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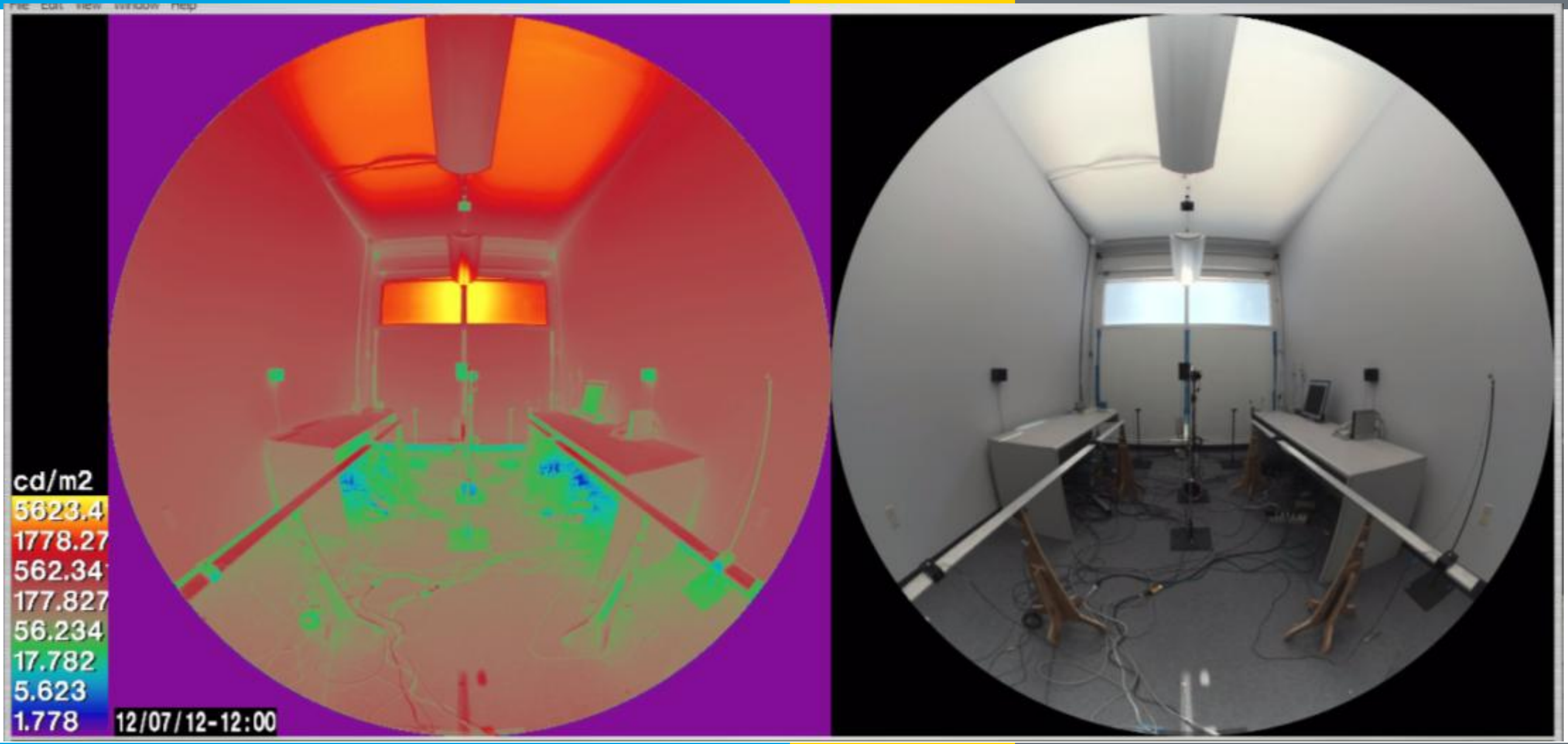

Advanced Facades, Daylighting, and Complex Fenestration Systems

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April 5, 2013

Purpose & Objectives

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Problem Statement: In order to reach BTO's aggressive 50% energy savings goal by 2030, innovative façade systems must minimize both lighting and HVAC energy end use consumption more optimally while addressing occupant comfort and amenity requirements.

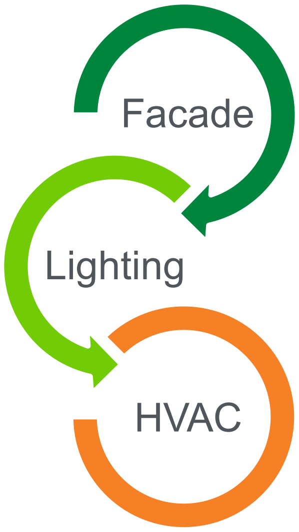
Impact of Project: An estimated 1-2 Q of energy could be saved annually if these integrated façade systems are adopted across the commercial building sector.

Project Focus: Develop, assess, and accelerate adoption of:

1) daylighting technologies that extend the depth of useful daylight to 30-40 ft from the window without adverse impacts on solar gains and visual comfort;

2) angular selective technologies that control direct solar irradiance while maintaining useful daylight and outdoor view, reducing perimeter zone energy use by the targeted goal of 30-50% and peak demand of less than 4 W/ft^2-floor;

3) dynamic façade technologies that automatically modulate solar and daylight admission in response to time-of-day load management and comfort objectives to achieve 50% energy savings goal.



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Approach

1) Develop tools needed to model window heat gain and daylighting impacts of light-scattering materials and systems

2) Conduct sensitivity analysis to define performance limits and use optimization studies to improve performance

3) Characterize prototypes with lab and full-scale field tests

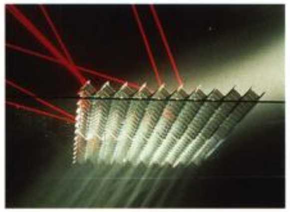
4) Partner with industry to develop innovative new solutions and accelerate commercialization

Key Issues

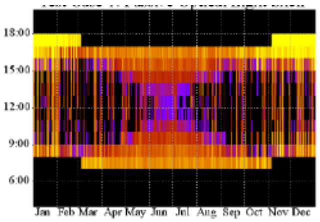
Finding solutions that achieve an acceptable balance between competing parameters (energy, comfort, view, indoor environmental quality)

Distinctive Characteristics (unique aspects of approach)

- Significantly greater modeling accuracy with empirically derived scattering distribution data
- Annual energy performance including discomfort glare assessments
- Field tests and demonstrations used to validate findings from simulations



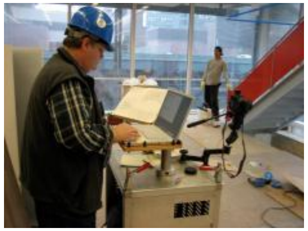
1



2

3

LBNL WIndows Testbed Facility

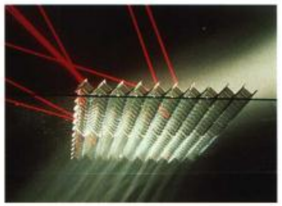


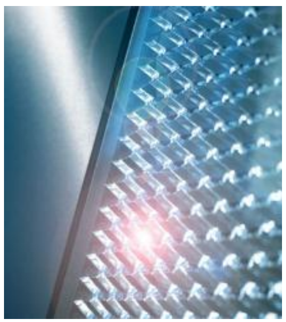
4

Field demo at The New York Times Building

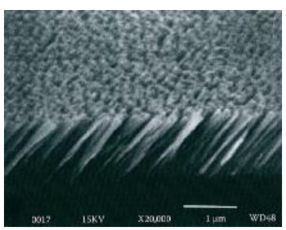
Approach
Modeling solar heat gains

1 sample materials

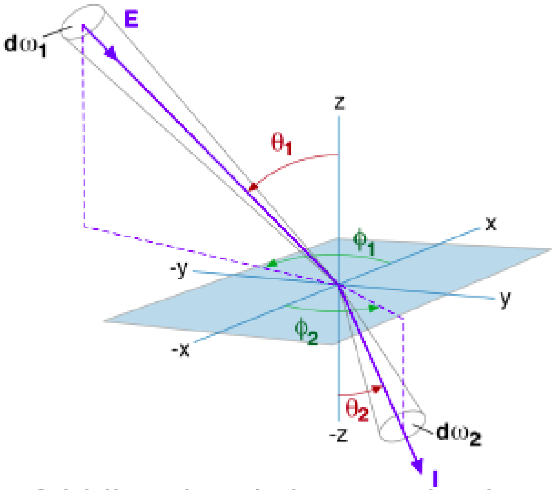




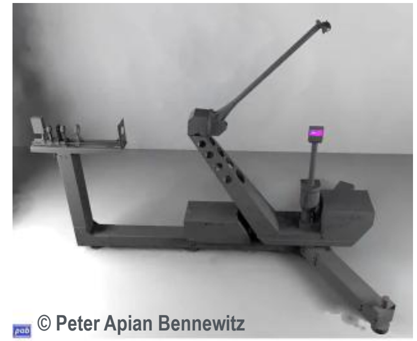
Source: St. Gobain/ Eckelt
DLS COOLSHADE HR 32/9



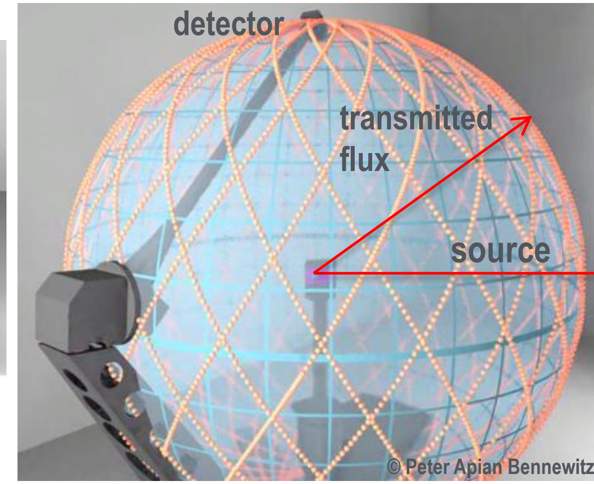
Inclined columnar nanostructures (MJ. Brett, *J.Mater.Sci* 24(1989); GW Mbise et al. *J.Phys.D: Appl. Phys.* 30(1997))

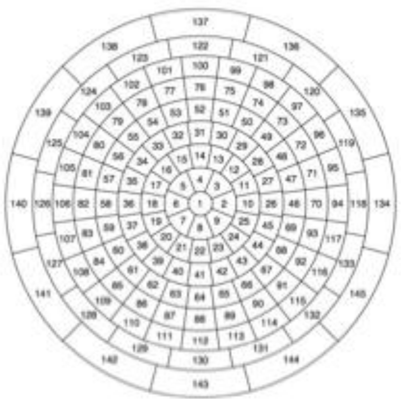


2 bidirectional characterization for anisotropic materials

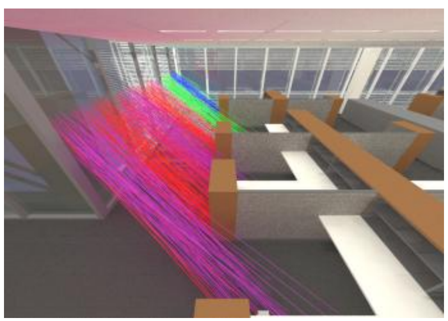


3 LBNL scanning goniophotometer

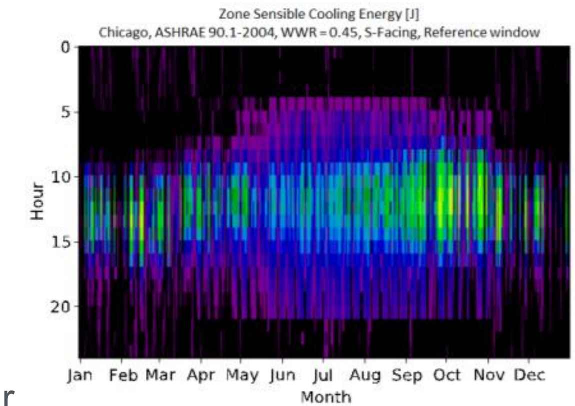




4 klems hemispherical basis



5 distribution of transmitted solar
The Times Company Building



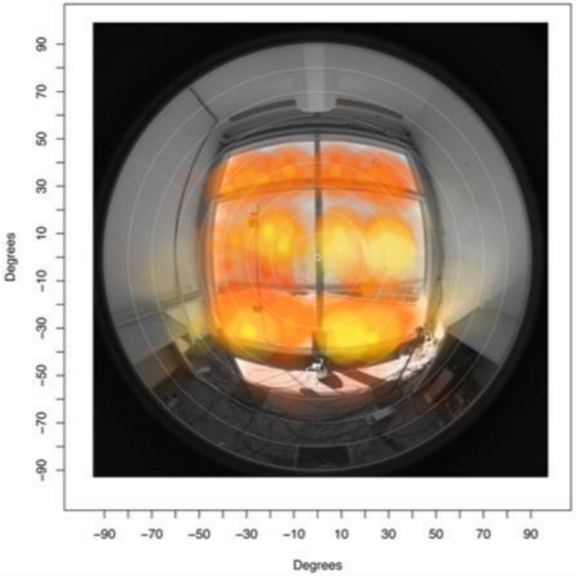
6 radiance-energyplus window heat gains

$$L_o(\theta_o, \varphi_o) = \iint L_i(\theta_i, \varphi_i)\, f_r(\theta_i, \varphi_i\,;\, \theta_o, \varphi_o) \cos(\theta_i)\, d\theta_i\, d\varphi_i$$

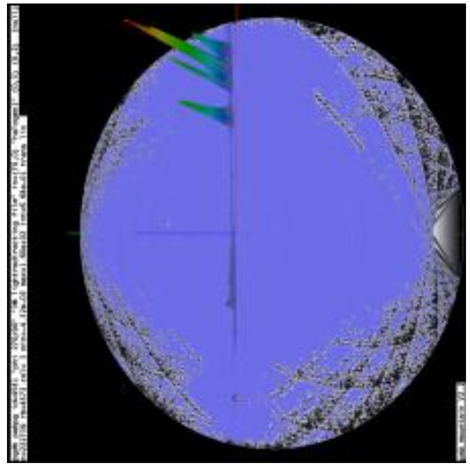
Integral over incident directions of light out = light in * BRDF * cosine

Approach

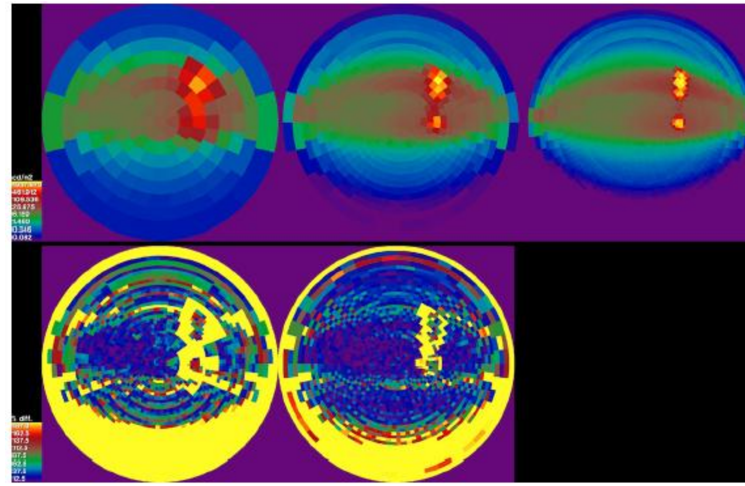
Modeling daylight and discomfort glare



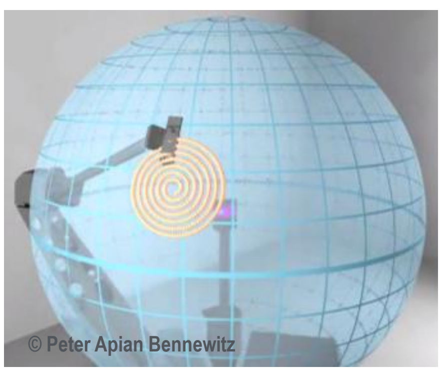
1 time-lapsed field measurements of glare



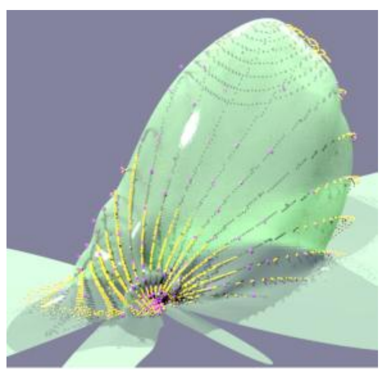
2 “peaky” bidirectional transmission data from goniophotometer



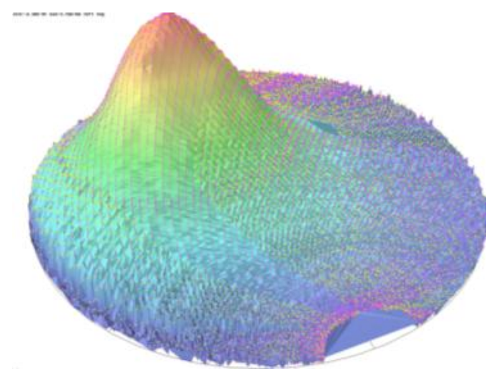
3 resolution of glare source for 1x, 2x, 4x klems basis (upper) and difference in luminance (lower); 4x captures peaks



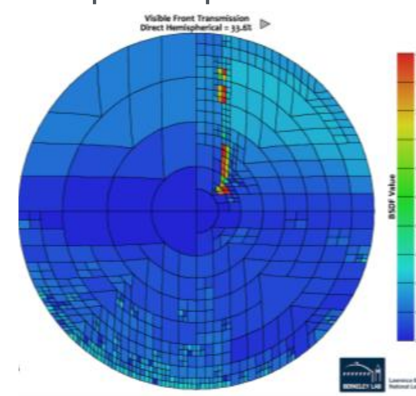
4 peak sampling with goniophotometer



5 interpolation models using gaussian lobes

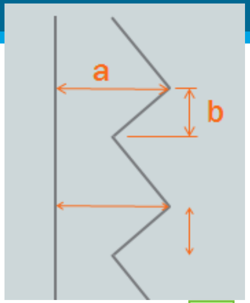


6 measured and fitted data (pink overlay)

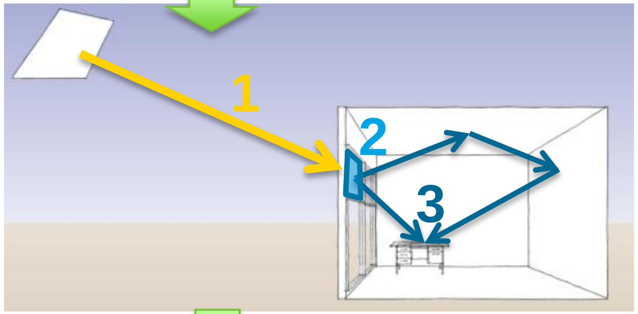


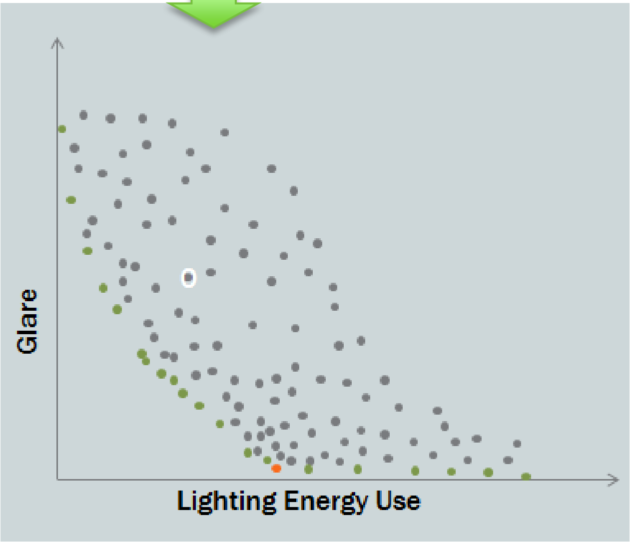
7 variable resolution BSDF for light-redirecting system

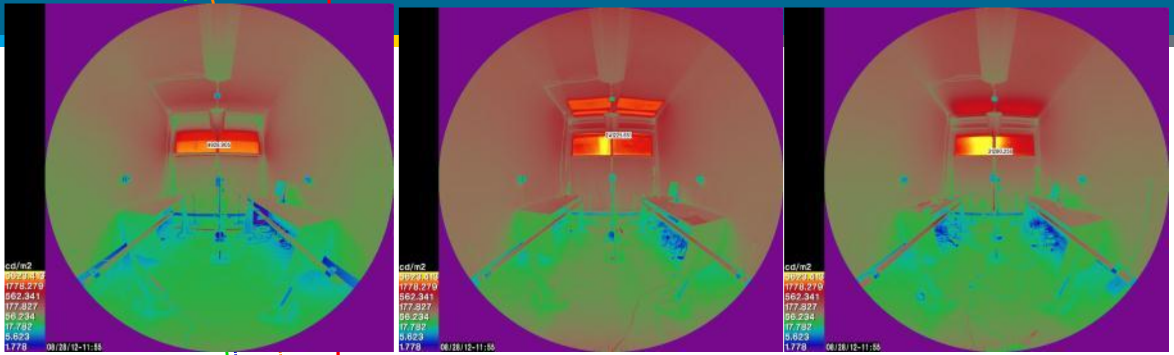
Task 1: Daylight-redirecting systems



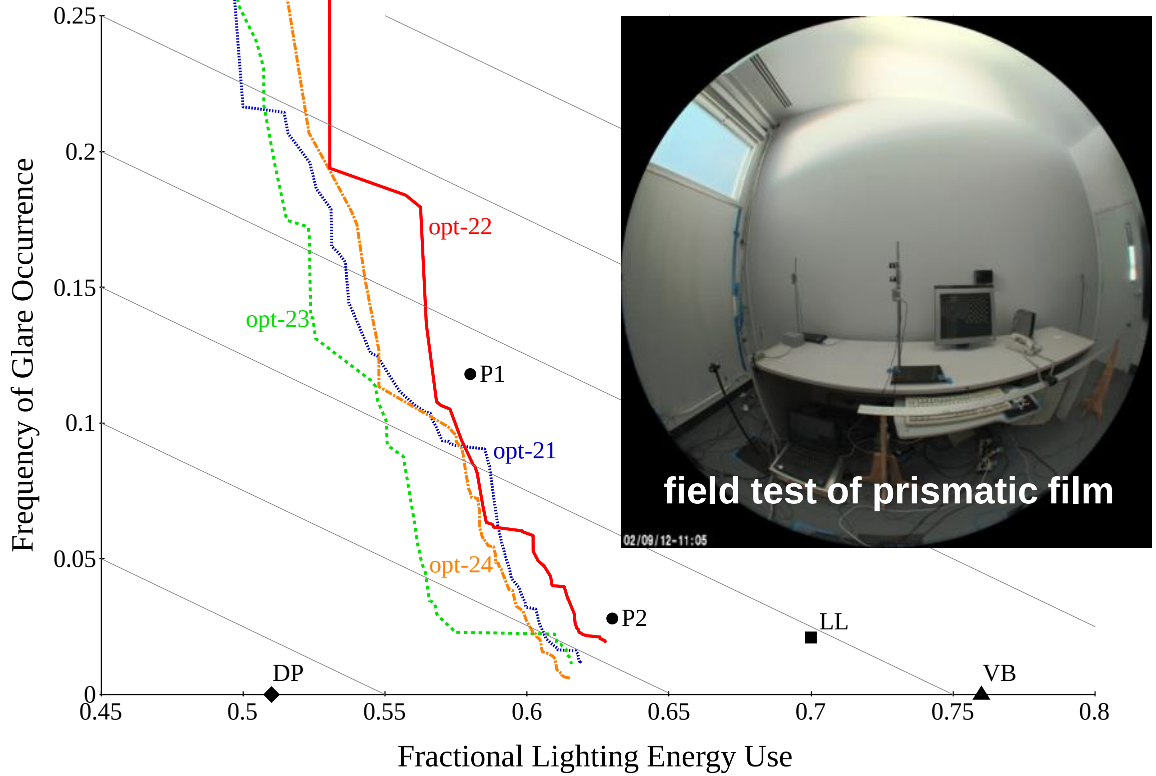
1 Simulation method







2 (above) Field test of reference blind, P1, and P2 assessing glare
3 (below) Results of optimization studies



Task 1. Daylight-redirecting systems

- Developed and validated Radiance modeling tools for complex fenestration systems; improved accuracy of discomfort glare calculations using variable-resolution bidirectional datasets; upgraded goniophotometer to enable measurement of full BSDFs
- Industry prototypes evaluated via simulations and field tests: 38% lighting energy savings (90.1-2007), 3% occurrence of glare over 40-ft deep open plan office zone
- Major manufacturer to fabricate LBNL design for possible commercialization (IB-2013-062); 2nd major manufacturer developing alternate product line
- Progress on goal: Daylight-redirecting: Invention disclosure filed, 2/28/13 √

Task 2: Angular selective systems

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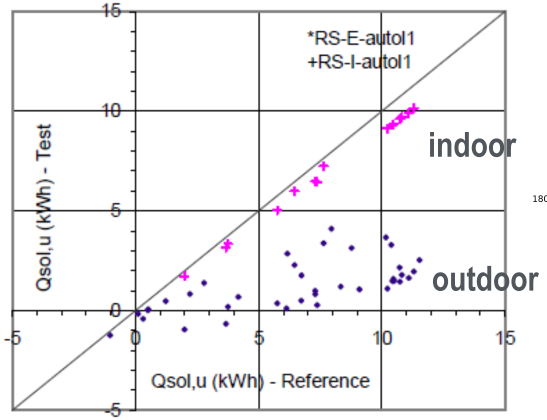
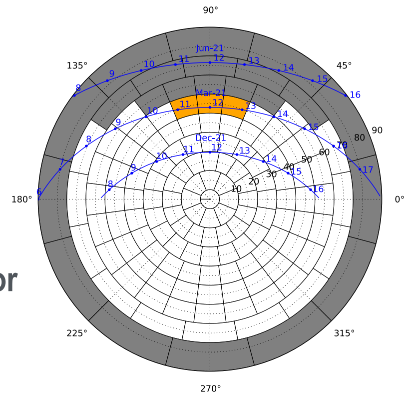
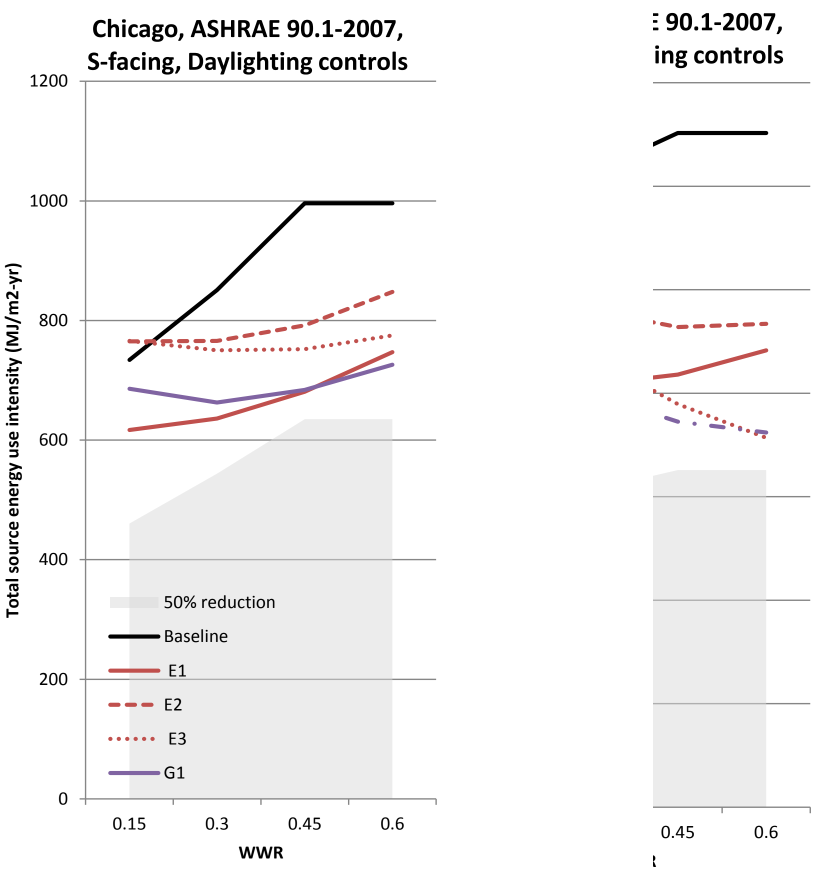




2 angular selective shading system with outdoor view (solar cut-off angles in image above)



3 annual source energy use for angle-selective shade (G1, G1R) compared to code, unshaded low-e (E1), E1+indoor shade (E2), and E1+outdoor shade (E3)

Task 3. Dynamic façade systems: Model predictive controls

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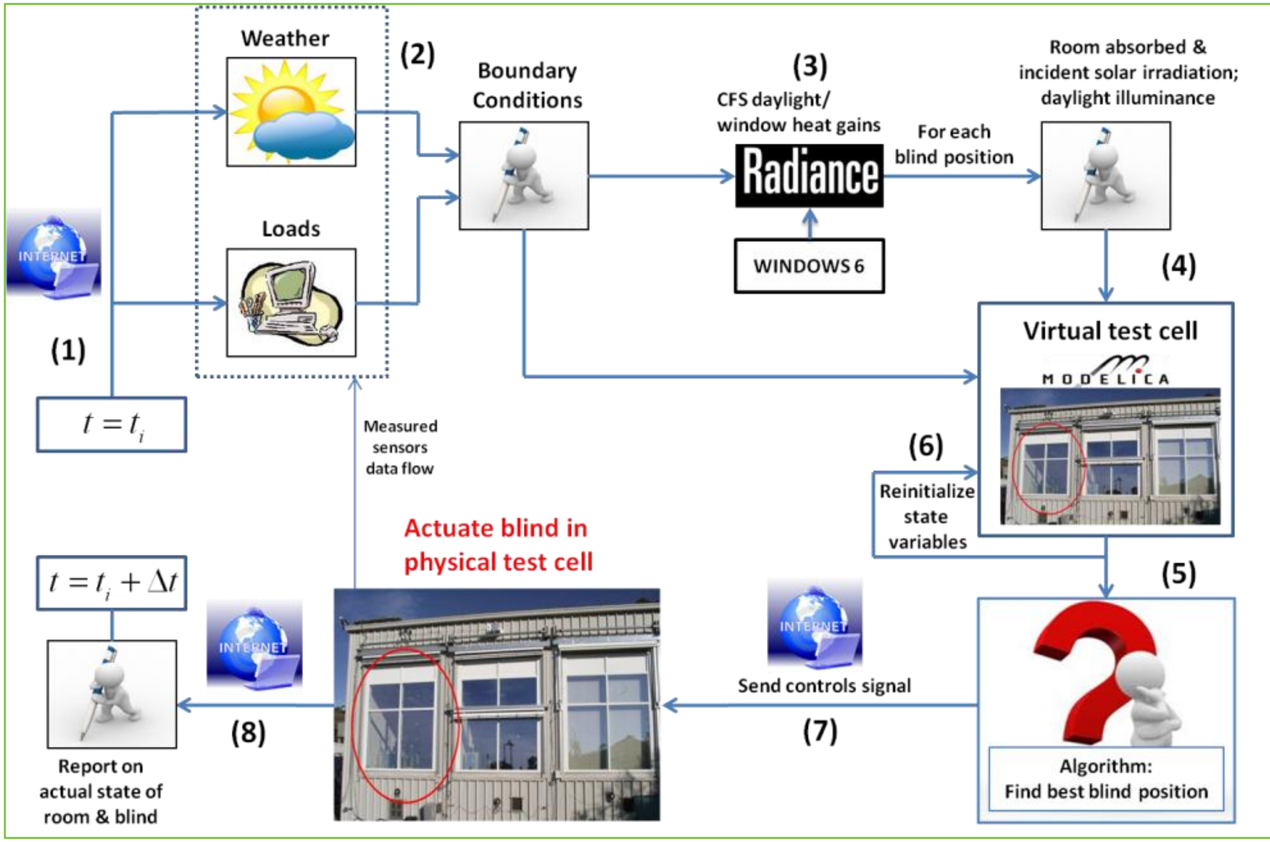
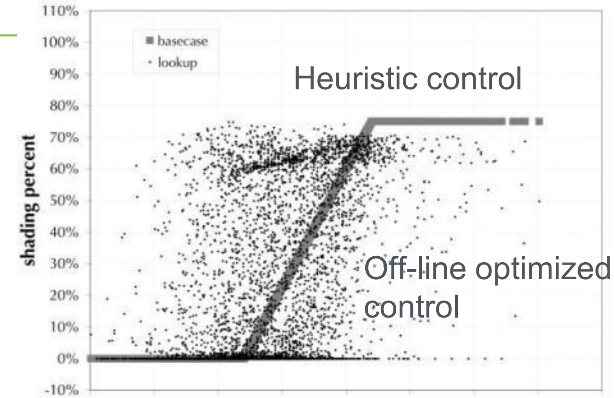
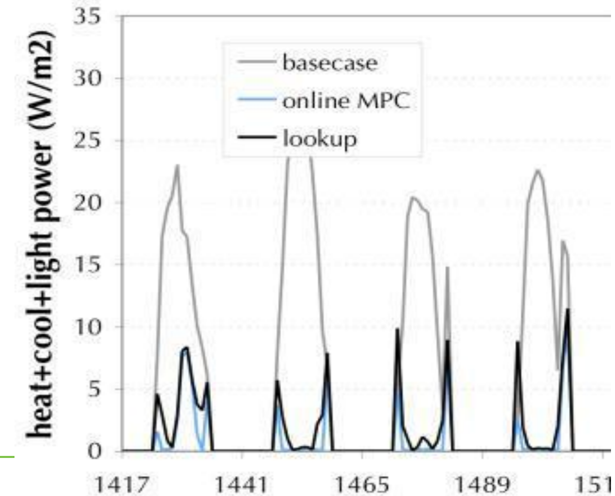


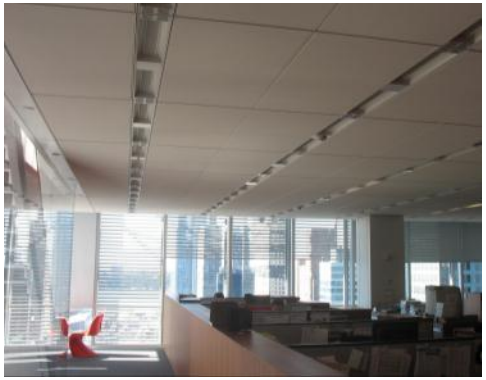




1 proof-of-concept implementation of on-line model predictive control in LBNL's full-scale windows testbed; real-time optimization of HVAC + lighting loads

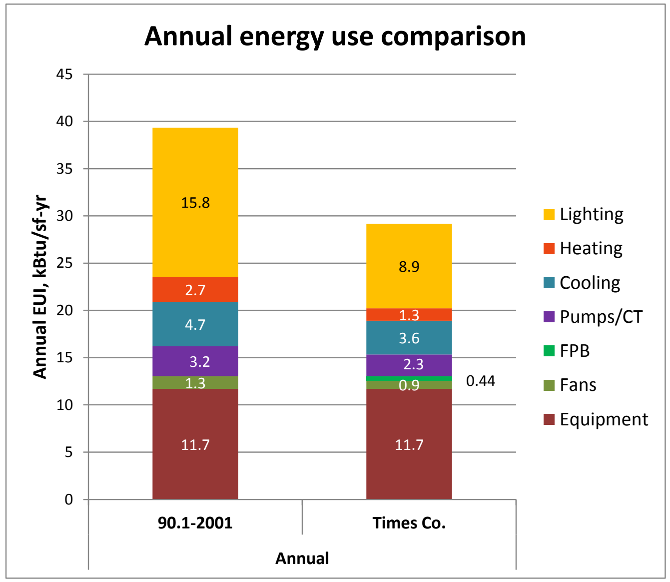
2 offline optimization via lookup table control captured 87% of the available savings (better than heuristic, rule-based control)

Task 3. Dynamic façade systems Post-occupancy evaluations



The New York Times Building ($628{,}000\ ft^2$ occupied by Times)

Automated shades, digital addressable lighting, underfloor air distribution system + integrated design

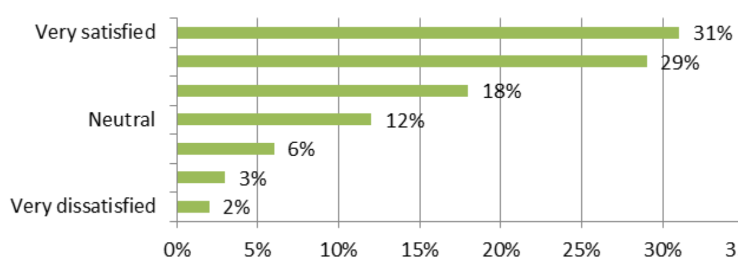


29 $kBtu/ft^2$-yr site energy use
2.65 W/ft^2 peak demand

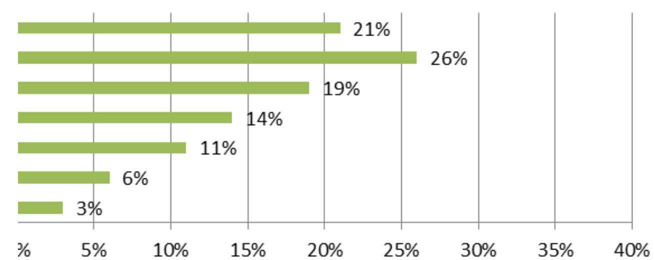
43% lighting savings
23% cooling savings
51% heating savings
22% peak electric demand

Annual end use energy comparison between ASHRAE 90.1-2001 baseline and calibrated model of the Times Building

In terms of the overall quality of light in your workpace, are you:



How satisifed are you with the visual comfort of the lighting (e.g., glare, reflections, contrast)?



Accomplishments and Progress

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Task 2. Angular selective shading

- Developed and tested Radiance-EnergyPlus modeling tools for complex fenestration systems; initiated incorporation into COMFEN design concepts tool (front end for EnergyPlus)
- Industry products evaluated via simulations and field tests: 31-43% reduction in annual source energy use compared to 90.1-2007 code with between-pane systems
- Initiated parametric studies to improve performance
- Progress on goal: Invention disclosure filed, 6/30/13 (pending)

Task 3. Dynamic façade technologies

- Developed proof-of-concept implementation of on-line model predictive controls (MPC) for a facade-lighting/HVAC system in a full-scale testbed
- Completed post-occupancy evaluation of integrated dynamic façade-lighting-UFAD system at The Times Company Building
- Completed sensitivity analysis, field tests, and GSA GPG demonstration of polymer VIS-switching thermochromic windows
- Progress on goal: Assessment of MPC performance, 9/30/13 (pending)

Project Plan & Schedule

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Initiated/ planned completion date: 2012 to 2016
Go/no-go decision points: Energy and comfort performance goals met with acceptable CCE (e.g., 30-50% energy savings at CCE \$0.15/kWh, < 4 W/ft^2-floor peak demand, less than 5% glare occurrence, 5-10 year payback

Summary	
WBS Number or Agreement Number	BT-480010-13
Project Number	18835
Agreement Number	7310
	ET-WIN-LBNL-FY13-02

Legend
Work completed
Active Task
Milestones & Deliverables (Original Plan)
Milestones & Deliverables (Actual)

	FY2012				FY2013				FY2014			
Task / Event	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Advanced Facades, Daylighting, and Complex Fenestration Systems												
Q4 Milestone: Validated Radiance-EnergyPlus tools for modeling CFS systems												
Q4 Milestone: Complete modeling and field testing of initial prototypes												
Q4 Milestone: Build proof-of-concept implementation of model predictive controls												
Current work and future research												
Q4 Milestone: Improve prototype designs and file invention disclosure(s)												
Q4 Milestone: Model and/or field test 2nd-generation prototypes												
Q4: Milestone: Model and field test building-integrated MPC systems												
Q4: Milestone: Release COMFEN 4.0												

Project Budget

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Project Budget (FY13 $700K)

Task 1. Daylight-redirecting systems ($300K)

Task 2. Angular selective shading systems ($250K)

Task 3. Dynamic façade technologies ($150K)

Task 4. COMFEN conceptual façade design tool ($0K)

Supports model development (Radiance, EnergyPlus), industry collaborations, prototype R&D, lab and full-scale field testing

Variances: None

Cost to Date: $290K FY13 spent to date

Additional Funding: $500K, FY13 CEC PIER

Budget History					
FY2010		FY2011		FY2012	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$1.0M	$0.2M	$1.0M	$0.2M	$1.0M	$0.2M

Project Integration, Collaboration & Market Impact

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Partners, Subcontractors, and Collaborators

3M, Dow Chemical, Schott, PhotoSolar, Panelite, Saint-Gobain (Sage), View, Ravenbrick, Pleotint, MechoShade, Lutron, Nysan, HunterDouglas, Siemens, Greg Ward, Anyhere Software (Radiance developer)

Technology Transfer, Deployment, Market Impact

COMFEN, an EnergyPlus conceptual façade design tool; Radiance annual simulation capabilities being incorporated into OpenStudio and Daysim; GSA GPG demonstrations; subcommittees on 90.1, CA Title-24; invited talks at GreenBuild, LightFair, GlassBuild, ASHRAE, ACEEE, WCMA

Communications about 15 technical reports and journal articles underway including:

- McNeil, A., E.S. Lee, A validation of the Radiance three-phase simulation method for modeling annual daylight performance of optically complex fenestration systems, *J Building Performance Simulation* 2012: 1-14.
- Clear, R.D., Discomfort glare: What do we actually know?, *Lighting Research and Technology*, April 2012.
- McNeil, A. et al., Validation of a ray-tracing tool used to generate bi-directional scattering distribution functions for complex fenestration systems; under review, *Energy and Buildings*, August 2012.
- Lee, E.S., et al., An empirical study of a full-scale polymer thermochromic window and its implications on material science development objectives; under review, *Solar Energy Materials & Solar Cells*, December 2012.
- Fernandes, L.L., et al., Monitored lighting energy savings from dimmable lighting controls in The New York Times Headquarters Building; under review, *Energy and Buildings*, February 2013.

Next Steps and Future Plans

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Task 1. Daylight redirecting systems
- Move from exploratory development phase to fully functional lab prototypes in collaboration with industry partners.
- Field test 2nd-generation prototypes.
- Use alternate design approaches to improve performance and reduce glare.

Task 2. Angular selective shading systems
- Conduct sensitivity analysis and begin to improve designs for microstructured, between-pane scrims.
- Identify low-cost means of fabricating microstructures in collaboration with industry.
- Begin to field test early prototypes.

Task 3. Dynamic façade technologies
- Investigate energy savings potential of whole building façade control systems using “gold-standard” model predictive controls.
- Develop proof-of-principle sensors and controls and field test early prototypes.