architectural lighting

Up Ahead: Hybrid Lighting

February 12, 2004

An emerging technology combining natural and electric light together in a single luminaire confronts conventional wisdom on daylighting design.

By Jeff Muhs

»**Lighting** designers and architects have long toiled over problems of glare, variability, heat gain, and architectural design and maintenance issues associated with various topside daylighting approaches. A research effort led by the Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee, may soon make the job a little easier. Analogous to hybrid electric vehicles that use both batteries and internal combustion engines to power cars, hybrid lighting employs roof-mounted collectors to concentrate sunlight into flexible optical fibers and carry it inside buildings to "hybrid" light fixtures that also contain electric lamps. As the two light sources work in tandem, control systems keep lighting levels constant by dimming the electric lights when sunlight is bright, and turning them up as the sky darkens with weather conditions or nightfall. Hybrid lighting is more energy efficient than traditional electric lighting systems and provides designers with unprecedented design flexibility and control over where and how sunlight is used inside a building.

A BRIEF HISTORY

In the early 1980s, researchers in Japan developed a precursor to hybrid lighting systems. However, at the time, tracking the sun accurately was difficult, expensive and unreliable. Light distribution losses in polymer optical fibers were high, and different portions of sunlight were attenuated more than others, making emerging light look different from natural sunlight. And on cloudy days and at night, there was no way to automatically adjust electric lights. Recent advances in microprocessors and control algorithms have made tracking the sun a relatively easy, inexpensive and reliable task. Light losses in low-cost polymer optical fibers have dropped by a factor of three, and dimmable electronic ballasts capable of automatically adjusting several types of electric lamps are now commonplace. With this ongoing progress in its components, hybrid lighting is an increasingly realizable goal.

Indeed, the first hybrid lighting system was finally unveiled on October 7, 2003, after three years of development, during a day-and-a-half-long summit for designers and energy conservation advocates. (The system is being used in a commercial building in Knoxville, Tennessee, as part of an alpha prototype test.) Seventy-five participants witnessed a fully functional hybrid lighting system in operation, examined a second-generation collector, and discussed hybrid lighting in breakout sessions related to research and development needs, feedback from lighting designers and architects, and hybrid-lighting-based green energy marketing and incentive programs.

The current prototype incorporates a sunlight collector, which consists of a 1-meter-square parabolic primary mirror that tracks the sun throughout the day. A segmented secondary mirror reflects the visible portion of the converging sunlight into eight large core (12.6 millimeters) optical fibers, while allowing the ultraviolet and infrared energy to pass out of the system.

The collector is mounted on a 4-inch pipe, through which the eight fibers are routed into the building. The amount of light transmitted through each fiber is in the range of 5,000 to 6,000 lumens during sunny periods. According to lab measurements, distributed sunlight is virtually indistinguishable from direct sunlight in terms of color temperature, color rendering index and spectral power distribution. In the initial prototype shown last October, light was routed to eight separate luminaires that are traditional 2-foot-by-4-foot light fixtures containing four lamps each. The fixtures were modified to accommodate 3M side-emitting acrylic diffusers located between the fluorescent lamps, which spatially distribute the sunlight into the room below, as the fluorescent lamps located in the same fixture would. Other luminaire options are under development both at the lab and by manufacturers that will insure compati-bility of hybrid lighting with sources including incandescent/halogen, LED and metal halide lamps.

As with any nascent technology, research is still necessary. The existing prototype is only about half the size of anticipated commercial units. By making the system larger, analyses predict more light can be collected and delivered at a lower overall cost per lumen. A larger commercial system is expected to illuminate, for example, about 1,000 square feet of floor space in a typical office building, compared to the 500 square feet the current prototype is capable of illuminating. Further, a second-generation collector and light distribution design is being tested that will allow for a more open "plug-and-play" design philosophy. In addition to being simpler to install, align and calibrate, it uses a new type of fiber optic bundle that reduces attenuation and color shift, while improving the flexibility of the fiber optic light distribution system. The redesign, which should be ready late summer 2004, is expected to produce a stand-alone hybrid lighting system that can be integrated with several different electric lamps of differing lumen outputs and used in a variety of applications.

ARGUMENTS FOR APPLICATION

Experiments show hybrid lighting is a viable option for lighting on the top two floors of most small commercial buildings. Even this early capability—sure to improve rapidly in the coming decade—is applicable to roughly two-thirds of the commercial floor space in the United States, meaning this technology has immense potential for impact.

For architects, lighting designers and building owners interested in incorporating natural light into their building designs, hybrid lighting presents many reasons for specification. Unlike daylighting systems such as roof monitors, this system does not restrict site orientation; and unlike skylight designs, roof penetrations are few and small, reducing winter heat loss, summer heat gain and the potential for leaks. Hybrid lighting is better adapted to buildings with relatively low ceilings and many interior walls. As ceiling heights decrease, more and smaller skylights are needed to evenly illuminate interior spaces. Likewise, walls block daylight, so at least one skylight and typically more are needed per room. In hybrid lighting systems, optical fibers route sunlight horizontally above walls to various rooms so one hybrid lighting system, with an associated 4-inch-roof penetration, can illuminate several offices simultaneously; and unlike skylights, fibers can be routed through walls to floors below.

Hybrid lighting systems are also more easily integrated with daylight harvesting control systems compared to other daylighting strategies. With windows, non-diffuse skylights and roof monitors, the changing location of sunlight during the day makes commissioning of daylight harvesting systems difficult. In hybrid lighting systems, sunlight and electric light emerge from the same fixture with the same distribution pattern regardless of sun position. The spatial constancy of the light emerging from hybrid luminaries takes much of the ambiguity out of positioning and calibrating photosensors used in daylight harvesting control systems.

The technology also means more flexible incorporation of full-spectrum sunlight: The light emerging from the optical fibers can be used for indirect lighting or downlighting applications, or tightly focused on a work surface in combination with small point-source lamps for task lighting. Skylights simply do not provide such flexibility. By moving the collector slightly "off-sun," distributed sunlight can be dimmed or shut off completely like electric lights, addressing occupant complaints about spatial variability, glare and over-illumination.

Certainly, hybrid lighting is not the only advanced daylighting solution that will be considered by designers of the future. In some buildings, other technologies such as light pipes and light wells may be more appropriate given the context of the architect or lighting consultant's overall design strategy. But research indicates a range of very viable and effective applications for this technology. Based on initial assessments by the Antares Group Engineers and Economists in Landover, Maryland, and the University of Wisconsin, Madison, as well as input from participants at the October 2003 summit, the first use of hybrid lighting is likely to be in high-end retail stores, where small, low-efficiency lamps are traditionally used to highlight products. Further, hybrid systems will likely be installed in the Sunbelt, where electricity prices during peak demand (typical store hours) are usually twice that of off-peak prices. In these markets, analyses project that once fully commercialized, hybrid lighting systems could have a payback period of under five years.

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