Featured Articles

Development of an LED Ceiling Light for Home Use

Keiichi Fujimori
Takeshi Hoshino
Yoshifumi Sekiguchi

*OVERVIEW: The percentage of energy consumption attributed to lighting is high, with approximately 13% of energy consumed by lighting in the case of residential consumers[*1], and approximately 21% in the case of office buildings and other such facilities[*2]. This has increased the demand for LED lighting due to its excellent energy-saving performance. Hitachi is developing products based on the fundamental concept of simultaneously achieving both brightness and energy-saving performance. Our FY2014 residential LED ceiling light includes a new easy viewing function, which provides a level of brightness preferred by older consumers. Also, by taking advantage of light-guiding technology, Hitachi has developed a new category of products that add new value to ceiling lights.*

INTRODUCTION

HITACHI is developing its residential light-emitting diode (LED) ceiling lights based the fundamental concept of simultaneously achieving both brightness and energy-saving performance. In FY2013, for the types of its products with their respective indicated largest room sizes from 13 m^2 to 23 m^2 room type, Hitachi achieved the maximum brightness stipulated by the Japan Lighting Manufacturers Association in its standard brightness ranges for fixtures based on room size, as well as excellent energy-saving performance with energy consumption efficacy ratings of 102 lm/W or higher. The performance offered by these products has been highly praised, and in FY2013 Hitachi received Chairman's Prizes, the Energy Conservation Center, Japan at the presentation of the 2013 Grand Prize for Excellence in Energy Efficiency and Conservation (in the product and business model category)[*3].

According to a survey conducted by Hitachi as part of the process of developing products for FY2014, both energy-saving performance and brightness are given priority when making a purchase. These results confirmed that the fundamental concept behind Hitachi's development efforts matches consumer needs. Furthermore, when the survey results were analyzed by age group, a new trend was discovered showing the older the respondent, the greater the emphasis the respondent placed on brightness (see Fig. 1).

It is for this reason that in addition to improvements in brightness and energy-saving performance, Hitachi has started developing the easy viewing function, which achieves the level of brightness preferred by older consumers.

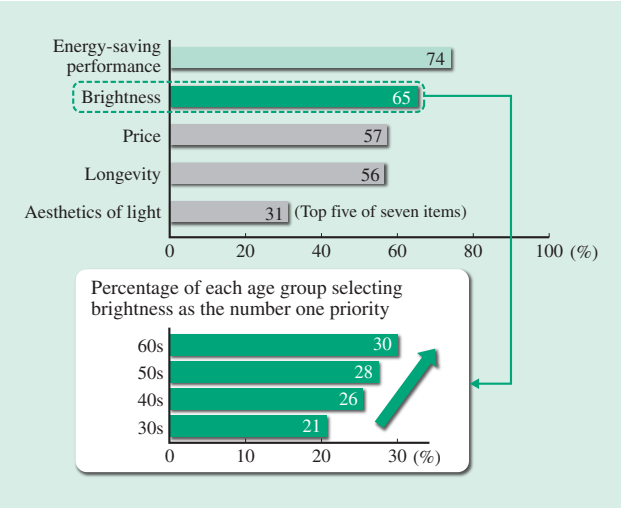

Fig. 1—Priorities in Selecting LED Ceiling Lights (Multiple Responses) (Research by Hitachi, March 2014: n=328). The older the consumer, the greater the emphasis placed on brightness during the selection of LED ceiling lights.

*1 From the Agency for Natural Resources and Energy's civilian sector energy consumption survey "Breakdown of Energy Consumption Amounts by Device in the Home" (FY2009) in Japanese.
*2 From the Energy Conservation Center, Japan's document "Energy Conservation in Office Buildings" (FY2009) in Japanese.
*3 Award-winning models: 22 models, including the LEC-AHS1410B LED ceiling light.

Fig. 2—Left: LED Ceiling Light (LEC-AHS1810CC), Right: Light Guiding Ring Type LED Ceiling Light (LEC-DHS1230C). The new easy viewing function has been adopted in order to achieve the level of brightness preferred by older consumers (left). A light different from those lights used in the past was developed through the use of the new light guiding technology called unique light guiding technology (right).

This article discusses the LEC-AHS1810CC, a residential LED ceiling light that uses this easy viewing technology (see the left photo of Fig. 2), as well as the LEC-DHS1230C, an light-guiding ring-type LED ceiling light that uses unique light guiding technology in order to provide sparkle illumination (see the right photo of Fig. 2), which differs from that offered by diffusion-type lights that use the traditional milky white cover.

A HIGH-INTENSITY ENERGY-SAVING LED CEILING LIGHT WITH EASY VIEWING FUNCTION

Developing Easy Viewing Function

On the assumption that brightness is given priority due to the need for easy viewing of objects and easy reading, in FY2014, Hitachi worked on developing technology targeting the components of light. In general, the ability of the pupils of the eyes to widen deteriorates as a person ages, and this necessitates brighter lighting. Another phenomenon that occurs is yellowing of the lens, which can make blue colors difficult to see[1]. This is why LEDs with the easy viewing function (see Fig. 3) not only shine at a higher brightness, equivalent to approximately 1.2 times the brightness of the full intensity setting when either daylight-color or light-bulb-color LEDs are used, but also emphasize energy-saving performance at full intensity while providing a stronger blue-green component in order to make up for the somewhat lack of intensity of that color in other bulbs. The result is a natural light that is closer to sunlight (see Fig. 4).

The resulting clear white light improves contrast so that fine print is easy to read, and causes the colors of photographs and other objects to appear more vivid.

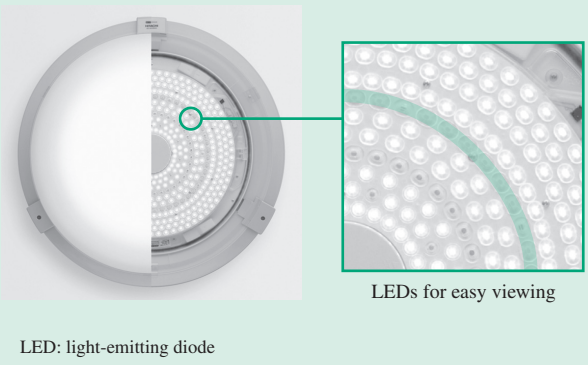

Fig. 3—Activation Image of LEDs for Easy Viewing
When the easy viewing button is pressed, the LEDs for easy viewing are activated and blue-green light is added to the mix.

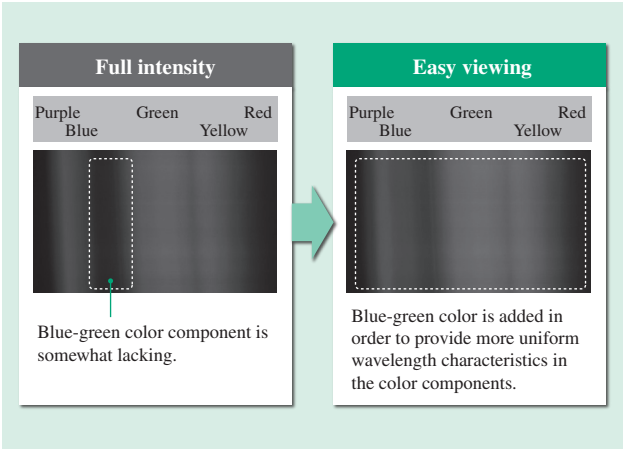

Fig. 4—Light Wavelength Component Comparison (Prism Spectroscopy).
The addition of the blue-green color makes the components uniform, resulting in a natural light that is close to sunlight.

Testing Easy Viewing Function

To test the easy viewing function from the two perspectives of visibility and ease of viewing, Hitachi enlisted 24 participants with ages ranging from the 30s to the 70s. The tests were carried out at full intensity in order to compare legibility of text, ease of differentiating between pale colors, and vividness of colors.

As a result of these tests, the effectiveness of the easy viewing function was demonstrated with approximately 79% of all participants reporting that the easy viewing function makes it easier to recognize colors and read text than the full intensity setting (based on testing performed by Hitachi in July 2014, n=24).

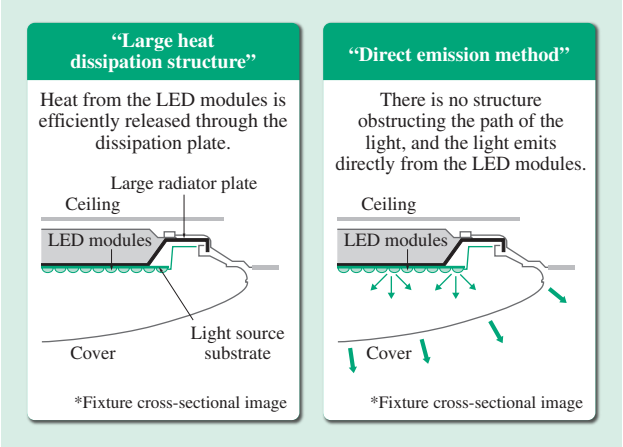

Fig. 5—"Large Heat Dissipation Structure" and "Direct Emission Method."
Hitachi has achieved both high light output and energy-saving performance at the same time.

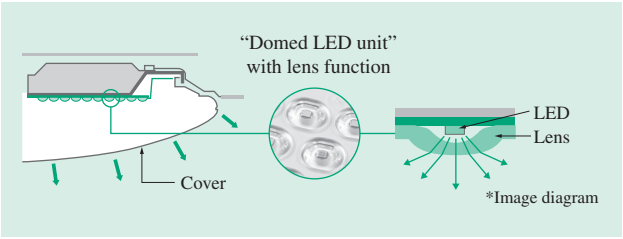

Fig. 6—"Domed LED Unit" with Lens Function.
Light output from the LED is efficiently diffused.

Providing High Light Intensity and Excellent Energy-Saving Performance at the Same Time

LED modules are characterized by a reduction in efficiency that occurs when the temperature rises due to the heat that is generated in conjunction with the emitted light. Also, direct light radiation is an effective means of reducing the loss of light emitted from the light source.

Hitachi therefore developed a "large heat dissipation structure" in order to efficiently release the heat generated by LED modules, and a "direct emission method" to directly emit light from the LED's light source through the cover (see Fig. 5).

In general, when a method is utilized where the light from a light source is radiated directly through a cover that has a low amount of light transmission loss, various issues may occur such as the light failing to spread out, the LED granules (LED modules) being visible, or only the area directly underneath the LED ceiling light being lit.

In response to these issues, Hitachi developed a "domed LED unit" with a unique lens function that covers each individual LED module, so that light efficiently covers a wide angle and the LED granules cannot be seen (see Fig. 6).

There are other issues surrounding the improvement of energy-saving performance, including the number of LEDs and positioning on the light source substrate. For instance, in the case of the brightest 30 m^2 room type model (defined by Hitachi)[*4], the number of LEDs was greatly increased over the previous product (LEC-AHS1810BC), and the amount of heat generated was reduced by running the LEDs at a lower power level. Furthermore, heat distribution was homogenized by evenly arranging the LED modules on the light source substrate. These measures successfully reduced the rise in temperature, thereby improving the LED luminance efficiency. In addition, the ratio of more efficient daylight-color LEDs was increased over light-bulb-color LEDs in order to improve energy-saving performance (see Table 1).

These technologies have enabled Hitachi to achieve a top-class luminance rating in the industry for an 30 m^2 room type model (defined by Hitachi) at 8,000 lm, and to achieve the maximum brightness in the brightness standard range for room size in the lineup, from the new 10 m^2 room type to the 23 m^2 room type model[*5] (see Fig. 7).

Furthermore, Hitachi achieved excellent energy-saving performance of 123 lm/W or higher for room size from 10 to 30 m^2. For instance, the 23 m^2 room type model consumes less than half the power of a

TABLE 1. Comparison of Previous and New 30 m^2 room type LED Ceiling Light Products
The number of LEDs was increased in order to improve luminance efficiency.

		Previous product (LEC-AHS1810BC)	New product (LEC-AHS1810CC)
Room size		30 m^2 room type model (Defined by Hitachi)	30 m^2 room type model (Defined by Hitachi)
Total flux		7,290 lm	8,000 lm
Power consumption		86 W	63.6 W
Fluorescent luminaire efficacy rating		84.8 lm/W	125.8 lm/W
Number of LEDs	Daylight-color	160	275
	Light-bulb-color	160	141
	(Blue-green color)	–	(41)
	Total	320	416 (457)

*4 Hitachi independently defined the standard for the 30 m^2 room type models.
*5 "Residential catalog applicable room size standards" (guide 121: 2011) established by the Japan Lighting Manufacturers Association.

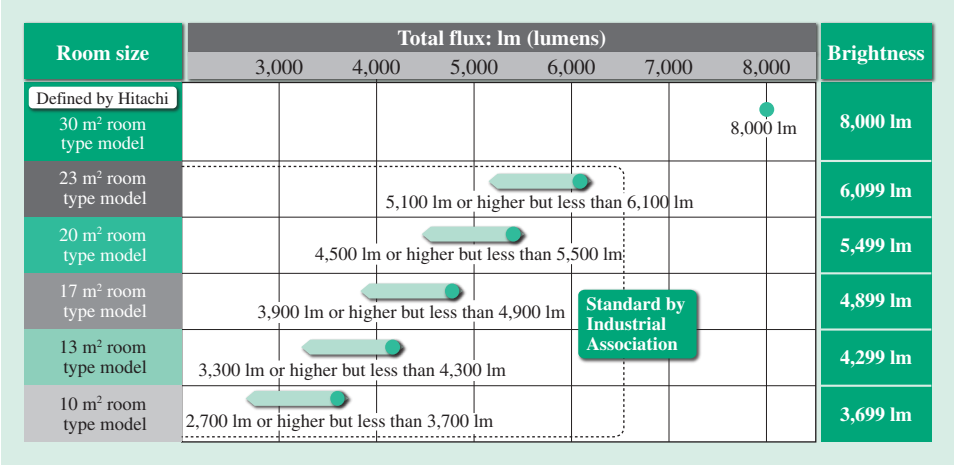

Fig. 7—Brightness Standard Range by Room Size and Total Flux Value from 10 to 30 m² Room Type.
Hitachi achieved maximum brightness within the brightness standard ranges (dotted lines) for room size according to the Japan Lighting Manufacturers Association.

high-efficiency fluorescent lamp, and even reduces power consumption by approximately 14% when compared to the LEC-AHS1410B model, which was awarded the Grand Prize for Excellence in Energy Efficiency and Conservation in FY2013 (see Fig. 8).

DEVELOPMENT OF THE INNOVATIVE LIGHT GUIDING TYPE LED CEILING LIGHT

The innovative new light guiding type LED ceiling light developed by Hitachi marks a clear departure from previous lighting fixtures, and it features a new type of shining illumination that spreads light throughout the room, a high-quality design, and easy viewing technology.

Unique Light Guiding Technology

Unique light guiding technology was newly developed, and is characterized by a transparent cover to which light is guided from LEDs arranged along the periphery of the fixture, and by light guiding rings on the surface that efficiently emits the light while controlling light distribution at the same time. Using this light emission principle, light is spread out and a "sparkling" shine is achieved.

The light guiding ring gap is narrow in the middle and wider toward the periphery so that the transparent cover is uniformly bright from the center to the periphery (see Fig. 9).

The sparkle of the light is achieved by varying level of luminance in the part where the light guiding rings is located on the cover surface and in the other transparent parts. The spreading of light through the room from the ceiling light is achieved by optimizing the output luminance characteristics of the light guiding rings. A sufficient amount of extracted light is directed towards the floor, but light is also emitted in the directions of the walls, so that all of this light can be used together to brighten the entire room (see Fig. 10).

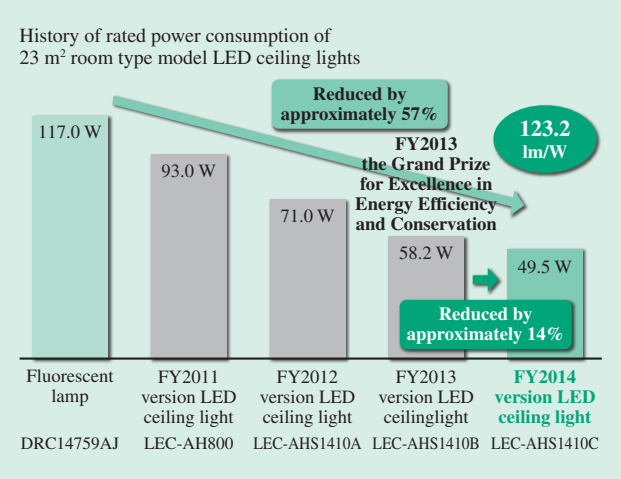

Fig. 8—History of 23 m² Room Type Model LED Ceiling Light Energy-saving Performance.
Power consumption of less than half has been achieved compared to high-efficiency fluorescent lamp.

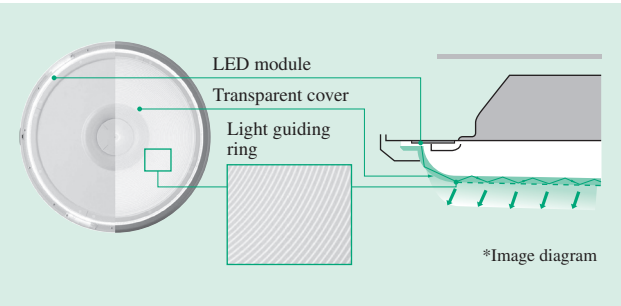

Fig. 9—Unique Light Guiding Technology Structure and Light with "Sparkle."
The light guiding ring spreads out the light in order to achieve light with "sparkle."

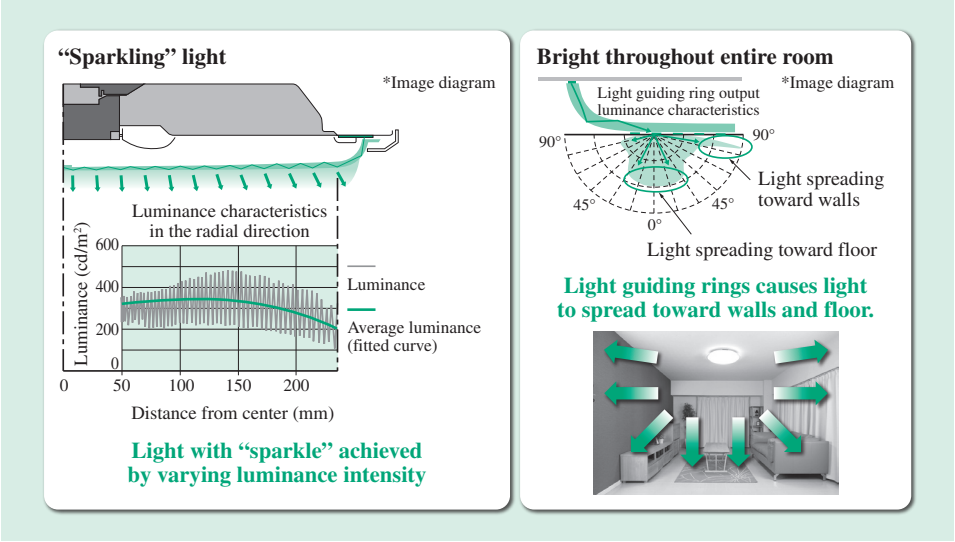

Fig. 10—Unique Light Guiding Technology Characteristics. This technology brightens the entire room by emitting light toward both the floor and the walls.

To improve the energy-saving performance of this kind of mechanism, the LED light that passes through the cover via the light guide path must be extracted uniformly.

In the case of a general light guiding plate, which scatters particles, the concentration of scattering particles included in the plate must be high in order to extract sufficient light. When the concentration of scattering particles is high, however, a large amount of light is emitted near the LED, and the luminance drops off farther away from the LED, making uniform light emission impossible. On the other hand, when light is extracted using reflection, it is necessary to place the light extraction portion on the inside of the light guiding rings, so the light reflects off the surface after reflecting off the light extraction portion first, resulting in a greater loss.

The unique light guiding technology developed by Hitachi controls the arrangement of the transparent cover and the light extraction structure (light guiding rings) of the surface in order to efficiently extract uniform light. Also, the light extraction structure that is used is based on the surface's transmitting material, and since the light diffuses while transmitting through the light guiding rings, it can be output efficiently with less light returning (see Fig. 11).

This system has enabled Hitachi to achieve an industry-leading 90.7 lm/W by its light guiding method, a rated luminous flux of 5,499 lm, and a maximized brightness (20 m^2 room type).

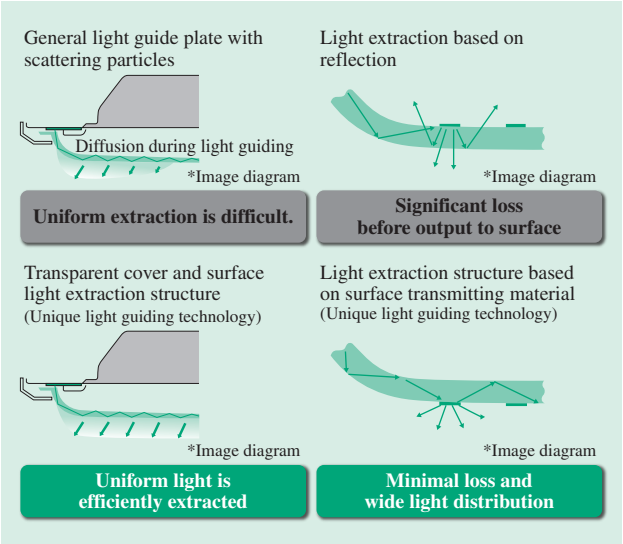

Fig. 11—Differences in Efficiencies of Structures Extracting Light.
Unique light guiding technology efficiently extracts uniform light while reducing loss.

High-quality Design

Unique light guiding technology makes the milky white cover that has been used to diffuse light in previous LED ceiling light models no longer necessary. This technology achieves a slim-design fixture height of 72 mm that accentuates the ceiling

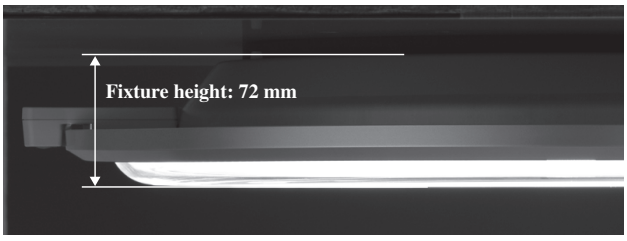

Fig. 12—Slim Design.
A slim fixture design with a height of 72 mm has been achieved.

while making the room appear more spacious (see Fig. 12).

CONCLUSIONS

Expectations for LED lighting with its excellent energy-saving performance will only grow stronger in the future. To provide lighting that can earn the support of consumers based on this background, issues that must be given consideration in addition to energy-saving performance include lighting quality and how objects and colors appear, shape and mass considerations in the design of a slim and lightweight product, and a construction that makes both installation and removal easy to perform.

We will continue mobilizing the technologies of the Hitachi Group and applying them to the rapid development of LED lighting products that satisfy consumers, while contributing to society through our lighting business.

REFERENCE

(1) The Illuminating Engineering Institute of Japan, "Fundamental Considerations Regarding Lighting Environments and the Visual Characteristics of the Elderly," (1999) in Japanese.

ABOUT THE AUTHORS

Keiichi Fujimori
Design Department V, Taga Home Appliance Works, Home Appliance Group, Hitachi Appliances, Inc. He is currently engaged in the design and development of LED lighting products.

Takeshi Hoshino
Eco & Lighting Products Planning Department, Products Planning Division, Hitachi Appliances, Inc. He is currently engaged in the planning of lighting products.

Yoshifumi Sekiguchi
Advanced Materials Research Department, Hitachi Research Laboratory, Hitachi, Ltd. He is currently engaged in the research and development of LED lighting products.