The decorative side of daylighting

Enhanced optical technologies allow designers to use daylight for visual effect

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Traditionally viewed as an energy saving technique, daylighting’s aesthetic qualities are becoming more prominent. Today’s more advanced systems have opened the door to decorative applications that were once only possible using electric light sources.

When daylight is artfully applied to an interior space, the result can be a dramatic expression of a building’s architecture. Light (especially daylighting systems) serve as form-giver to the building. Natural light and its dynamic characteristics can add an expressive quality to architectural form and interior design elements. Some of the most beautiful and interesting buildings in the public mind have an abundance of natural lighting integrated into the design.

A prime example of the use of daylight to drive the architectural expression of a building is shown in the National Renewable Energy Laboratory’s (NREL) Solar Energy Research Facility (SERF) in Golden, Colorado. The building’s sloping site required a south-facing primary façade. With the site’s unique orientation and sun exposure, a complex, stair-stepped daylighting solution was developed. The system needed to carefully control sunlight penetration and provide indirect daylight to large, open-plan office environments. The building occupants’ fields of view were improved by variations in glazing and design.

Building facades help control sun penetration into the building, while the horizontal roof planes reflect daylight up onto the interior ceiling planes of the building. The result is a beautifully articulated building, whose form was largely defined by the daylighting system.

Figures 1: The highly engineered daylighting system employing carefully tuned windows façade articulation of the NREL SERF building became the basis for architectural expression of the building’s exterior design, and as such, the daylighting system serves largely as the form-giver to this unique and beautiful building.”
TRADITIONAL APPROACHES A TRANSITION

Current design practice yields daylighting that fulfills only ambient daytime requirements, while electric lighting is required to provide additional decorative and or accent lighting effects. As a result, the full energy-saving potential of daylight as the dominant source of illumination is not fully realized.

Fortunately, daylighting technologies continue to evolve, opening new opportunities for the creative and effective use of daylight. Traditional daylighting design technologies such as windows, skylights and fenestration control elements (i.e., light shelves) have been enhanced to incorporate new optical design techniques; and high-tech, spectrally selective optical materials are now available that can change the daylighting landscape, by allowing a more robust use of daylight’s full potential.

Spectrally Selective Coatings for Windows and Skylights: The continued development and application of spectrally selective coatings to windows and skylights that have two or more glazing layers helps to decrease potential cooling loads associated with traditional daylighting glazing solutions. Low-emittance (low-e) coatings are microscopically thin, virtually invisible metal or metallic oxide layers that are deposited to an interior surface of a multiple-glazed window or skylight. Transparent to visible light, the low-e coating can be used to reflect infrared energy transfer through the fenestration system, thereby suppressing radiative heat flow to or from the building’s conditioned interior. Perimeter glazings can then be applied to larger areas while minimizing the effects on a building’s mechanical systems. The result can be a high-performance window or skylight with a high visible transmittance coupled with a low U-factor and low solar heat gain coefficient (SHGC), thereby opening new opportunities for creative daylight application and architectural expression.

Optical Light Shelf Technologies: The development of optical light shelf technologies allows daylight incident on a building’s glazed façade to be more effectively collected and redirected into a building’s interior. These light shelves provide more controlled and consistent ambient lighting over larger perimeter zones of a building during daytime hours than would be associated with just traditional vertical glazing (window wall) daylighting solutions. One such product consists of an array of small, horizontal optical elements placed adjacent to dedicated daylight-glazing elements within a building’s curtain wall framing system. The product’s louver slats use precise optical geometries and reflective surfaces to control and redirect incident daylight back onto the interior ceiling plane of the occupied, daylit space, providing controlled, indirect daylight to the building’s interior.

While these new technologies greatly enhance traditional daylighting solutions and significantly expand the opportunities to light buildings naturally, the complete displacement of all daytime electric lighting equipment has remained elusive. Daytime electric lighting equipment still has its place, for now.

MOVING BEYOND AMBIENT DAYLIGHTING

In addition to improved traditional daylighting technologies, new enhanced optical daylighting systems and categories of fenestration systems have radically changed how daylight can be applied to a building; these systems address traditional daylighting challenges and create new opportunities through optical innovation and control. They not only allow substantially more of a building’s floor plate to be daylit, including core areas of low-rise, multi-story buildings, but can do so without forcing a change in a building’s form.
Tubular Daylighting Devices: One significant new fenestration product category that is based upon new optical technologies is the Tubular Daylighting Device (TDD). The TDD is an advanced optical system that uses carefully engineered reflective and refractive optical components and technologies to radically change how daylight is collected, redirected and transported, and ultimately delivered and controlled within a building’s interior.

At the rooftop level, new optical daylighting collection techniques and materials allow for spectrally selective and angularly selective collection of the available daylight resource, effectively harvesting the desired wavelengths of light that humans need to see and function from specific regions of the sky vault. Super-reflective optical surfaces and tubing allow the harvested light to be efficiently redirected and transported over simple or highly complex pathways with ease and minimal loss.

DECORATIVE DAYLIGHT APPLICATIONS

The enhanced optical control afforded by the TDDs allows a daylighting designer to easily establish multiple layers of ambient, task, and decorative layers of daylight illumination within a space, creating balanced and visually interesting luminous environments without the need for electric lighting during daytime hours. In addition, this new type of optical daylighting allows various daylighting elements and daylight layers to be tuned (through design or control-based optical dimming) for visual effect. Contrast ratios between elements can be designed to remain constant while daylight intensity varies hourly or seasonally. This enhanced optical harvesting and control means daylight can be used in expressive applications, such as luminous walls and decorative chandeliers, as well as functional ones.

Luminous Walls: Brightly lit walls can visually extend an interior space, providing occupants with the impression that the space is more expansive than it may physically be. Applying optical TDD systems to create a dramatic, yet functional, luminous wall can provide occupants with both important visual and psychological connection to the outside, while also providing useful and comfortable illumination for the space. When effectively applied, the luminous wall can also balance luminance ratios within the occupied space and minimize the need for daytime electric lighting.

When optical TDD systems deliver daylight into the top of a glazed wall cavity, occupants benefit from the ever-changing color and intensity of daylight in spaces that may otherwise lack a connection to the outside environment. If desired, daylight delivery optics can be applied to create an ever-changing art installation, with subtle changes in light patterning (shade and shadows) across the luminous wall’s surface heralding changes in solar position, sky condition and even season.

This technique is demonstrated in the case of an interior classroom located on the ground floor of a multi-story building that is daylit on two sides using a simple daylit luminous wall, illustrated in the photo. In this design, the architect established a 21-in.-deep wall cavity behind the “finished” wall’s surface. The exposed wall’s surface consists of double-walled, semi-transparent, acrylic panels mounted to standard metal stud framing. Within the interior of the luminous wall volume, drywall finishes the top and back surfaces of the wall, and all non-translucent elements are finished with a highly reflective, bright white, diffuse paint. In all, seventeen 14-inch-diameter TDDs are used to evenly illuminate 60 linear feet of luminous wall. An electric, optical dimming control allows space occupants to modulate the brightness of the walls in unison, or individually, as desired. The result is a visually comfortable daylit environment that wouldn’t have had access to daylight in the past.
Figure 3: Tubular Daylighting Devices deliver controlled daylight to illuminate an interior, ground-floor space using a luminous wall. The luminous wall consists of a shallow, dry-walled cavity with a translucent glazed surface open to the daylit space. Controlled, optical dimming allows the brightness of each wall to be individually controlled by the occupants.

**Chandeliers and Pendants:** Another decorative application of daylight comes in the form of daylit chandeliers and decorative pendant fixtures. Luminous pendant light fixtures are a common decorative element that can be used to create visual drama in a space and to establish a visual focus; these elements draw occupants’ attention to a specific portion of a room such as a reception desk or lobby seating area. TDDs can be used to illuminate pendants and chandeliers from within. For example, at the REI retail store in Boulder, Colorado, decorative daylight pendants are used to provide dramatic luminous elements that punctuate the retail floor. These unique elements were created by appending custom translucent fabric structures to the bottom of traditional Tubular Daylighting Devices that are terminated just above the finished ceiling plane.

In other applications, a luminous daylight chandelier can be created by extending the TDD’s optical tubing below the normal ceiling plane, terminating within a decorative pendant diffuser assembly. If desired, the TDD’s optical tubing may remain exposed to create an industrial design element, or the outside of the optical tubing may be field-painted to suit the interior design requirements. Electric light sources may be included within the TDD optical system to provide supplemental nighttime illumination as well.

With imagination and the unique capabilities of these new optical daylighting technologies, the opportunities for the creative application of daylight to a building’s interior are limitless. Daylight can now easily be used to create dramatic decorative daylight pendants and chandeliers, interior luminous walls, wall-wash effects, daylight wall sconces and art applications, daylit fish tanks, and even daylit luminous niches.

Figure 4: Dramatic chandeliers and decorative pendant lighting fixtures are lit from within using Tubular Daylighting Devices. Supplemental electric light sources are integrated into the TDD assembly to illuminate the fixtures at night.

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Did you know?

The Heschong Mahone Group, supported by Southern California Edison, Pacific Gas and Electric and the Northwest Energy Efficiency Alliance, conducted a study of existing daylight-responsive lighting controls in sidelit buildings. The study covered 123 spaces in 49 different buildings mostly consisting of offices and classrooms. During the study, measurements were taken for two weeks. Each space included measurements of the controlled electric lighting’s current, the uncontrolled electric lighting’s current, and the vertical illuminance entering the window. Additional measurements were made of the illuminance level at the photosensor and on the critical task if possible. Through these measurements, the electric lighting savings for the actual, installed daylight control system was calculated by comparing the measured current to the total current during occupied periods.

An energy model of each space was then constructed in DOE-2.2 using eQUEST as the front end. The simulation used real weather data collected over the same two week period as the measurements. In this way, the electric lighting savings were calculated for an idealized, perfectly operating daylight control system. The ratio of measured savings to predicted savings, or Realized Savings Ratio (RSR), was then calculated for each space. An RSR = 0 means that the photocontrols are saving no energy, while an RSR = 1 means they are working as designed.

Of the spaces studied, 64, or a little over 50%, had controls that were either not functioning or achieving no savings. Of these systems, 35 controls were intentionally disabled by setting the sensor illuminance target too high, putting tape over the photosensor, or disconnecting the wire to the photosensor. Nine of the remaining systems had never worked or never been activated. However, older systems were found to save more energy than newer ones. Also, it was common that all of the spaces in a building with daylight controls were disabled together, instead of only in problematic spaces.

The daylighting control systems in the remaining spaces were achieving actual savings of roughly half of the predicted energy savings. This equated to a lighting energy savings of approximately 1.1 kWh/sq.foot-yr and a net peak demand reduction of approximately 0.6 W/sq.foot of photosensor controlled area. Higher levels of energy savings were correlated with more uniform daylighting and higher levels of daylight illuminance. These savings were often accomplished via windows on multiple facades, utilizing glazing with high visible transmittance, ensuring that the interior surfaces had high reflectances, and minimizing partition heights. Dimming controls had higher rates of functionality with only slightly less overall energy savings when compared to stepped systems. Further, the highest performing systems were in spaces with controlled zone depths no greater than 2 times the window head height.

The study concluded that two main factors were instrumental to successful daylighting control systems:

- Integrating the design of the architecture, lighting and controls design
- Educating the building occupants about the daylighting controls and operation