. Robert Karlicek

7:00-8:00 pm Final team competition

8:00-9:00 pm Winners announced and networking

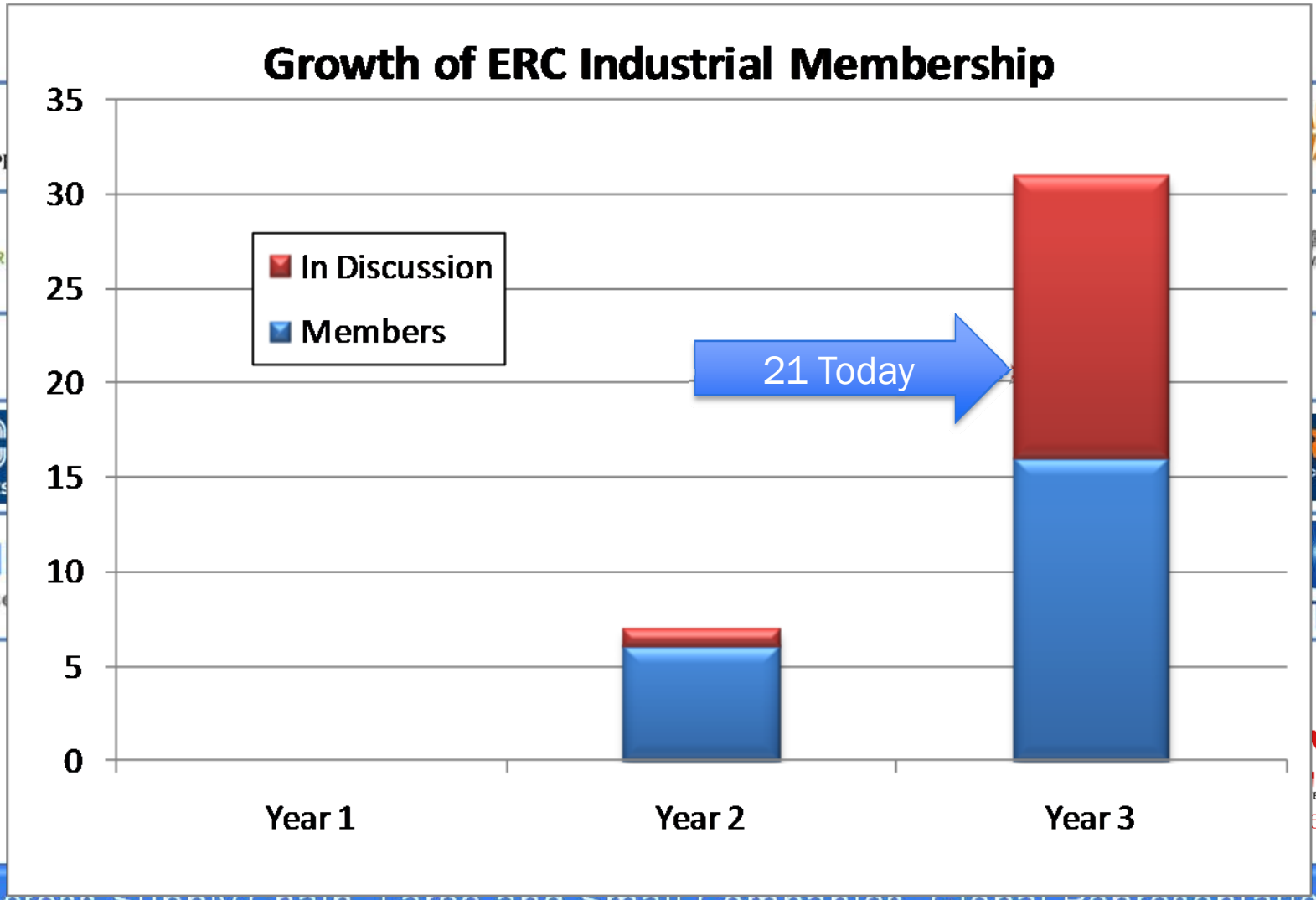
Location: **BU School of Management, 595 Commonwealth Ave. Boston, MA**

Sponsored by

NSF · Boston University School of Management · Chevron · Clean Energy and Environmental Sustainability Initiative · Smart Lighting Engineering Research Center · CISE

Expand this model in the coming years

INDUSTRY RECRUITING



Across Supply Chain, Large and Small Companies, Global Representation

ACTIVITIES WITH HIGH TRANSLATIONAL POTENTIAL

Task	Task Name	Technology Transfer Assessment/Potential
T1.4.1	Healthy Circadian Lighting	Lumentech SECO Activities for Circadian Management (NSF, with LRC)
T1.3.1	Advanced Detection & Diagnostic Platforms	Significant field testing underway (Synergistic with activities in S2.1.3 below)
T1.3.2	Photocatalytic Nanotubes	Currently in discussions with industry on sponsored research programs to develop systems based on this technology
S2.1.3	Advanced Plasmonic Sensors	Applications for biosensing have significant potential for near term medical applications (synergistic with activities in T1.3.1)
S1.2.4	Non-scattering Phosphor LEDs	Strong interest on new phosphor systems for specialized Luminaire Development
S1.2.5	High Refractive Index Polymer Systems	Strong interest from industry on near term applications for LED encapsulation for high efficiency packages

- Commercialization of Daysimeter for Circadian Studies
- Original Biosensor work enters translational phase
- Strong interest on key materials work from industry

BROADER IMPACTS: DOE ENGAGEMENT

DOE Project Task	ERC Project(s)
B3.6 Package Architecture	S1.2 T1.5
B6.4 Novel Luminaire Systems	S1.3 S2.1 T1.5
B7.3 Smart System Controls	S1.3 S2.1 T1.1 T1.2

…from the DOE SSL R&D Workshop Report, 2011

DOE Engagement

- Gets the Smart Lighting Message to a larger audience
- Funding for Associated Projects related to the Smart Lighting Vision
- Coordination with a broader base of Academia and Industry working in Solid State Lighting

OUTREACH: LIGHT IS A GREAT TOOL FOR OUTREACH

- Publish LIGHT Teaching Modules (on-line)
- Create “Mobile Studio” Lighting Educational Modules
- Work closely with State and Local Teaching Organizations to Leverage LIGHT for STEM objectives

Exploring Engineering Day 2/19/11

300 parents/community members

450 3 – 6 grade students

Diversity Outreach

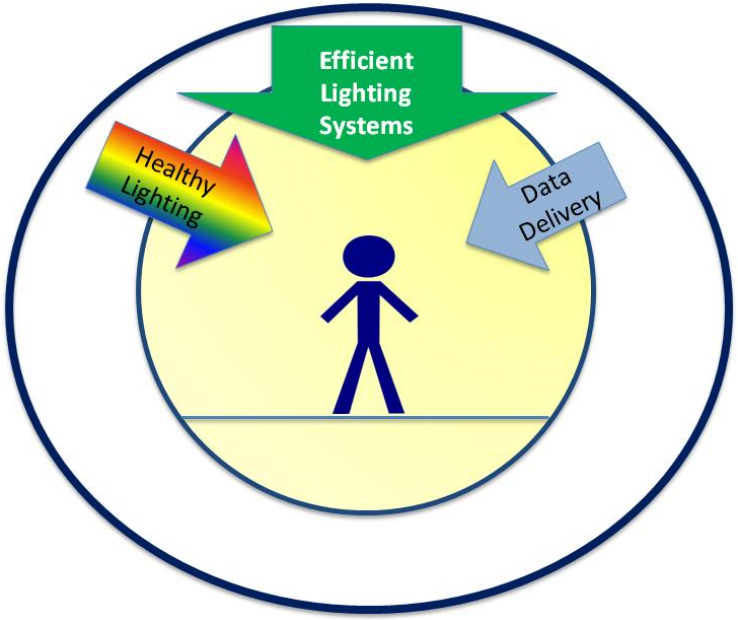
GOAL

To meet or exceed the number of female and URM Faculty and Students

STRATEGIES

- **Invite** diverse groups to participate & collaborate
- **Recruit & retain** diverse faculty, students, and staff
- **Track and assess** our progress
- **Celebrate, share, & promote** ERC diversity best practices
- **Benchmark & integrate** external diversity best practices

SMART LIGHTING – THE FUTURE OF LIGHT



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