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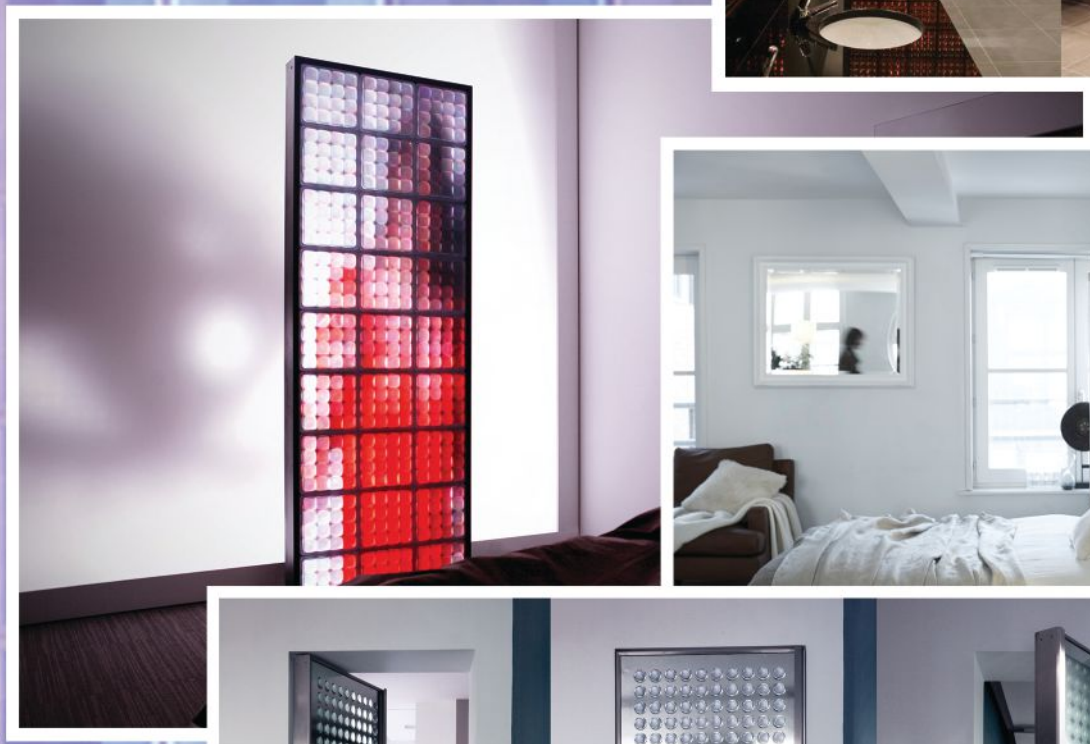
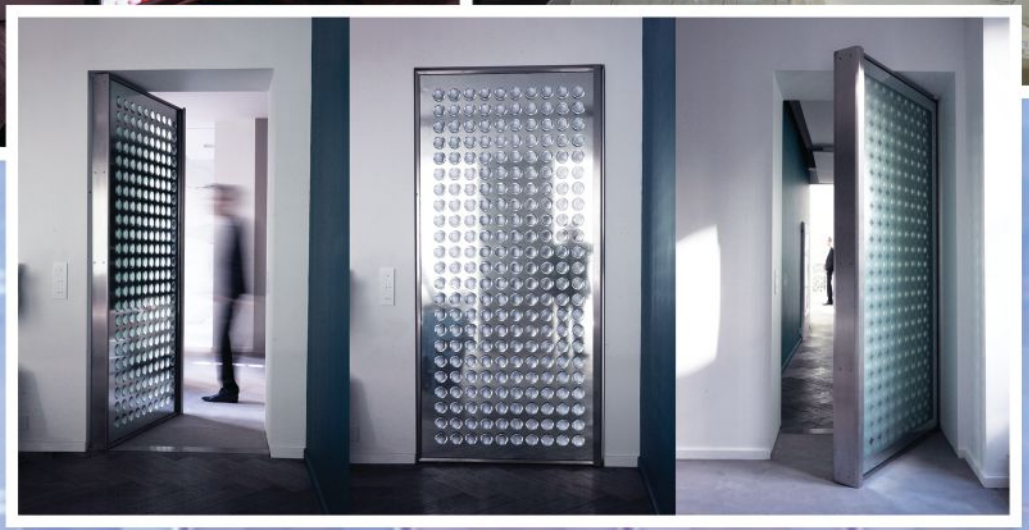
**On the Cover:**
The Giant Ocean Tank and the penguin tray at the New England Aquarium in Boston. Photo by Kwesi Budu-Arthur/Cambridge Seven Associates.

Clockwise From Top Left: Kwesi Budu-Arthur/Cambridge Seven Associates; Courtesy Luminale and Light+Building; Peiheng Tsai

FRED & FRED







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# DOES ARCHITECTURAL LIGHTING DESIGN NEED A PRITZKER-LIKE PRIZE?

**"Such a prize would also give a new kind of definition to the lighting community, one that exists on a global scale, and would elevate the profession as a whole."**

**With the announcement this week** that Japanese architect Shigeru Ban had won the 2014 Pritzker Architecture Prize, architecture's most prestigious award, a question I've often thought about has tempted me again: Does architectural lighting need a Pritzker-like prize?

Modeled after the Nobel Prize, the Pritzker was established in 1979 by Jay and Cindy Pritzker of Chicago, through their Hyatt Foundation, with the following purpose: "To honor a living architect/s whose built work demonstrates a combination of those qualities of talent, vision, and commitment, which has produced consistent and significant contributions to humanity and the built environment through the art of architecture." Since its inception, the Pritzker has been awarded 36 times.

The Pritzker plays an important role in the architecture profession. It continues the tradition of the "patron of architecture" and it sets a benchmark for practitioners in establishing a best of the best. But it is by no means a perfect system. For one thing, the program has been severely criticized lately for its failure to recognize female members of the architecture community. (The Denise Scott Brown controversy is a harsh reminder of the lack of parity in the field.)

With the affinity that exists between architecture and lighting, it is often easy to default to trying to construct parallel systems between the two, even where no true parallel exists. And so I wonder: Is lighting doomed to always be the bridesmaid to architecture's bride? I say: No.

Establishing an award for lighting design that recognizes a living person's body of work would be a way for the profession to take a step forward as it matures as a design discipline. Although there are many lighting design award programs sponsored by the community's professional organizations, manufacturers, and publications, most only recognize individual projects. Even fewer recognize particular lighting designers. There really is no singular lighting award program that recognizes a designer's body of work and cites for the lighting community, as well as for the larger field of architecture and design, that here is a person who serves as a role model and whose work represents excellence.

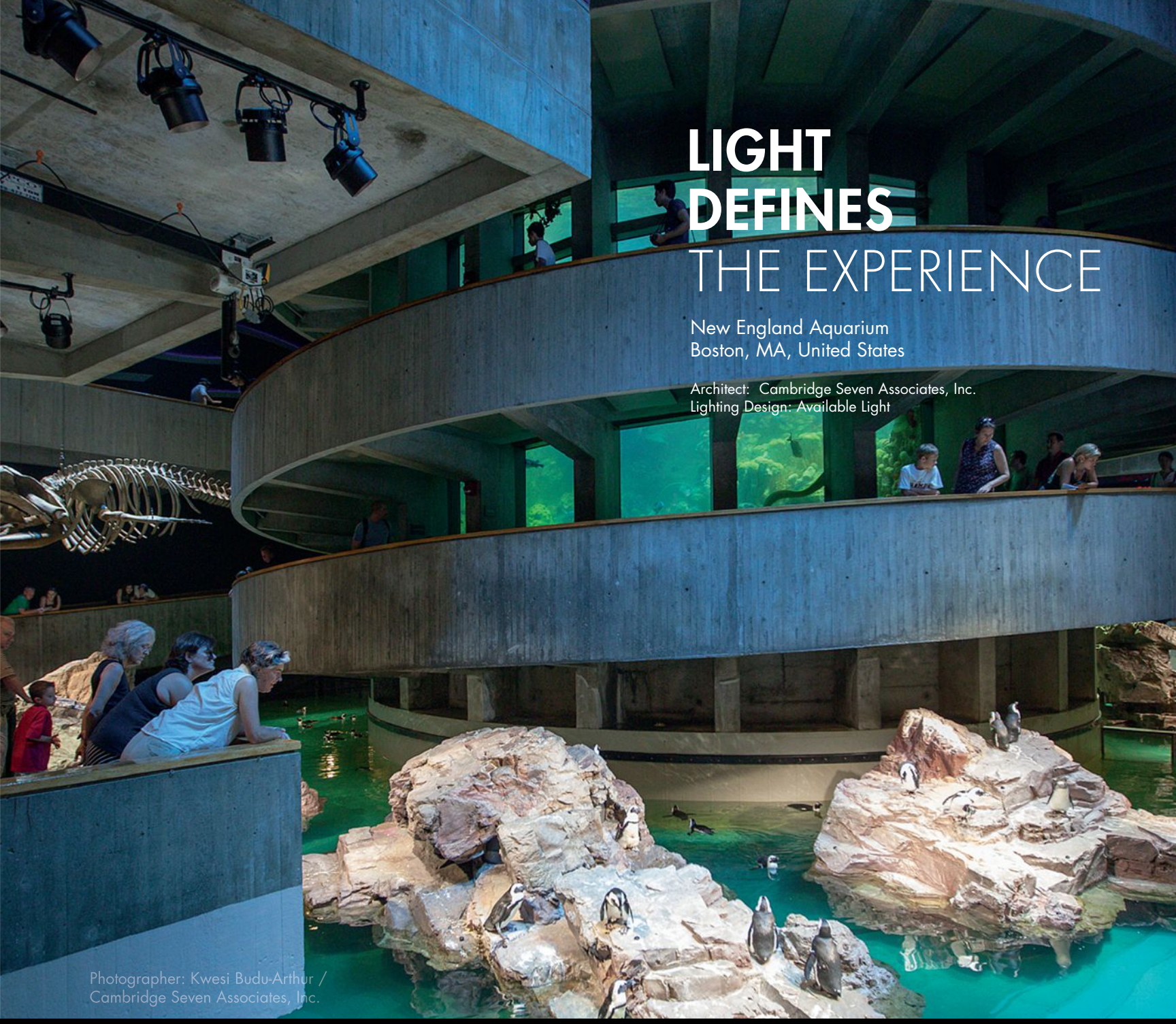
Look at the model of the Pritzker and how the jury is structured—it fluctuates between five and nine members, each of whom serves for several years to provide continuity and all of whom are "recognized professionals in their own fields of architecture, business, education, publishing, and culture." The award, thus, seeks to evaluate architecture beyond the profession's traditional boundaries. Creating such a prize for lighting would move lighting design to a much broader place of discussion—and, in turn, broader recognition. It would be a way for the lighting community to reconcile how it speaks to itself and how it speaks to a wider audience.

Such a prize would also be a way for the lighting design profession to show fellow architects and designers that it takes itself seriously, and that they should too. The profession has its own specific skill set, expertise, and knowledge base, and there is an established precedent of what constitutes good lighting design.

Such a prize would also give a new kind of definition to the lighting community, one that exists on a global scale, and would elevate the profession as a whole. Attaching a $100,000 purse, as the Pritzker does, would only help to convey the level of the profession's seriousness.

The Pritzker seeks to build "greater public awareness of buildings" and to "inspire greater creativity within the architectural profession." Doing something similar for lighting would be a good thing.

Elizabeth Donoff, Editor-in-Chief
edonoff@hanleywood.com



# LIGHT DEFINES THE EXPERIENCE

New England Aquarium
Boston, MA, United States

Architect: Cambridge Seven Associates, Inc.
Lighting Design: Available Light

Photographer: Kwesi Budu-Arthur / Cambridge Seven Associates, Inc.

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# PATRICIA DIMAGGIO, 1964–2014

*The lighting industry has lost Patricia DiMaggio, a trusted member of its community. She died on Feb. 28 after a long battle with cancer.*

text by Elizabeth Donoff

**Patricia DiMaggio** graduated from Brooklyn College in Brooklyn, N.Y., with a degree in architecture, and then worked in historic preservation and electrical engineering. Then she went to work for Osram Sylvania as a commercial engineer, and stayed there for the rest of her career. Over her 19-year tenure with the company, she collaborated on a number of projects, including New York's Battery Park City redevelopment as well as the Times Square revitalization. For their work on the Alexander Hamilton U.S. Custom House restoration in Lower Manhattan in 2007, she and lighting colleague Randy Sabedra of Brooklyn, N.Y.–based RS Lighting Design received a number of lighting awards, including a 2008 AL Light & Architecture Design Award Outstanding Achievement from ARCHITECTURAL LIGHTING and a 2008 Lumen Awards Citation for Exterior Lighting of a Historic Façade from the Illuminating Engineering Society's New York City Section (IESNYC).

DiMaggio was an active member of the lighting community, particularly in the New York City area, and she lent her time and expertise to a number of lighting community activities. She established partnerships for Sylvania with Green Light New York and Park Avenue Audio, strengthening her company's ties to the New York community. In 2010, a new position was created for her, that of lighting project design manager, enabling DiMaggio to work on special projects and to report directly to Sylvania's vice president of sales for the United States.

In addition to her professional work and accomplishments, DiMaggio was an educator, teaching lighting design at the New York School of Interior Design for more than six years. Devoted to her students, she continued to hold design reviews with them from the hospital via video conference.

DiMaggio volunteered her time with the IES for more than 20 years. She transformed the New York City Section's Lumen Awards presentations to include music, and initiated the AfterGlow post party. She served as secretary and vice president of the New York City Section and then as section president in 2004–2005.

She was also a founder of the IESNYC's Student Lighting Competition, which is now in its 14th year and reaches more than 200 students in seven architecture and design schools in New York state. The inclusive, competitive, and artistic tone of the competition make it a significant part of DiMaggio's legacy.

An artistic and creative person, DiMaggio will be sorely missed by her friends, family, and extended family of lighting colleagues. Funeral services were held on March 4 in Brooklyn, N.Y. In lieu of flowers, the IESNYC is establishing a fund in her honor that will assist New York City lighting students. •

# NGL DESIGN COMPETITION WINNERS

text by Elizabeth Donoff

**In February,** the winners in the outdoor category of the sixth annual Next Generation Luminaires (NGL) Solid-State Lighting Design Competition were announced during the Strategies in Light conference in Santa Clara, Calif. The competition is sponsored by the U.S. Department of Energy, the Illuminating Engineering Society, and the International Association of Lighting Designers. This year, 26 commercial LED outdoor luminaires were recognized from a pool of 68 entries, which in turn had passed the judging of entries from 41 different manufacturers in 12 outdoor lighting categories. The six Best in Class winners are:

- Juno Lighting Group's PL2 Series bollard and the company's Finia building wallpack
- LED Roadway Lighting's NXT-S local residential roadway fixture
- Cooper Lighting by Eaton's McGraw-Edison TopTier LED parking garage and canopy luminaire
- Cree's CPY250 canopy luminaire
- Louis Poulsen Lighting's LP Icon LED pedestrian walkway fixture

For the complete list of recognized luminaires go to www.*ngldc.org*. •

Top: Courtesy IESNYC; Bottom: Courtesy NGL Design Competition

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# FLEX YOUR RESEARCH ARM

text by Wanda Lau

Roy Kaltschmidt © The Regents of the University of California, Lawrence Berkeley National Laboratory

**Construction of the** Facility for Low Energy Experiments in Buildings (FLEXLAB) at the Lawrence Berkeley National Laboratory (LBNL) in Berkeley, Calif., will be substantially complete this April. Funded by the U.S. Department of Energy, the $15.9-million facility features seven testbeds in which researchers, manufacturers, and owners can test individual building products or whole-building environments. The four exterior testbeds exemplify FLEXLAB's versatility best. Totaling 5,600 square feet, the adiabatic testbeds can be outfitted with interchangeable components—from glazing units to shading devices, luminaires to variable air valve boxes—to create a user-specified space. Even more exciting, one testbed sits on what is essentially a building-scale turntable that can rotate the entire structure to a specified orientation or incrementally to track the sun. LBNL is now seeking partnerships with those interested in testing design environments and technologies in FLEXLAB. Read more at *archlighting.com*. •

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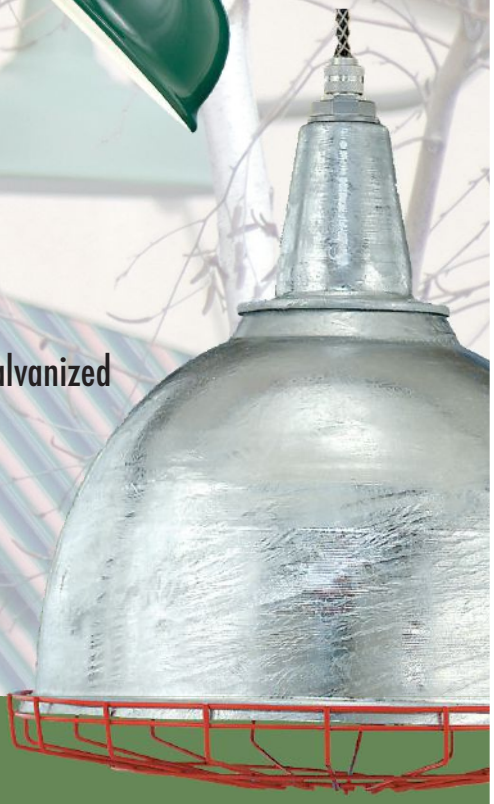

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REPORT

# LUMINALE 2014

*This lighting festival, held during Light+Building in Frankfurt, showcases light's ability to inspire and transform the city at even the largest of urban scales.*

interview by Elizabeth Donoff
images courtesy Luminale and Light+Building

**Luminale has become** the signature event associated with Light+Building, the international building and lighting trade show that takes place every two years in Frankfurt, Germany. ARCHITECTURAL LIGHTING spoke with Helmut M. Bien, director and owner of Westermann Kommunikation and curator of Luminale since 2000, about the event and its important role not only during the fair, but on the city and region long after this year's lighting displays have been packed away.


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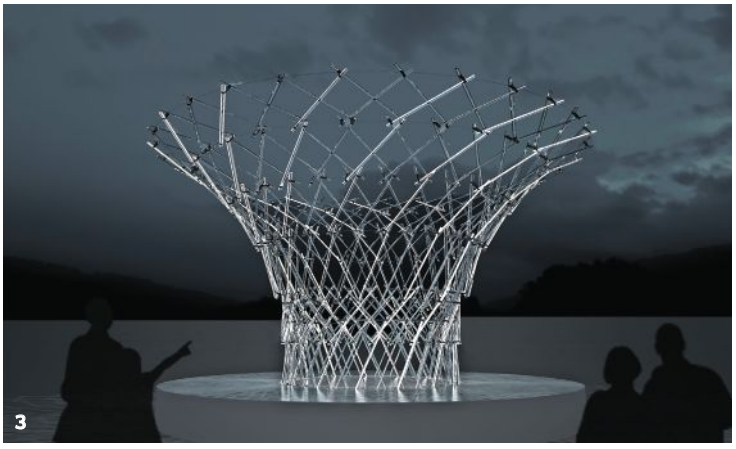
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**How did Luminale come about?**
As a museum consultant and exhibition director, I am fascinated by light and the possibilities of creating different atmospheres. In 2000, I was asked by Messe Frankfurt to create a concept that could build a bridge between the [then] new trade show Light+Building and the city of Frankfurt, something that would allow each to complement one another. Frankfurt is an exciting city for architects and architecture, and the trade show was positioned to become a leading international meeting place for all who are interested in technology. That was the key idea: to create a synergy between the commercial marketplace for the industry and the city where this event takes place. That was the birth of Luminale.

**How has the event evolved over time?**
We started with 50 projects in 2002. The second edition expanded to 100 installations, and the third edition had just over 200 projects. For the upcoming seventh edition of Luminale—March 30 to April 4—we will have approximately 180 installations throughout the city and environs. The main point is to involve a lot of people and to initialize a process of working with light, for professional lighting designers as well as Frankfurt residents. Participation is a key idea of Luminale. The festival is a platform for experiments with light. It's about exposing professionals and non-professionals alike to the many facets of light.

**How many people are involved in the planning of Luminale?**
We are a very small office, only two people, but we are connected with more than 600 partners

Some of the lighting installations for the 2014 edition of Luminale: **Opening page:** tiptopexpress: projections and light installations at the site of the future Romance Museums; **1.** Installation in the public part of Offenbach Port by werkbund.jung; **2.** re:connect-reflect: a variety of installations in Frankfurt's main railway station—the Hauptbahnhof—by Tjark Ihmels and his team; **3.** Twinkle Twinkle: lighting object by Glasbau Hahn with NE-AR and Studio HeyHey; **4.** Water Lily installation in the Palmengarten, by Luminauten; **5.** Metamorphoses: performances by the Kopffarben Group in the Naxos Hall; **6.** Orchestrating the Depth of Light: installation at Rossmarkt by the Städelschule and Media Architecture Institute, Vienna; **7.** Façade illumination of the Hauptbahnhof, by Christian Uitz for iGuzzini.

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to create this festival, and we cultivate a network with the international lighting community. It takes more than a year to find the partners for the upcoming event. Luminale is a no-budget festival. Each artist or designer has to raise his or her own funds to support their work. We simply moderate the process. We ask architects and artists to envision a project and we help them to find a site and partners, such as the many exhibitors at Light+Building. It's like design match making. We also do the marketing for the festival.

**What distinguishes Luminale from other lighting festivals?**

Most festivals are driven by city marketing, tourism, and big budgets. Luminale is free of these intentions. Frankfurt is filled with lighting professionals during Light+Building. The city becomes a center of lighting during the week, and Luminale uses this opportunity to create a festival with these [lighting] experts, for these experts, each night after the fair.

For the people of Frankfurt and the region, Luminale is a huge opportunity to see what

lighting designers can do in addressing quality of life issues with the resources and needs for the urban age. A lot of students and startups also use this chance to exhibit at Luminale as a way to start a career. Seasoned professionals like to see the experiments of the next generation. Many projects are not perfect but that adds to their charm because they are telling the artist's story through their personal passion about light. That's an authentic approach and a huge source of inspiration for everyone who sees the festival.

**How do you keep Luminale up to date?**
Luminale is deeply connected with the fair, and the trade show follows the stream of innovations. In between each edition of Luminale, we scout new talent while we follow the evolutions of technology: the digitalization of light and its interactivity; LEDs and OLEDs; sustainability and green building strategies. It is not a festival of lanterns and romanticism, but a festival of art, design, and technology. We also follow the urban development and growth of Frankfurt. For example, this year there will be installations in some of the new residential neighborhoods—reclaimed industrial areas—along the River Main. Cultural campuses and museums are also our stages for installations. In this way, we introduce new places, so Luminale is as fresh as the city itself. We also have symposia within Luminale on topics such as light art and media façades. And there are Pecha Kucha gatherings, concerts, and guided tours.

**How did you get the city of Frankfurt involved as well as the private sector?**
Frankfurt is one of the leading green cities in Europe; it's the capital of Passive Haus construction. The city administration, along with real-estate developers, architects and designers, and schools, such as the Frankfurt University of Applied Sciences, are keen on being part of Luminale. The festival is like a display window for new ideas, buildings, and the involved people in a vibrant region.

**How does Luminale serve as a catalyst for growth for Frankfurt and the region?**
Luminale is a stage for the new. It showcases a strong and fast-developing region in the heart of Europe. Images from Luminale's installations and activities are dispersed globally. Some of the projects that have taken place during Luminale have served as symbols of change for the city, such as the now-iconic exterior illumination of the Commerzbank Tower in its wash of yellow light and the lighting along the River Main.

**What do you hope visitors take away from their Luminale experience?**
For every colleague working in lighting, it's reassuring to see that so many people share an interest in and a fascination with light. Luminale provides motivation and inspiration for the entire lighting community. It gives one the sense that your work is valued and that people are interested in seeing what you've done.

**What do you hope residents of Frankfurt take away from their Luminale experience?**
It's as the German Romantic poet Novalis said 200 years ago, "We must transform the things of everyday life into something new and fascinating." Luminale motivates people to "see" with new eyes.

**How do you see Luminale growing?**
Luminale will follow Light+Building and will reflect the developments of technology and urban life. More than half of humanity is living in cities today. We have to face that challenge, urbanistically and environmentally. Luminale should be an urban-age festival to see and discuss all the challenges of participation, interactivity, automatization, and sustainability. •

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IN FOCUS

# FRIENDS SEMINARY CAFETERIA

text by Jennifer Bickford
photos by Peiheng Tsai

**CHALLENGE:** Transform a low-ceiling basement kitchen and lunchroom into an open, welcoming dining area for K–12 students.

**LIGHTING SOLUTION:** On East 16th Street, in the heart of the Gramercy neighborhood in New York, sits the city's oldest coeducational school, Friends Seminary. Educating students from kindergarten through 12th grade, this private day school subleases its site and buildings from the New York Quarterly Meeting of the Religious Society of Friends. Totaling approximately 700 pupils, the student body is broken into three groups: the Lower School has grades K–4, the Middle School has grades 5–8, and the Upper School has grades 9–12.

Located beneath the school's historic and landmarked Meeting House, the cafeteria had not been renovated in more than 25 years. In dire need of a facilities upgrade, the school contacted architect John Tinmouth of New York–based Tinmouth Chang Architects and lighting designer Peiheng Tsai of New York–based PHT Lighting Design to improve the existing space. The project renovation consisted of a brand new kitchen, an upgrade of the entire electrical and plumbing framework, integration of a new air conditioning system, and the creation of separate dining areas for the Lower and Upper schools.

The designers were constrained by the cafeteria's location, which, because of its basement position, had small windows and very low ceiling heights. Existing joists and the need to hide the utilities limited the renovated space to a ceiling height of 7 feet 9 inches in the center, and 6 feet 8 inches at the north and south walls. This slope in ceiling height allowed for clever integration of air supply units at the room's edges. Separating the two dining rooms

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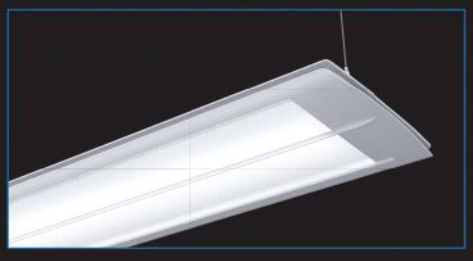

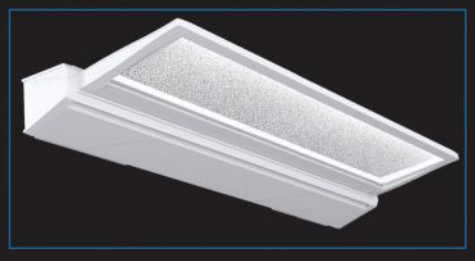

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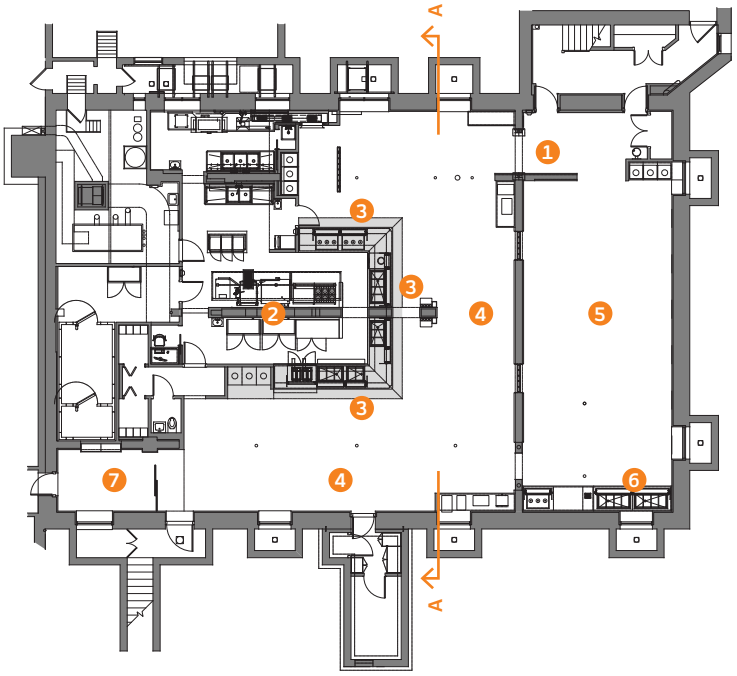
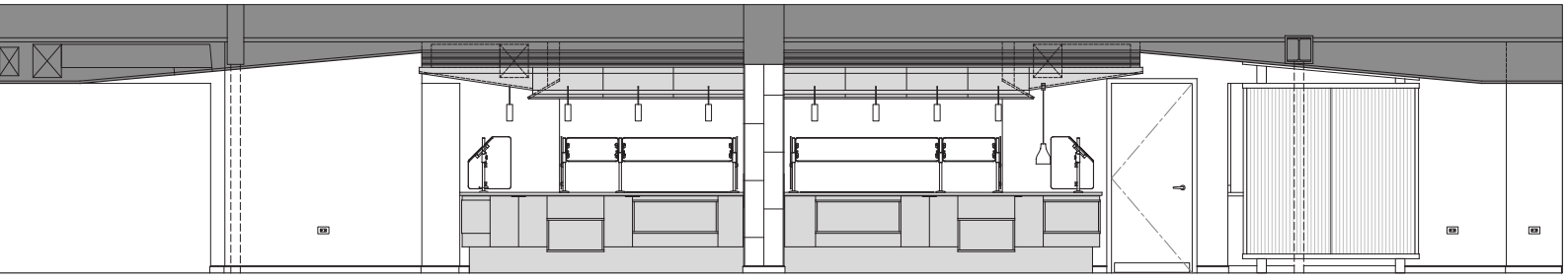
## Floor Plan




1. Cafeteria Entry
2. Open Kitchen
3. Serving Line
4. Upper School Dining Area
5. Lower School Dining Area
6. Tray Drop-off
7. Private Dining

## Section A: Looking at Serving Counter



A fritted-glass panel, framed in steel, provides separation between the cafeteria entry area and the Lower School dining area. Shallow housing, 28W T5 linear fluorescent fixtures provide general illumination (above). A view of the open kitchen and serving line (previous page).

is an existing structural brick wall. Linear fritted glass, framed in steel, fills in two existing archways, and provides acoustical separation while allowing light to filter through.

Seeking to create a more open, vibrant space with improved circulation through the serving line, Tinmouth settled on a U-shaped open kitchen layout. Three separate serving stations help hungry students pick up their food faster and more easily than before.

Above the kitchen area is an angled wood canopy, dropped to create the required smoke baffle that divides the kitchen from the dining area. Sprinklers, as well as additional air conditioning units and ductwork, were also concealed in the wood soffit. "We wanted to give the illusion of a taller ceiling and create a sense of warmth in the center of the space," Tinmouth says. At the inside edge of the canopy, a 4.4W-per-linear foot LED strip in 3000K warm white emits a soft glow, warming the wood panels. Cylindrical pendants with 40-degree 50W MR16 halogen lamps, selected for their high-color-rendering properties and small fixture scale, are suspended above the counter, illuminating the food below.

For general lighting, shallow housing, semi-recessed, 4-foot-long 28W T5 linear fluorescent fixtures in 3000K are located in a non-linear pattern on the ceiling. This allowed for coordination with the other equipment also fighting for the limited ceiling cavity real estate. The seemingly random luminaire layout is mirrored in the floor with 4-foot-long strips of green and orange tiles, helping to tie the space together. Given the low ceilings and the east–west orientation of the fixtures, Tsai sought a fixture that would reduce glare when viewed from the side. Remembering a fluorescent fixture with perforated side baffles she had seen

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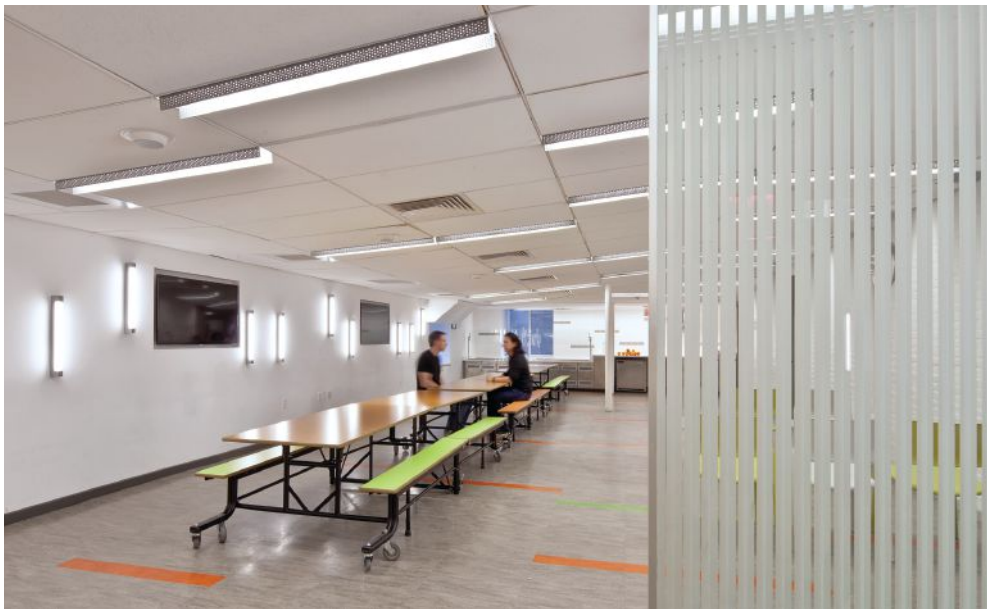

Fluorescent fixtures with perforated side baffles help diffuse glare and provide dappled light on the ceiling surface in the Lower School dining area. Wall sconces also use the same perforated metal (above).

at New York's Kennedy Airport, Tsai contacted the manufacturer to create a similar fixture for Friends Seminary. The perforated baffle helps to diffuse glare as well as provide a bit of dappled light on the ceiling surface. "The fixture pattern and the light on the ceiling help reinforce the liveliness" of the space, according to Tsai. Vertically mounted, 2-foot-long linear fluorescent wall sconces are shielded with the same perforated metal and provide illumination at the north and south walls.

This bright and colorful dining space offers the students a view of the food preparation and allows for greater flexibility and better traffic flow during lunchtime. Playful relationships between fixtures and materials enhance the lightness of the space and "allow for continued discovery" of design elements, explains Tinmouth. Through the collaborative efforts of the design team, this new student dining room serves as a revitalized and dynamic cafeteria. •

**DETAILS** **Project:** Cafeteria, Friends Seminary, New York • **Client:** Friends Seminary, New York • **Architect:** Tinmouth Chang Architects, New York • **Lighting Designer:** PHT Lighting Design, New York • **Kitchen Designer:** DesignSmart, Charlotte, N.C. • **Mechanical and Plumbing Engineer:** Stanislav Slutsky Engineers, New York • **Electrical Engineer:** Forum Engineering, New York • **Total Square Footage:** 4,825 square feet • **Project Cost:** $1.9 million • **Lighting Cost:** $44,500 (cost of light fixtures), installed cost not available • **Watts per Square Foot:** 0.88 • **Code Compliance:** The Energy Conservation Construction Code of New York State 2010 and ASHRAE 90.1-2007 • **Manufacturers:** **Bartco Lighting:** Semi-recessed fluorescent fixture with perforated shield at ceiling and surface-mounted fluorescent fixture with perforated shield at perimeter wall • **Sistemalux:** Ceiling-suspended cylindrical pendant at serving counter • **Zaneen:** Surface-mounted decorative pendant with white blown glass

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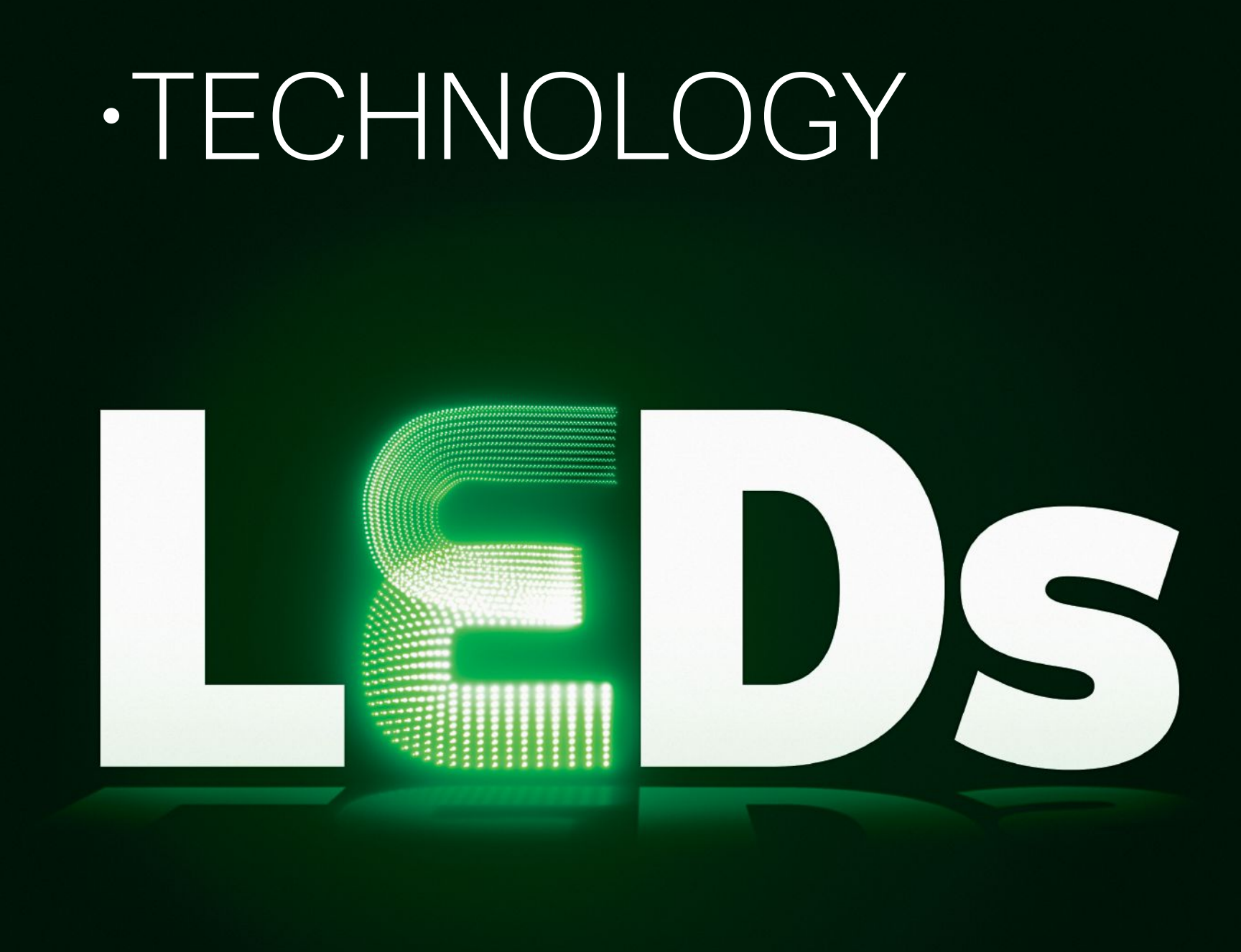



TECHNOLOGY

# FIGHTING FLICKER

## The onset of LEDs in lighting has brought manufacturers and designers back to the drawing board to discuss an age-old problem.

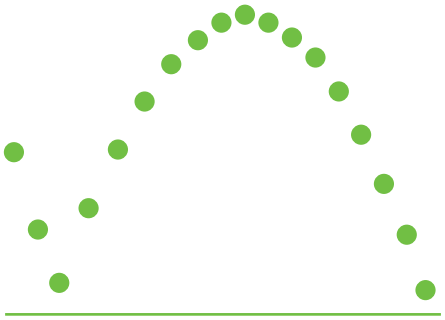
With the increasing ubiquity of solid-state lighting, AL is kicking off a multi-part series that examines the critical issues facing this market-transforming technology, beginning with flicker.

text by Wanda Lau
illustration by AnotherExample

**From headaches** to underexposed photographs, the consequences of flicker can manifest in many ways. Though the lighting industry has readily adopted solid-state lighting as the energy-efficient source of today and tomorrow, it has generally fallen short in addressing the causes and effects of periodic modulation in LEDs. If left unchecked, flicker can lead to a host of problems that can ruin an otherwise well-designed luminaire or space. Understanding the basics behind the issue will help architects and lighting professionals avoid the annoying and even harmful effects of oscillating light.

### WHAT IS FLICKER?

In its simplest definition, flicker is the constant fluctuation of light output from on to off. Because electricity is delivered through alternating current (AC) at a power line frequency of 60 hertz in the U.S., the voltage delivered to a source bounces between on



The stroboscopic effect can make objects in motion appear stationary or slow moving.

and off as it rides the sine wave between the positive and negative poles. As a result, the potential flicker frequency is twice the power line frequency, or 120 hertz. Without the proper electronic circuitry—such as a ballast, driver, or capacitor—a source will flicker.

Flicker can be intentional, as in the case of oscillating bicycle headlights. "There are degrees of flicker that no one notices and are not neurologically a problem, and [there are] degrees that really are a problem," says Naomi Miller, lighting designer and senior scientist with the Advanced Lighting Team at the Portland, Ore.–based Pacific Northwest National Laboratory (PNNL). The lighting industry, she says, is "concerned about certain [frequency] ranges that can cause neurological problems in individuals or can affect task performance."

Humans can perceive light oscillation at frequencies slower than 50 hertz, although some people notice it up to 100 hertz, says Nadarajah Narendran, director of research at the Lighting Research Center (LRC) in Troy, N.Y. Slow frequencies, of approximately 3 to 70 hertz, can cause seizures in highly sensitive individuals, while moderate flicker frequencies, from about 100 hertz to as high as 500 hertz, can lead to indirect perception of stroboscopic effects, in which objects in motion can appear as a series of still images. But what may be desirable in a dance club can be dangerous in an industrial setting. For example, flicker can make moving gears or blades look slower or even stationary, and it has been associated with adverse health effects such as headaches, eye strain, and fatigue.

As the flicker frequency increases into the kilohertz range, around 2 kilohertz and higher, preliminary research suggests that "we can no longer detect it," says Jim Benya, principal at Davis, Calif.–based Benya Burnett Consultancy. "It no longer becomes a problem." Achieving these high frequencies with different sources, however, can be a problem.

### MEASURING OSCILLATION

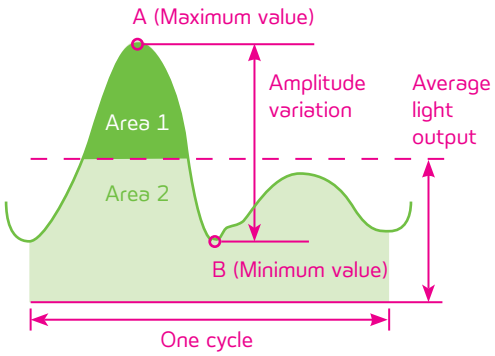
Currently, there is no official standard procedure for manufacturers to measure flicker, but the Illuminating Engineering Society (IES) has developed two metrics to quantify flicker that are described in *RP-16-10, Nomenclature and Definitions for Illuminating Engineering*. The first and more commonly used metric is percent flicker. It indicates the average amount of modulation, or reduction, in light output over a single on–off cycle. A source with 100 percent flicker would indicate that, at some point in its cycle, it produces no light, while a completely steady light would have zero percent flicker.

The other metric is the flicker index, which ranges from zero to one. It accounts for the percent flicker and two other variables: the shape of the light's waveform, or output curve, and the duty cycle, which refers to the percentage of time that the light source is on in a single on–off cycle. The lower the percent flicker and flicker index, the less a source oscillates or produces perceptible stroboscopic effects.

### FLICKER IN CONVENTIONAL SOURCES

All AC-powered sources flicker. In high-intensity discharge (HID) lamps, Benya says, flicker became patently obvious during the 1972 Olympic Games when photographers discovered that many of their pictures were pitch black "because they tried to take a very short exposure picture at exactly the wrong time, and the lights would be effectively off." A three-phase lighting distribution system, in which adjacent sources are pulsed 120 degrees out of phase—such that one lamp is turning on while another is turning

## Calculating Flicker Metrics




$$\text{Percent flicker} = 100\% \times \frac{A - B}{A + B}$$

$$\text{Flicker index} = \frac{\text{Area 1}}{\text{Area 1} + \text{Area 2}}$$

## Flicker Metrics for Common Sources

| Technology | Percent Flicker | Flicker Index |
|---|---|---|
| Incandescent lamp | 6.3 | 0.02 |
| T12 linear with magnetic ballast | 28.4 | 0.07 |
| Spiral compact fluorescent lamp (CFL) | 7.7 | 0.02 |
| Quad-tube CFL with magnetic ballast | 37.0 | 0.11 |
| Quad-tube CFL with electronic ballast | 1.8 | 0.00 |
| Metal halide lamp | 52.0 | 0.16 |
| High-pressure sodium lamp | 95.0 | 0.30 |
| Direct current LED | 2.8 | 0.0037 |
| LED with significant flicker | 99.0 | 0.45 |

Source for graph at left: Modified from *The Lighting Handbook*, IES (10th ed., 2011).
Source for table at right: Michael Poplawski, Naomi Miller, PNNL (2011); Michael Grather, Luminaire Testing Laboratory (2009)

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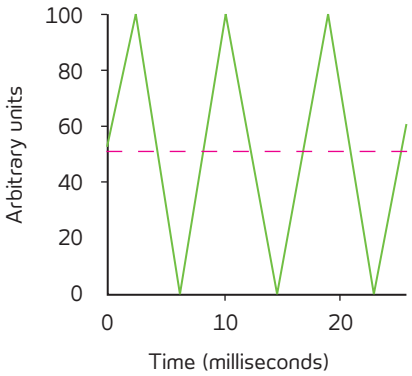
## Simple Periodic Waveforms Properties and Flicker Metrics

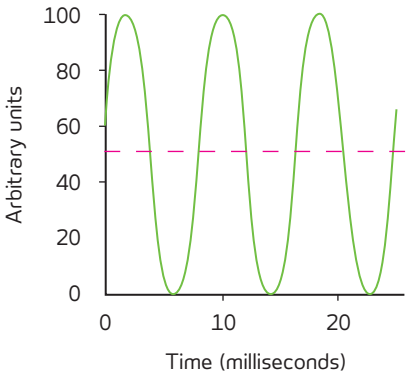



**Triangle Waveform Shape**

Percent flicker = 100%

Flicker index = 0.250

Duty cycle = N/A

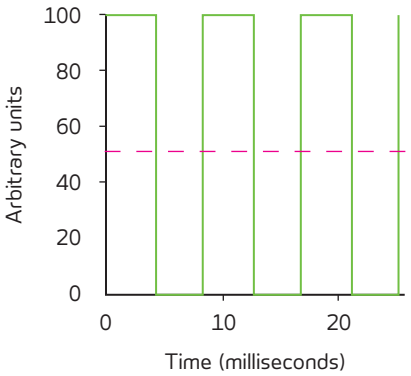



**Sine Waveform Shape**

Percent Flicker = 100%

Flicker Index = 0.318

Duty cycle = N/A




**Square Waveform Shape**

Percent Flicker = 100%

Flicker Index = 0.500

Duty cycle = 50%

off, and a third is somewhere in between—solved the issue of flicker in stadium lighting.

Even the beloved incandescent lamp flickers. We don't notice it, however, because thermal persistence, the same trait that makes incandescent lamps energy inefficient—about 90 percent of the electricity used is lost as heat—masks the effects of flicker. After the power is cut, the residual heat in the filament holds its glow until the next burst of power is delivered.

This isn't the case for fluorescent lamps and LEDs, however. "These lighting sources react very quickly to power," Benya says. "So when there's no power, there's no light." In the 1990s, magnetically ballasted fluorescent lamps came under fire for their flicker. Manufacturers resolved the problem by moving to electronic ballasts, which operated the lamps above 20 kilohertz, well above the frequency at which people notice flicker.

### WHY DO LEDS FLICKER?

When a new source comes to market, the issue of flicker bubbles to the surface. However, LEDs may oscillate in light output even more than incandescent or fluorescent lamps did, says PNNL's Miller. Unlike HID or fluorescent, solid-state lighting is a direct current (DC) device, meaning that as long as constant current is supplied, the LED will illuminate without flicker, Benya says.

In the case of a simple LED circuit in which no constant current regulation is implemented vis-à-vis a driver, the LED's brightness will vary in phase with the cycle of the alternating current. When a driver exists, it presents both a source and a solution. Rectifying the AC to DC conversion causes a ripple in the voltage and current output from the driver to the LED. This ripple typically occurs at twice the frequency of the incoming line voltage—120 hertz in the U.S. The LED output then correlates with the output waveform of the driver.

Dimming is the other primary cause of flicker. Conventional dimmers, such as TRIAC (meaning an electronic component that can conduct current in either direction) dimmers, modulate the current by extending the off time in the on–off cycle, reducing light output. Pulse width modulation (PWM) dims LEDs by turning them on and off at frequencies that ideally exceed 200 hertz. However, Benya says, "if you do PWM at a low enough frequency, such as our normal power line frequency, then once again, we've introduced a very high percentage of flicker."

### MINIMIZING FLICKER

The key to mitigating flicker thus lies in the driver, which can eliminate the problem by supplying the LED with a constant, non-oscillating current. But manufacturers have to weigh several factors—cost, size, reliability, and efficiency—when choosing which driver to build into their products, says Mark McClear, vice president of applications engineering at Cree. The intended use of the luminaire also plays a role—flicker may be more tolerable in certain lighting scenarios than others—in ensuring that a product also isn't overdesigned.

"Manufacturers are always trying to optimize what's good enough for this application, and how we can make it acceptable from a flicker standpoint without driving the cost point up," McClear says. A capacitor can help modulate the AC ripples from the driver to LED, but they, too, have shortcomings, Benya says. "They're large … and they hate heat." So, in a space that is often already too tight, such as in many LED replacement lamps, a capacitor won't work.

For LEDs dimmed using PWM, manufacturers can modulate the current to a very high frequency exceeding several thousand hertz. This is similar to what electronic ballasts do for fluorescent lamps. The higher the desired frequency, however, the closer the driver and the LED physically need to be. "Unfortunately, a lot of people want to have a driver somewhat remote from their lighting system, so that isn't always possible," Benya says.

In an effort to simplify testing compatibility between dimmers and dimmable LED light engines (LLEs), the National Electrical Manufacturers Association (NEMA) issued *NEMA SSL 7A-2013, Phase Cut Dimming for Solid State Lighting: Basic Compatibility*, a guide for lighting product designers and manufacturers. Dimmers and LLEs that are compliant with the standard will thus be compatible with each other.

The standard represents a first for the industry, says Megan Hayes, a technical program manager at NEMA. Signed off on by 24 major manufacturers, *SSL 7A* aims "to get rid of matched-pair testing for lamps and dimmers," she says. The catch is that the standard only applies to forward-looking technologies and does not, as the title would suggest, provide a method to "determine compatibility with existing products or the installed base of LLEs and phase-cut dimmers."

### SETTING THE LIMITS

On Sept. 30, the U.S. Environmental Protection Agency's Energy Star program will require

Source for chart: Michael Poplawski, Naomi Miller, PNNL (2011)

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manufacturers to report the highest percent flicker and highest flicker index on all of their dimmable lamps. But guidelines for what value ranges are deemed acceptable have remained conspicuously absent.

Enter the Lighting Research Center, which, in 2002, established the Alliance for Solid-State Illumination Systems and Technologies (ASSIST), a collaboration of government organizations, researchers, and manufacturers led by the LRC's Narendran. The organization took a first step toward defining acceptable oscillation rates in 2012 when it released *ASSIST Recommends… Flicker Parameters for Reducing Stroboscopic Effects from Solid-State Lighting Systems*, which includes equations to estimate the detectability and acceptability of stroboscopic effects in a source.

More recently, ASSIST sponsored a study on indirect flicker perception and human factors, conducted by LRC senior research scientist John Bullough. Having determined that frequency and magnitude of modulation are the two primary indicators of predicting people's annoyance with flicker, Bullough is trying to pinpoint "at what points do [stroboscopic] effects become noticeable and … not acceptable for someone to constantly work under this type of lighting." For example, he says, although computer screens flicker at about 60 to 70 hertz, the flicker largely passes unnoticed.

Ideally, Bullough wants to create a reference that lists a source's flicker metrics, and the percent of occupants that would likely notice the flicker. Narendran says that the study, due to be released this year, has moved to the analysis phase to determine limits for flicker index for selected lighting applications.

**SPEC TIPS**

Lighting professionals can take some steps to reduce their chances of specifying solid-state lighting products that flicker. For interiors, be wary of products advertised as AC-LEDs, Miller says. The simpler circuit design, lack of a driver, and, consequently, low price may seem attractive, but some AC-LEDs produce up to 40 percent flicker at full output. At dimmed levels, the percent flicker can be even higher.

Replacement LED lamps, such as MR16, A-lamps, and PAR lamps, are also more likely to flicker than, say, a high-bay lamp, McClear says. The replacement lamps have space limitations, so they may rely on simple drivers that lack the necessary electronics to rectify the output.

For non-dimming applications, flicker may not be perceptible if a high-quality driver is installed. But if a designer pairs a replacement lamp with a conventional wall box or TRIAC dimmer instead of investing in a dedicated LED fixture with a zero-to-10V or digital volt-dimming system, "you're going to get flicker from even the best name products," Benya says. "Clue number one is that if you go cheap, you're probably going to have flicker."

Designers should work with lighting manufacturers to identify a compatible system and test that system firsthand under the driver and dimming settings expected in the final installation. One low-tech test, Miller says, is to illuminate a spinning top and look for stroboscopic effects. Another is to wave a pencil quickly under the light source to produce the illusion of a fan. Under a flickering light source, gaps or dark lines will be apparent in the fan; if there's no flicker, the fan will appear to be smooth, continuous, and free of gaps.

It may sound like the dark days of fluorescent lamps and magnetic ballasts have returned, but solid-state lighting that is free of perceptible stroboscopic effects does exist. Designers and specifiers have to be careful and do their research. "It's not like everything is gloomy," Narendran says. "You've got to invest the time up front to ensure that these are compatible systems that you're using." •

*Additional reporting by Heidi Moore.*



## RESOURCES

**An introductory list of articles that discuss the issue of flicker in LEDs.**


*ASSIST Recommends … Flicker Parameters for Reducing Stroboscopic Effects from Solid-State Lighting Systems*, by the Alliance for Solid-State Illumination Systems and Technologies and the Lighting Research Center, May 2012. Available at *bit.ly/Q84AvS*.

"Flicker happens. But does it have to?" by Cree, 2013. Available under white papers at *bit.ly/1iUBg5U*.

"Exploring flicker in Solid State Lighting: What you might find, and how to deal with it," by Michael Poplawski and Naomi Miller, Pacific Northwest National Laboratory, 2011. Available at *bit.ly/1hgwlrH*.

*Dimming LEDs with Phase-Cut Dimmers: The Specifier's Process for Maximizing Success*, ibid., October 2013. Available at *1.usa.gov/Q84Fzu*.

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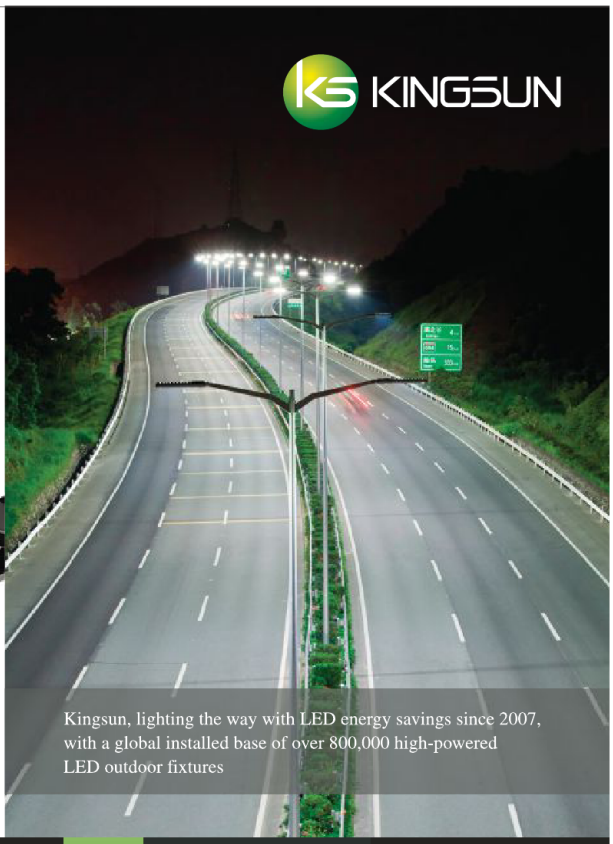


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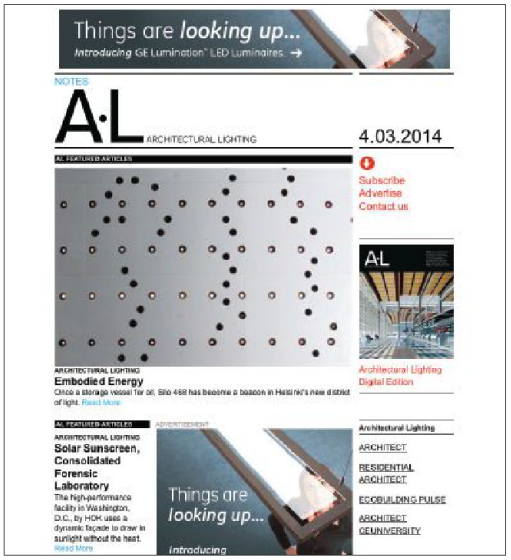


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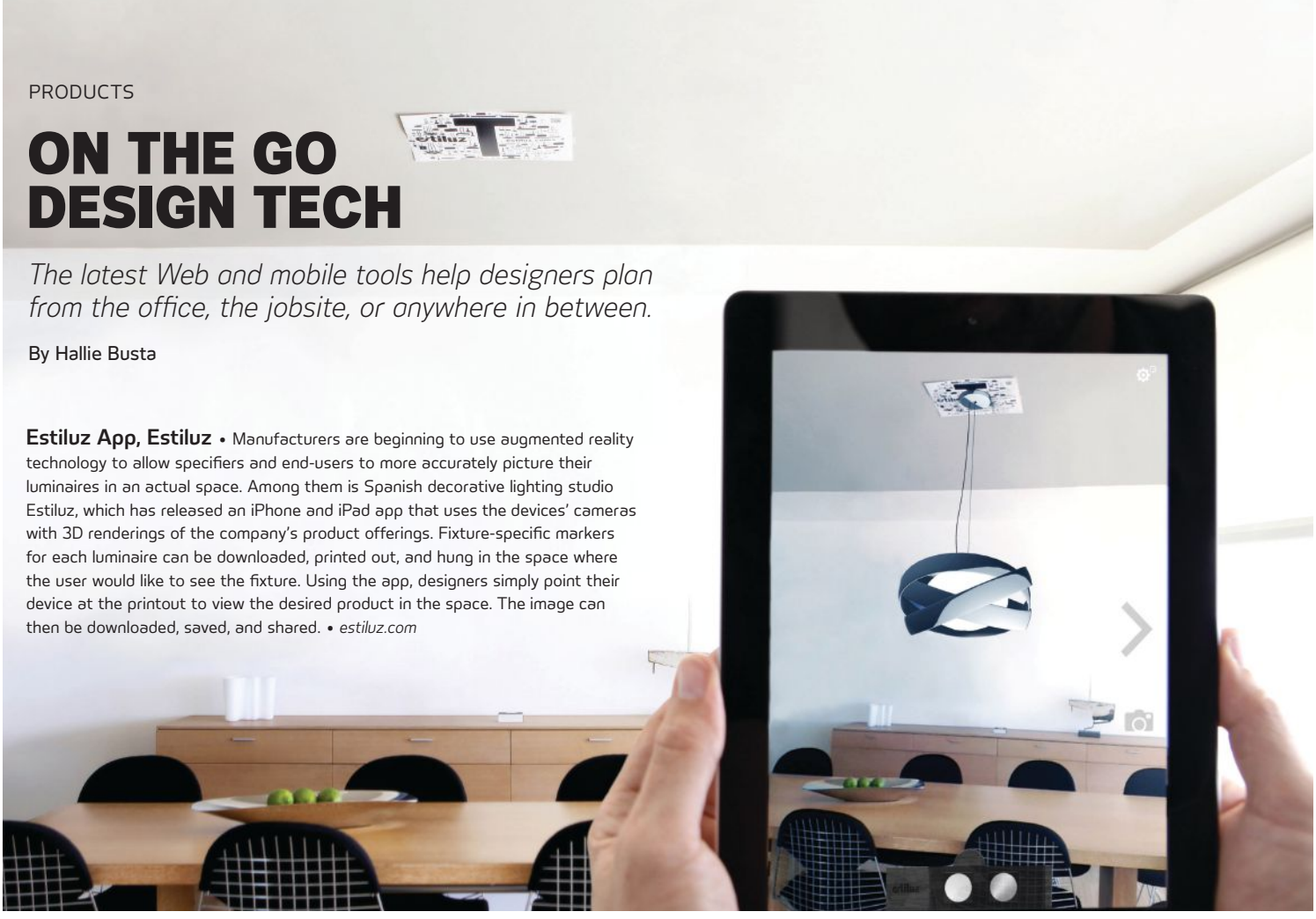
By Hallie Busta



**Estiluz App, Estiluz** • Manufacturers are beginning to use augmented reality technology to allow specifiers and end-users to more accurately picture their luminaires in an actual space. Among them is Spanish decorative lighting studio Estiluz, which has released an iPhone and iPad app that uses the devices' cameras with 3D renderings of the company's product offerings. Fixture-specific markers for each luminaire can be downloaded, printed out, and hung in the space where the user would like to see the fixture. Using the app, designers simply point their device at the printout to view the desired product in the space. The image can then be downloaded, saved, and shared. • *estiluz.com*

**Lutron Energi Advisor, Lutron Electronics** • A new iPhone and iPad app from Lutron assists designers with the task of specifying lighting systems for commercial retrofit applications. Energi Advisor uses data such as space dimensions, fixture type and count, local utility rates and rebates, and labor costs to generate reports such as a bill of materials, anticipated energy savings, and an energy-use audit of the existing system. The app can be used to monitor multiple projects and is free to download from the iTunes store. • *lutron.com*

**Light Finder, Erco** • Erco's Web-based tool helps designers develop lighting plans using the company's products. Light Finder guides users through an eight-step process to gather project-specific information such as the room zones and dimensions, objects to be illuminated, and desired color temperature. Users also can download documents including 3D and planning data for light distribution and technical spec sheets for the Erco luminaires that the app recommends for use in the application. • *erco.com*

**Lighting Performance Calculator, Guardian Industries** • Guardian Industries' free online tool is designed to augment designers' understanding of high-performance glass and coatings relative to daylighting. The Lighting Performance Calculator relies on metrics such as fixture count, light output, lumens, wattage, and photometric data. Designers can use the PDFs generated by the tool to determine the number of fixtures required for a job and to compare performance, costs, and payback periods. • *guardian.com*

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# DEEP DIVE

*Major renovations at the New England Aquarium in Boston and National Aquarium in Baltimore creatively illuminate the depths of ocean life for visitors, while being mindful of the habitat needs of the animals.*

text by Elizabeth Evitts Dickinson
photos by Kwesi Budu-Arthur/Cambridge Seven Associates

Flickr/Abigail Batchelder

**Decades ago,** Cambridge, Mass.–based Cambridge Seven Associates (C7A) revolutionized aquarium design. Starting with the New England Aquarium in Boston, built in 1969, the firm pioneered a new kind of immersive aquarium experience, one that eschewed small tanks and staid taxonomy that had been common in the past in favor of the massive, awe-inducing displays of live sea creatures that we've grown accustomed to since. Recently, C7A renovated two of these first-generation buildings—the New England Aquarium and 1981's National Aquarium in Baltimore, which they also designed. Where the original buildings had been trailblazers when it came to the presentation of marine life, these latest projects are a marvel in how to retrofit cutting-edge architecture and lighting design into existing spaces in order to transform the visitor experience.

"The thing that was originally groundbreaking in these two aquariums was that there were living animals and they relied on the idea that we would take you into a deep-sea dive," says Peter Kuttner, president of C7A. "The new trend [today] in aquariums is to bring the habitat out and to engage the visitor in the habitat even more. Rockwork is starting to leave the tanks and come out [in]to the visitor space. Advances in acrylic technology mean you can walk under a tank and see a shark swimming. It's that sense of immersion, that you're in there with the animals."

Lighting design is pivotal in creating that fantasy, of being underwater with the fish and other sea life. Establishing an atmosphere that mimics a deep-sea dive—capturing the coral, the fish, and the undulation of light and shadow—requires a complex lighting scheme that illuminates the subaqueous world while simultaneously fostering the health of the animals and the illusion of immersion for the general public. "This is as close to the experience of a deep-sea dive as you can get," Kuttner says.


# THE NEW ENGLAND AQUARIUM

The Giant Ocean Tank and Penguin Tray
Original building completed in 1969
Renovation completed in 2013

**In Boston,** C7A was tasked with renovating the New England Aquarium's Giant Ocean Tank, which is a replica of a Caribbean coral reef. When that four-story, 40-foot-diameter, 200,000 gallon tank was first conceived in the 1960s, the technology that existed dictated that the fixtures be set up to rim the perimeter at the top of the tank in order to create the desired effect of an underwater deep-sea dive. The lamps at the time simply weren't powerful enough to filter through the volume of salt water without being positioned directly above the surface.

One of the biggest gains for the New England Aquarium in renovating the tank now is the ability to reposition the luminaires above the water and into a dome, thus transforming the top of the tank from an industrial space with visible hardware into a public-friendly spot where visitors can stand and look down into the water (see above). "The Giant Ocean Tank is the heart of why this particular aquarium is as successful as it is," says Steven Imrich, principal of C7A. "Both the firm and the aquarium staff always felt that there could be an enhancement to the top of the tank where that environment could become a nice place for programs."

Figuring out how to retrofit a massive dome above the tank and into the center of the building—while keeping the aquarium open to visitors—required extensive planning, according to Matt Zelkowitz, principal of Salem, Mass.–based lighting design firm Available Light. First, there was the question of what lamp type to use. An important dictate from the aquarium


staff was that the exhibit should feel as real as possible by highlighting the colors of the coral and the fish, but that it also should prevent the growth of algae. "The first color test compared [400W] metal-halide to LED, and we came away convinced that LED was the right way to go," Zelkowitz says. "We did extensive mock-ups about color temperature and found that the warmer color temps [3000K] tended to promote algae growth. So we showed everyone spectrum charts for LEDs and we used a higher color temperature [of 5700K]."

Available Light mixed white LEDs with some green and some blue LEDs, in fixtures outfitted with narrow 10-degree spots and medium 20-degree spots with deep snoots to minimize glare, to add depth to the exhibit by piercing through the water and creating the effect of sunlight streaming in from above. The lighting designers also creatively washed the walls of the tank to give the illusion of an unending horizon, and with a DMX system gave the LEDs dynamic control so that the color temperature constantly shifts and animates the space, the way real sunlight would. The firm even added a timed program every half hour that makes it appear as though a cloud is passing overhead.

Another dictate from the aquarium was that the lighting hardware should be hidden, but easy to maintain. "We did a lot of sight line studies and sections to set the width of the dome, getting it so that the fixtures hang at just the right height and angle but don't protrude past the dome," Zelkowitz says. Walkways now allow maintenance staff to access the fixtures from above. The complexity of placing the luminaires and other infrastructure in the dome was like "making a Swiss watch," according to Imrich.

The color and finish of the dome also went through several iterations in the planning phase. The initial thought was that the dome should be highly reflective, with a mirrored surface to support reflections off the water. But after Available Light created mock-ups over water, it became clear that the mirroring effect didn't work — it just competed with the amount of light that was absorbed in the water. The final dome is a blue color with an eggshell finish that creates a similar effect, Imrich says, to the way the bottom of a bridge over a river gently reflects the light off of the water below.

Before finalizing the lighting design, Available Light ordered sample fixtures, set up theatrical pipe with boom bases around the perimeter of the tank, and performed an on-site mock-up. "They did some testing of the color temperature and the punch and the effects of the new lighting layout," Imrich says. "That mock-up was really valuable to everybody's level of comfort and how the light would be transformative."

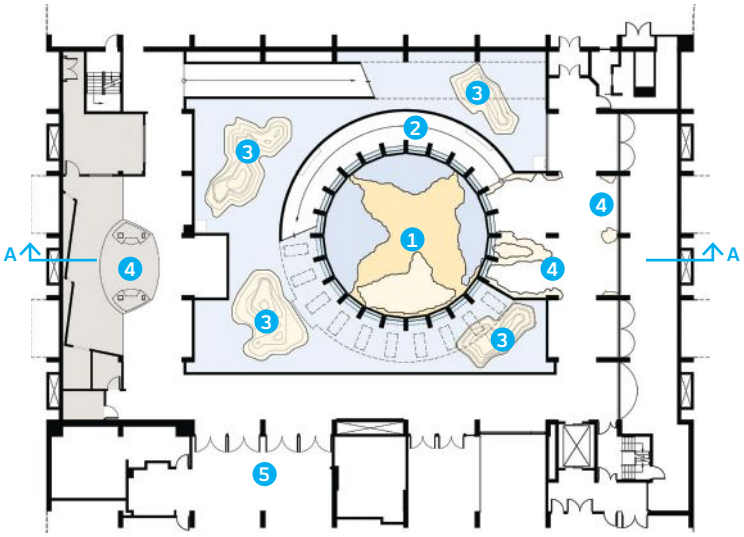
And, amazingly, that mock-up happened in just one evening, a fact owed to the timing and complex nature of this renovation. "We were literally taking the center part of the aquarium out, and the amount of logistics and coordination needed to get the old tank environment demolished and taken away, to get the animals out of the tank, was extraordinary," Imrich says. "If we had had our druthers, we would have prefabricated the dome off-site to be lowered into the building with a crane. But because we didn't have that luxury, we had to bring it in in pieces."

It wasn't just the top of the tank that saw a big change in lighting design. Available Light also had to renovate the penguin tray located at the base of the Giant Ocean Tank. In addition to replacing old halogen lighting with

The New England Aquarium, as seen from the exterior (opposite). From the top of the four-story Giant Ocean Tank looking down at the penguin tray below (this page).

A view of the Giant Ocean Tank and the penguin tray at its base (top). Along the perimeter walkway, overlooking the penguin tray, sharks species graphics are silhouetted and backlit with blue LEDs (this image). The Giant Ocean Tank, which houses 2,000 animals and 140 species, features 52 new viewing windows (opposite, top).

## Floor Plan

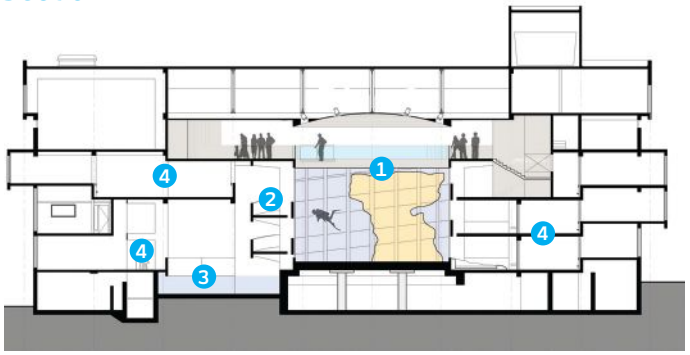



4000K LED fixtures—some with narrow spots (10-degree) and others with flood spots (40-degree)—the designers had to understand the biology of penguins.

"When we started, they gave us this big scientific paper on penguins and I read through it and learned that it wasn't just the amount of light, but the amount of time the penguins [were exposed to light]," Zelkowitz says. "The aquarium wanted to increase the light on the penguins, but what's critical to their health is the period of daylight. The aquarium has a very complex spreadsheet that shows how much daylight the penguins get each day. They had to balance that biological rhythm with the needs of visitors."

Last but not least, there were the requirements of the events staff, who needed to host parties after-hours. In the original design, there had only been one light level for the Giant Ocean Tank. Available Light developed a two-tiered solution, one in the penguin tray itself where the luminaires dim slowly over a 45-minute period when the penguins' day "ends" and the other, a dimmer, evening "event" setting for the Giant Ocean exhibit so that the light from the tank won't disturb the animals. Now that the exhibit has opened, the aquarium staff called to say that the changes are working. "The birds look great," Zelkowitz says. "We got a call that they just finished their first molt and are doing well."

## Section A




1. Giant Ocean Tank
2. Ramp
3. Penguin Tray
4. Exhibits
5. Entry

**Details** **Project:** The New England Aquarium Giant Ocean Tank Renovation, Boston • **Client/Owner:** The New England Aquarium, Boston • **Architect:** Cambridge Seven Associates, Cambridge, Mass. • **Lighting Designer:** Available Light, Salem, Mass. • **Structural Engineer:** Weidlinger Associates, New York • **M/E/P Engineer:** R.W. Sullivan Engineering, Boston • **Project Size:** 8,000 square feet • **Project Cost:** $17.8 million • **Lighting Cost:** $400,000 (for hardware) • **Code Compliance:** Fell under exhibit lighting category of IECC 2009 and was exempt • **Watts per Square Foot:** 2 (for exhibit lighting) • **Manufacturers/Applications:** **Acuity Brands/Winona** (steplights at new exhibit annex bridge) • **Acolyte LED** (LED tape at wave and shark wall displays) • **Interactive Technologies** (cueserver for DMX control) • **Lumenpulse** (LED luminaires at Giant Ocean Tank and penguin tray) • **Pathway Connectivity** (DMX networking) • **Philips Lightolier** (tracklighting at perimeter exhibit areas) • **Prolume** (illuminated handrails at annex bridge)

# THE NATIONAL AQUARIUM

Blacktip Reef Exhibit
Original building completed in 1981
Blacktip Reef exhibit renovation completed in 2013

**At the National Aquarium** in Baltimore, the exhibit displays move from the Caribbean to the Great Barrier Reef with the transformation of a massive, five-story space at the core of the museum's structure. The building has been open since 1981, so the existing tank was due for an overhaul. "We had an exhibit that was aging and we were having structural problems with the tank," says Jack Cover, the general curator at Baltimore's aquarium.

The aquarium decided this would be an ideal opportunity to replace the existing exhibit—which consisted primarily of stingrays, a few sharks, and a sea turtle—with a more dynamic and multifaceted display that took visitors into a replica of the Great Barrier Reef. "We decided to go with a re-creation of an Indo-Pacific reef, to feature the blacktip reef shark," Cover says. "We wanted to duplicate the reef with the apex predator but also with all of the smaller fish and the coral." Cover says that they also had the goal of making the water "gin clear" and as vibrant as possible, which meant investing in filtration and life-support systems for the marine life.

The existing fixtures and illumination presented a challenge. "The lighting was much more general and it washed out a lot of the features of the tank," says Adam Mitchell, partner with C7A. "A starting goal was to make the lighting much more dramatic and theatrical. The design mantra became: How do we get more surprise into what we're doing?"

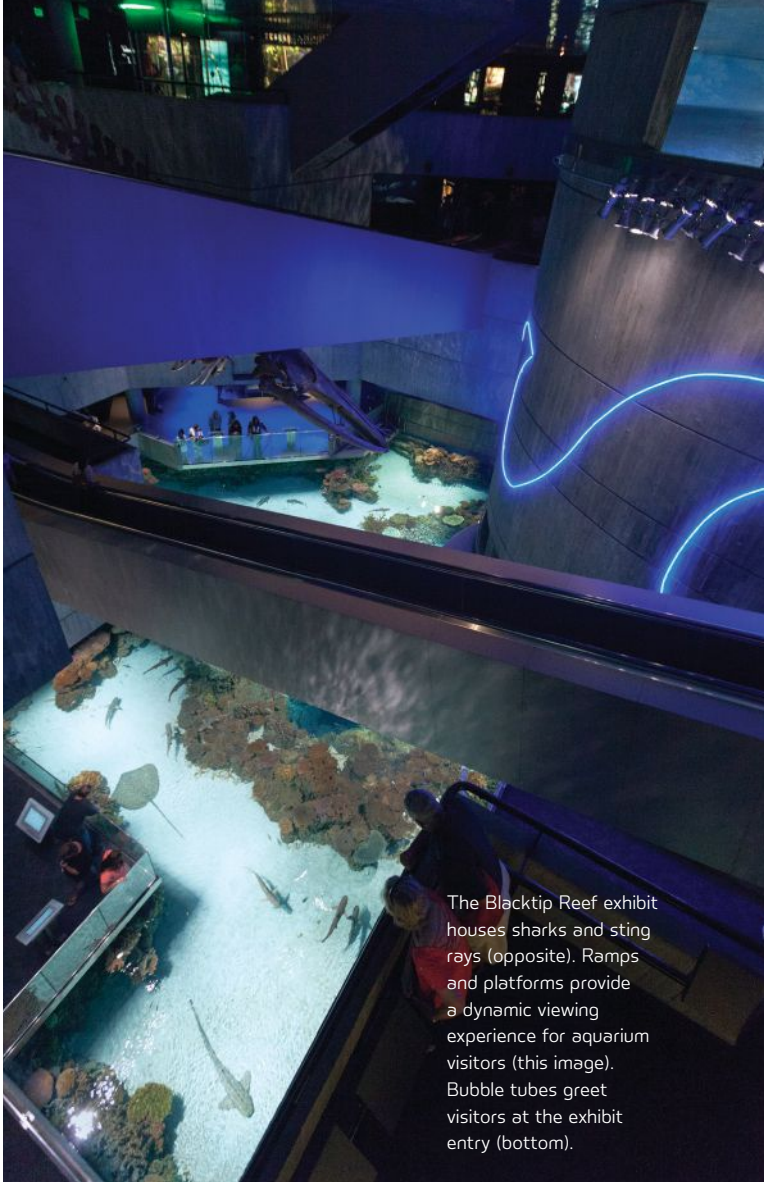
The architects turned to lighting designer Glenn Shrum, founder of Baltimore-based Flux Studio, to create that surprise. The experience for visitors now begins right off of the lobby, as guests come into a dim blue entryway with bubbling towers of water. This entryway leads to a soaring five-story space that is effectively an atrium at the heart of the building. Here, visitors are presented with a bird's-eye view of the tank, with the reef sharks and rays swimming in shallow water below. The path then winds up and over the reef, traveling through the aquarium's various exhibitions, before winding back down a platform that takes people down through the various depths of the sea. This means that guests experience the reef from multiple vantage points, creating a complex lighting plan.

"It's a five-story interior space, so it was always going to be a challenging experience to light," Shrum says. He and his team were limited by the existing conditions and the location options for the fixtures, so they "did a fair amount of color study."

One study looked at the angle of the light and the position of the fixtures as it related to the water's surface. The light needed to highlight the tank without bleeding into the public space and washing out the theatrical effect. "In terms of the light penetrating the water, the lighting angles were never more than 20 degrees off of vertical," Shrum says. "We did many studies on aiming angle, where we had access to the fixtures. In the end, there are more than 50 fixtures lighting the surface of the water, in six different locations throughout the five stories. Some are 10 feet above the water, some are 60 feet up." There were also several mock-ups done to check color, with the final choice being a cooler temperature—4000K—that simulated daylight at noon.

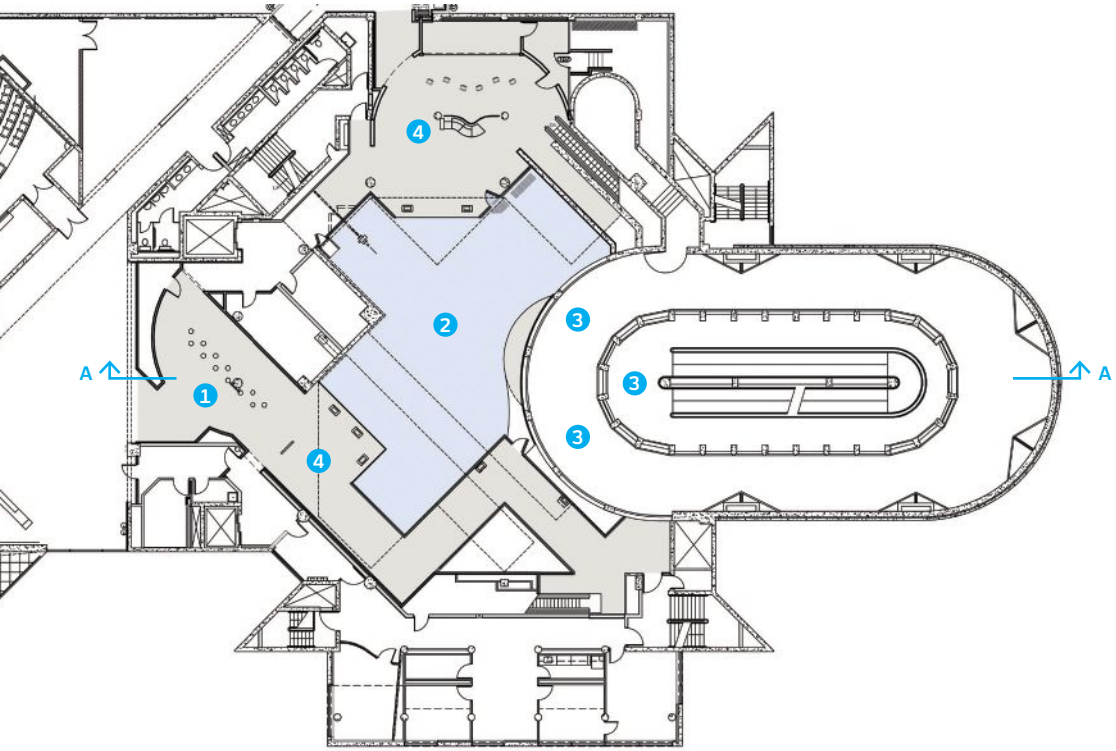
Another consideration that went into choosing the color temperature of the light was how the beam would pass through the water depth and make the exhibit elements ring true. The in-house exhibition team at the aquarium fabricated all of the coral in the tank and Shrum worked closely with them to finalize the paint colors in the habitat. "We did a smaller-scale mock-up to look at the color appearance of the coral and we looked at how the color rendering was changing as the water got deeper," Shrum says. "We found that the red spectrum (620–700 nm) was being absorbed more quickly than the blue (455–492 nm)."

This meant that in shallow water the coral looked fine, but at 12 feet it wasn't registering. In the end, the coral was painted incredibly vibrant hues. "Before the water went in, the habitat looked totally garish," Shrum says. "But once the water went in and the light was absorbed by the water depth, it looked natural. Sometimes there is only so much that you can



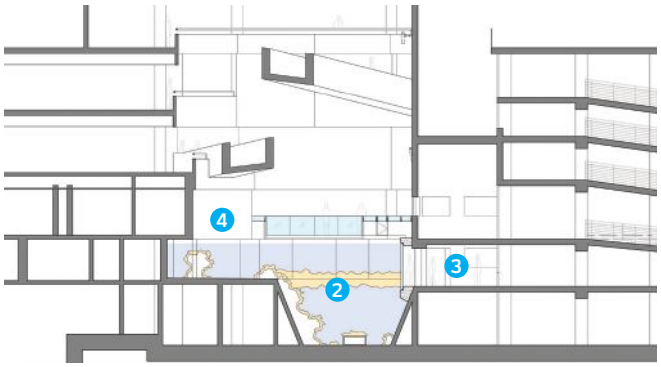
The Blacktip Reef exhibit houses sharks and sting rays (opposite). Ramps and platforms provide a dynamic viewing experience for aquarium visitors (this image). Bubble tubes greet visitors at the exhibit entry (bottom).

## Floor Plan




1. Blacktip Reef exhibit entry
2. Blacktip Reef exhibit tank
3. Underwater viewing area
4. Blacktip Reef exhibit

## Section A




do with the light, so you have to work with the pigment of the habitat."

To make the experience feel natural for visitors, Shrum also considered the lighting of the public space. "The design direction from the beginning was to support the spatial reading of this architectural space and one of the things that was quite successful was the introduction of shadows," he says. "By having the light be limited to the water, we have these caustic reflections of light all over the space that become incredibly theatrical."

C7A's Mitchell also says that Shrum's choice of a deep blue wayfinding light helps maintain that illusion of a deep-sea adventure. "The sense of immersion has been increased," he says.

The exhibit opened in August, and attracted more than 380,000 visitors in the first six months. Cover says it has been a major success: "The most common thing that I hear people say is, 'Wow.'" •

**Details** **Project:** Blacktip Reef Exhibit, The National Aquarium, Baltimore, Md. • **Client/Owner:** The National Aquarium, Baltimore, Md. • **Architect:** Cambridge Seven Associates, Cambridge, Mass. • **Lighting Designer:** Flux Studio, Baltimore, Md. • **Structural Engineer:** McLaren Engineering Group, Baltimore, Md. • **M/E/P Engineer:** Kovacs Whitney & Associates, Baltimore, Md. • **Additional Consultants (tank lighting):** Barbizon Lighting, Washington, D.C. • **Artist (acrylic entry feature):** Adam Nelson, Baltimore, Md. • **Project Size:** 13,500 square feet • **Project Cost:** $12.5 million • **Lighting Cost:** Not available • **Code Compliance:** ASHRAE 90.1-2010 • **Watts per Square Foot:** 1.1 • **Manufacturers/Applications:** **Cooper Lighting by Eaton/Iris** (P3LED fixture for exhibit graphics accent lighting) • **Dasal Architectural Lighting** (general lighting and emergency lighting) • **ETC** (Source Four HID Ellipsoidal Series with different beam spreads—14 degrees, 26 degrees, and zoom [25 to 50 degrees]—to light water surface) • **Insight Lighting** (backlit acrylic panels) • **Lighting Services Inc** (lighting for exhibit graphics and bench area at underwater viewing area) • **Lumenpulse** (Lumenfacade static white and static blue grazing fixtures at textured walls and 6500K Lumenbeam fixture at bubble tubes) • **Lutron** (existing building lighting control system) • **Philips** (75W and 150W MasterColor ceramic metal halide lamps for ETC fixtures) • **Rosco** (color filters for general lighting) • **Xicato** (LED modules for Lighting Services Inc fixtures and custom blue LED module for Dasal fixtures)

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# GEORGE BRAINARD

interview by Elizabeth Donoff
photo by Colin M. Lenton

"I've watched how lighting designers have gone from understanding that light might have clinical applications, like in winter depression or sleep disorders, to being something that's realistic for all architectural spaces. It's really these two different communities [design and medicine] that are at different stages of thinking about and grappling with the emergent evidence that light affects human health."

**While light** and its photobiological connection is a relatively new discussion in lighting design, it is by no means a new area of study. At the forefront of this research for the past 30 years has been George Brainard, Ph.D., a pioneer in the field based at Thomas Jefferson University in Philadelphia. Years of looking at circadian neuroendocrine and neurobehavioral responses to light in vertebrate species led to a watershed moment in 2001. That was when Brainard and his team published *Action Spectrum for Melatonin Regulation in Humans: Evidence for a Novel Circadian Photoreceptor*, in which the team of scientists probed deep into the physiology of the human eye, in an attempt to elucidate how it detects light and translates it into a hormonal response. This research led to the game-changing discovery the following year—by the Berson lab at Brown University and the Hattar lab at John Hopkins University—of intrinsically photosensitive ganglion cells in the eye, a development that moved a niche area into mainstream science, and altered the way designers think about light, people, and space.

**What fascinates you about light?**
As powerful and as useful as light is, it's shocking how little is known.

**What text has impacted your work?**
Kendric Smith's *The Science of Photobiology (Springer, 1989)*. It laid out the techniques, the technologies, [and] the thinking that you need to do for careful, controlled work like this. It [also] explains the numerous mistakes made by some investigators; there have been some pretty dramatic failures.

**When did the lighting community realize that light and its photobiological effects had an impact on their design work?**
It's a progression of key discoveries. One was the 1980 demonstration at the National Institutes of Health that showed light could suppress melatonin in healthy humans. In 2001, we published our paper *Action Spectrum*, which was quickly followed by the discovery of the photosensitive ganglion cells the next year.

**What is the most misunderstood aspect of the lighting research you are doing?**
We need evidence-based lighting in the design community, along with research validating architectural and lighting design applications as it relates to the basic health effects of light.

**What is the future of lighting research?**
There is much to be done, first in the area of fundamentals—what is the underlying biology? The second arena is applications. Evidence-based information must be developed. •

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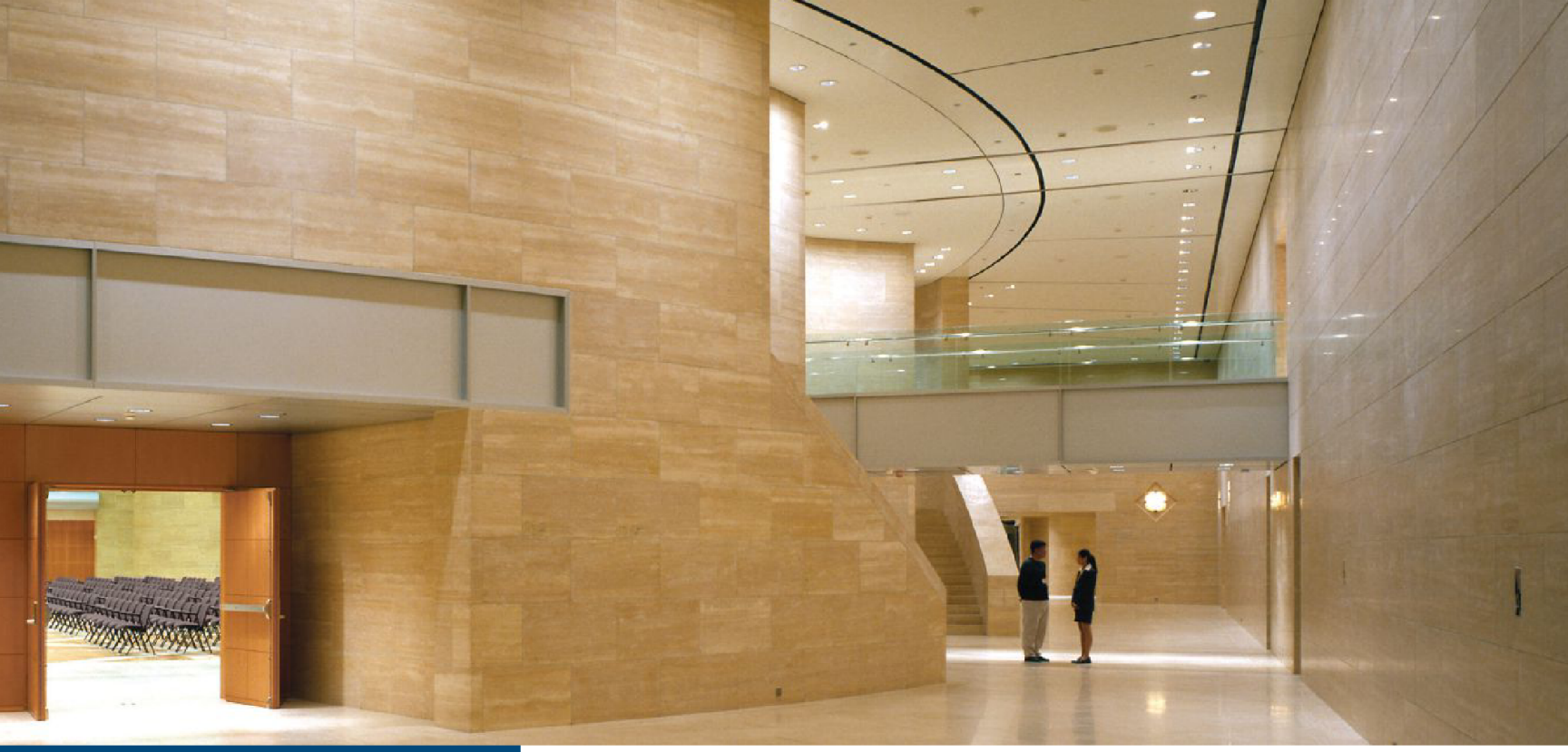

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