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# High acceptance angle optical fiber based daylighting system using two-stage reflective non-imaging dish concentrator

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**Abstract**

It has been observed that lighting systems consume a significant amount of energy in high-rise buildings even during the daytime. To save power consumption and improve indoor environments, daylighting can be implemented for the interior of buildings by guiding sunlight via optical fibers. In this paper, we propose a new two-stage reflective non-imaging dish concentrator (NIDC) consisted of reflective primary and secondary mirrors that focus sunlight onto high acceptance angle optical fibers located at the target of the concentrator. The optical fibers can guide the concentrated sunlight into the interior area of the building. The new concentrating type of daylighting system was designed, fabricated and evaluated. Under normal sunny day condition with solar irradiance of 1000 W/m$^2$, the calculated average illuminance for our prototype daylighting system with a reflective area of 0.2 m$^2$ is 647.94 lux to illuminate an office area of 6.3 m$^2$, which is also equivalent to illuminate a bigger area of 8.164 m$^2$ based on standard average illumination of 500 lux.


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*Keywords:* daylighting; solar concentrator; raytracing; optical fiber; illuminance; NIDC

## 1. Introduction

Daylight building is estimated to reduce lighting energy consumption by 50–80% [1]. Direct use of sunlight is environmental friendly, cheaper and a greener way to produce daylighting inside a building than indirectly through electricity from non-renewable sources. Moreover, direct use of sunlight for daylighting is more efficient than converting light energy to electrical energy and back to light energy as this process involves a lot of losses during power conversion. Green building status by daylighting can be achieved with several methods but it is more effective and pollution free to guide the sunlight through the optical fibers and into the building.

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Studies in the past have revealed that various kinds of conventional concentrators such as Fresnel lens, heliostat, parabolic concentrator, compound parabolic concentrator, etc. have been employed for daylighting and have been tested for coupling with optical fibers to guide the sunlight [2-7]. Most of these concentrators are expensive, having low acceptance angle, or producing non-uniform concentrated sunlight. Non-imaging dish concentrator (NIDC) has been previously used for concentrator photovoltaic system [8-18]. The newly proposed active daylighting system consists of a non-imaging dish concentrator, which can have a low rim angle with respect to the selected optical fiber with a high acceptance angle as compared to conventional solar concentrators; can produce high solar concentration ratio with reasonably uniform illumination on the receiver. The new design is proposed to have two stages reflection, in which flat primary reflectors (mirrors) are designed to face the sun and secondary reflectors (mirrors) are located above but facing the primary mirrors so as to reflect the sunlight to the optical fiber aperture located at the center of the primary mirror arrangement.

The main aim of this proposed daylighting system design using solar concentrator, optical fiber and dual-axis solar tracker is to have the lowest possible cost compared to the existing ones and highest possible efficiency. More so, dual-axis solar tracking system can maximize the intensity of the sunlight input and provide constant intensity of the sunlight in order to have uniform distribution of solar flux.

## 2. Solar concentrator design

The proposed solar concentrator was designed based on the concept of the Cassegrain reflector that is widely used in reflecting telescopes. It is a combination of a primary concave mirror and a secondary convex mirror [19]. The incident ray strikes on the primary reflector and is reflected to the secondary reflector which reflects the rays to the target or focus. For the proposed design, concave and convex (parabolic) mirrors were found to be very expensive. Therefore, square flat mirrors to be tilted were used as primary and secondary reflectors while the target is a bundle of plastic optical fibers (POF).

### *2.1 2D Optical Ray-tracing*

A readily available powerful, Java-based virtual optical bench called OpticalRay Tracer was used to verify the optical design of our system. Ray-tracing was performed in 2D from the primary mirror to the secondary mirror and then to the optical fiber. This was done mainly to get the required dimension for the secondary mirror as the dimension of each primary mirror was set to be 5 cm × 5 cm with a thickness of 0.2 cm. Each set consisted of four primary mirrors for easy adjustment with a distance of 0.5 cm from each other, which are all supposed to reflect to one secondary mirror located 60 cm above the primary mirror and finally reflects the light rays to the optical fiber. The total dimension of one set (4 mirrors) of primary mirrors is 10.5 cm × 10.5 cm. Since OpticalRay Tracer does ray-tracing in 2D, only two primary mirrors in a set of the four mirrors can be simulated. Two sets of reflections were simulated and the estimated size of the secondary mirror for all reflected rays to fit in was found to be 8 cm × 8 cm.