Splitting up anidolic daylighting systems

Friedrich Linhart, Stephen K. Wittkopf, and Jean-Louis Scartezzini

A computer model can help determine where to use highly reflective coatings in natural-lighting systems, thus increasing their overall efficiency.

Sunshine outdoors often exceeds the required workplace illuminance inside office buildings by several orders of magnitude. If sufficient daylight flux can be made available indoors without disturbing the occupants (for example, through glare), the building's artificial-lighting load can be drastically reduced, saving large amounts of electricity.¹ Increasing the availability of sunlight in buildings is not only highly desirable for energy-efficiency reasons, but also for improvements in health and well-being.²

Anidolic daylighting systems (ADS), typically a facade-integrated collector system with an adjacent horizontal-mirror light duct inside the building, are particularly interesting because they perform well in both sunny and overcast sky conditions.^{1,3,4} However, so far ADS exist mainly as prototypes. To make these systems viable for large-scale building integration, researchers must look closely at the parameters that influence performance to find appropriate solutions for most buildings. We recently developed a new computer model that makes it possible to analyze the effects of different coating materials applied to elements of an anidolic integrated ceiling (AIC).

The AIC, first introduced in 1998,⁵ is shown in Figure 1. A zenithal collector covered by double glazing captures daylight from the sun and a sky vault. Two anidolic elements then redirect the daylight flux into a highly reflective, 5m-long duct, which conducts it to the distributor element. The latter then distributes the light into the office room. G. Courret's team calculated an overall system efficiency of 32% (ratio of the light flux emerging at the distributor exit to the incoming flux at the collector entry).⁵

In the past, all simulations carried out for this system^{4,5} used a basic computer model that analyzed the entire AIC as one piece. Researchers assigned a global specular reflectance of 90% to the

Figure 1. Office room equipped with an anidolic integrated ceiling composed of two anidolic collector elements, a light duct and a distributor element.

entire AIC. Within the framework of the design of a zero-energy building in Singapore, we optimized this basic computer model and carried out various simulations for local sky conditions using the software tool Photopia.⁶ One of the advantages of this new model is that the AIC has been split up into different components. In theory, we can now assign a different coating material to each of these elements. This opens myriad new simulation options and is an important step towards development of customized ADS.

Our computer model enables us to look deeply into the three main components: collector, duct, and distributor. Figure 2 shows the distinct parts into which the zenithal collector can be split up. We save each of these components on a separate layer in an AutoCAD file and subsequently import them into Photopia as a luminaire. Photopia recognizes the different layers and allows us to assign a separate material to each one.

Figure 3 shows the simulation's predicted efficiency improvements when only one collector element is coated with a highly reflective silver-dot coating (98% specular reflectance) and all other AIC elements use the initial aluminum coating (90% specular reflectance). For simulated Singapore sky conditions, using

Continued on next page

Figure 2. Anidolic collector elements implemented in our model.

Figure 3. Efficiency improvement when only one collector element is coated with a highly reflective silver-dot coating.

this highly reflective coating makes the most sense on ‘Anidolic element 1,’ the main component of the zenithal collector (or ‘Sunscoop’).

Our computer model can be helpful in the design process of specific office buildings. It enables us to find optimized solutions for many different building types, orientations, and geographical locations. In the future, we will adapt our model to different building constraints and perform detailed assessment of lighting conditions in ADS-equipped office rooms.

Many thanks to Mark Jongewaard at LTI (Lighting Technologies Inc.) Optics for his help with the software tool Photopia 3.0.

Author Information

Friedrich Linhart and Jean-Louis Scartezzini

LESO-PB

EPFL

Lausanne, Switzerland

Friedrich Linhart is a PhD candidate working on energy-efficient lighting solutions. He holds degrees from the University of Technology in Darmstadt (electrical engineering and information technology) and the École Centrale de Lyon, France (general engineering science). Friedrich worked as an intern for ABB, Bosch, and A. T. Kearney before joining LESO-PB in June 2006.

Professor Jean-Louis Scartezzini heads LESO-PB and the doctoral program in environment. He is the author of more than 200 scientific publications, a member of several federal commissions and international experts groups, and associate editor of several scientific journals.

Stephen K. Wittkopf

Solar Energy Research Institute of Singapore (SERIS)

National University of Singapore (NUS)

Singapore, Singapore

and

Solar Energy and Building Physics Laboratory (LESO-PB)

Swiss Federal Institute of Technology in Lausanne (EPFL)

Lausanne, Switzerland

Associate professor Stephen Wittkopf earned his doctoral degree from the University of Technology in Darmstadt, Germany, in 2001. He then joined NUS to teach and research in the Architecture Department. In 2008 he took on a joint appointment with the newly established SERIS. His interest is in sustainable architecture with a focus on solar energy, promoting advanced daylighting, and building integrated photovoltaics.

References

1. F. Linhart and J.-L. Scartezzini, *Minimizing lighting power density in office rooms equipped with anidolic daylighting systems*, *Sol. Energy*, in press. doi:10.1016/j.solener.2009.05.001
2. F. Linhart, J.-L. Scartezzini, and M. Münch, *Ocular daylight exposure in office rooms equipped with anidolic daylighting systems*. *Proc. Int'l Conf. Sol. Energy Build. (CISBAT)*, Lausanne, Switzerland, 2–3 September 2009.

Continued on next page

3. F. Linhart and J.-L. Scartezzini, *Occupant satisfaction in office rooms equipped with anidolic daylighting systems*, **Int'l Conf. Sol. Heating Cooling Build. (EUROSUN)**, pp. 355–362, 2008.
4. S. K. Wittkopf, *Daylight performance of anidolic ceiling under different sky conditions*, **Sol. Energy** **81**, pp. 151–161, 2006.
5. G. Courret, J.-L. Scartezzini, D. Francioli, and J.-J. Meyer, *Design and assessment of an anidolic light-duct*, **Energy Build.** **28**, pp. 79–99, 1998. doi:10.1016/S0378-7788(97)00066-2
6. <http://www.ltioptics.com/Photopia/overview.html> Lighting Technologies Inc. Photopia website. Accessed 20 July 2009.