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Optimized design of daylight redirection microstructures combined with planar micro structured light sources for high efficient room lighting integrated in building façades

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Abstract

In the course of claiming more energy efficient buildings it is necessary to reduce the amount of artificial lighting. With the aim of realizing a very thin system integrated into building façades microstructures for the redirection of daylight are developed. In order to achieve sufficient room lighting at night or other situations of less sunshine, this daylighting system is coupled to a system for artificial lighting consisting of a microstructured light guide plate. This system transforms LED point light sources to a planar light source, which lights the room ceiling. The micro structures, its functionality and application are explained.

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Keywords: daylight redirection; light guide; microstructure; LED light; façade

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1. Introduction

Increased awareness of climate change has come with the realization, that creating new ways to greatly reduce CO_2 emission has become a very important issue. In this context, cutting back on energy consumption of buildings plays a vital part in the effort to decelerate global warming. [1] Every part of a building needs to be optimized in regard to energy efficiency. The following gives a presentation of a solution that aims to reduce energy consumption of buildings in the matter of lighting.

Today energy efficient light emitting diodes (LED) are the preferred light source. But even LEDs consume energy and have a significant negative impact on the environment. [2] Therefore it is highly desirable to reduce the amount of artificial lighting in general and to utilize daylight instead as a means to light the interior of buildings. Because of it being the interface to the environment (and therefore to daylight) the building envelope is the relevant part in our research.

Using conventional windows to open the building towards daylight poses three major problems regarding lighting. The first problem being that most of the daylight only reaches the part of a room nearest to the window, barely lightening the back of the room. Intense glare, caused by direct sunlight during certain altitudes of the sun is another problem. And third, the intensity of daylight fluctuates and is not constant over the whole day. Different systems and technologies exist to handle these problems. Shading systems like louvers or electrochromatic glass merely block out daylight in order to reduce the need of cooling the inside of a room and to reduce disruption by glare. Other systems work by redirecting daylight deeper into the room, also reducing glare this way. An insightful overview of established technologies is given by Ruck et al. [3].

In this paper we present a system based on the Invention of Klammt et al. [4], which uses the effect of total internal reflection on surfaces of micro structures to redirect daylight in an efficient way. A further notable research is done by Kostro et al. [5], who uses micro mirrors to redirect daylight. By only using the effect of total internal reflection we focus on a passive system that can be easily produced and at reasonable cost. The Invention of Kostro et al. however is more complicated in production and requires more components.

In order to solve the third problem mentioned, the fluctuation or absence of daylight, the redirecting system is complemented by a micro structured light guide plate (LGP) with newly designed structures similar to those used for backlight modules in LED-displays. [6,7] LED light is coupled into the LGP and directed into the room in a defined direction.

As the daylight redirecting system has to be placed into the window it would be an effective solution to integrate the LGP into the window as well. Because we have already presented this idea [8], this article will only give a short summary of this concept and focus on the developed microstructures and its application.

2. Redirecting the daylight

For the redirection of daylight microstructure lines are placed on the front and back of a 2-mm thick acrylic plate, which can be placed in the upper region of a triple glazing window replacing the middle pane. To guide the daylight to the room ceiling the structures are optimized in size and geometry using optical raytracing simulations and experience from previous research on daylight redirection structures. Figure 1 shows the idea and a cross-sectional view of the developed microstructures. Lens-like structures are placed at the outer side of the system. They spread the incident light rays by focusing them inside the acrylic plate. This is important to avoid interference patterns and the need to align the two sides in height. The widened light beam then hits the prisms on the room side of the plate, where the rays are reflected by total internal reflection towards the ceiling. The draft depicting a side view of the lens-like structure is a decentered cut off from a circle of a 300 µm radius. The structure is 60 µm high and 89.33 µm wide. The prisms placed on the opposite side of the plate have a height of 63.79 µm and a width of 44.67 µm. Figure 2 represents an example of light rays with an altitude of 35° passing through the daylight redirecting system from right to left.