"Sollektor" – Transporting Daylight with POF

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Abstract:
Using daylight for direct illumination has been a subject of high priority for R&D activities over the last years. A first demonstrating system implementing ideas presented at last year´s POF conference has been built up and tested.

Background & motivation

Using daylight for direct illumination even when available since 1986 [Him 86] has been a subject of high priority for R&D activities over the last years. Several international projects have been finished, none of them leading to a commercially available product. Independent from these projects, at least two products have become commercially available in the meantime in the USA [HSL 08] and in Europe [Par 07]. At last year´s POF conference in Turin we presented our approach for collecting and guiding direct solar light [Poi 07], the most characteristic items being:

- Modular construction to become less expensive and to be flexible in size and shape
- Flat to be mounted on tilted roofs (typical for Europe, not necessary for sun-belt countries)
- Simple mechanics and injection moulded optics
- Hybrid approach for light transport, i.e. fibers + rigid tubes
- Implementing new approaches from concentrating photovoltaics (CPV)

The target of our activities is to develop a system which provides natural light without the heat that normally comes with, thus saving energy in two ways: one part through efficient light generation, the second part by avoiding unnecessary air conditioning.

Principle of the current approach

The daylighting system consists essentially of three parts:

- solar light collecting and coupling sub-system
- transmission line
- light distribution, illumination unit or luminaire

In this paper we concentrate on the collecting system mainly. A key component is the coupling optics using a pin like device (Fig.1) we called "solar pin", the first generation with an elliptical surface refracting the light to a 1 mm diam. standard POF with a numerical aperture of 0.5. In this first step we restricted ourselves to a concentration ratio of 280 to allow for acceptable alignment tolerances. We preferred the pin approach to a (Fresnel-) lens approach because we could fix the fiber in the same component. In addition the next generation is planned to combine refection AND reflection to allow for higher concentration ratios combined with less critical alignment tolerances.
Each solar pin has a collecting area of 15 mm x 15 mm. The fibers are fixed in a "blind hole" at the lower end with a simple crimping technique.

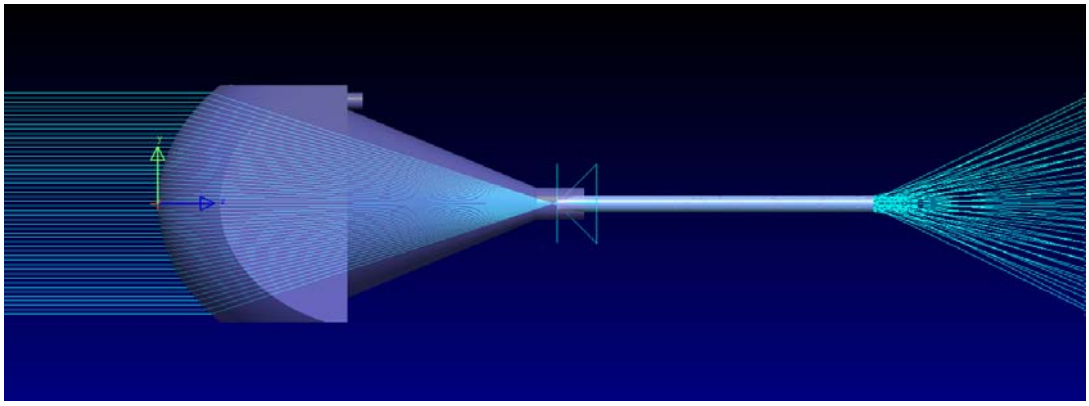

Fig. 1: Raytracing through a solar pin

We designed the optics such that we could allow for an angular misalignment of 1.5° in order to soften the requirements for accurate positioning of each individual pin. The angular acceptance range measured is shown in Fig.2.

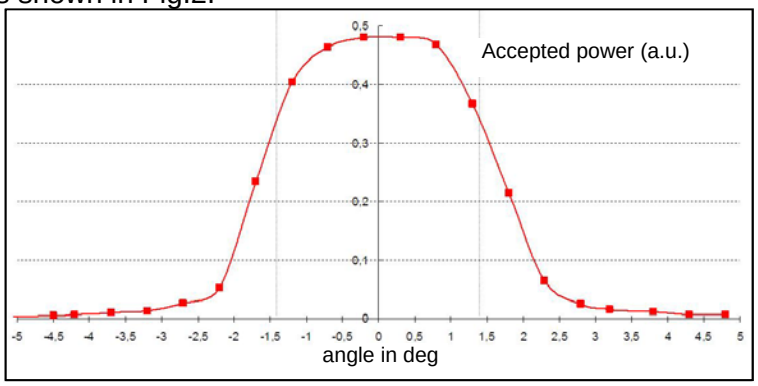

Fig. 2: Angular acceptance of solar pin with 1 mm POF

The solar pins are grouped into panels and these panels can be tilted individually and rotated all together to track the sun´s position (Fig.3). The geometry is such that is will be easy to form a mosaic like group of these Sollektors sharing parts of the mechanics such as the pistons for bearing and driving (Fig. 4).

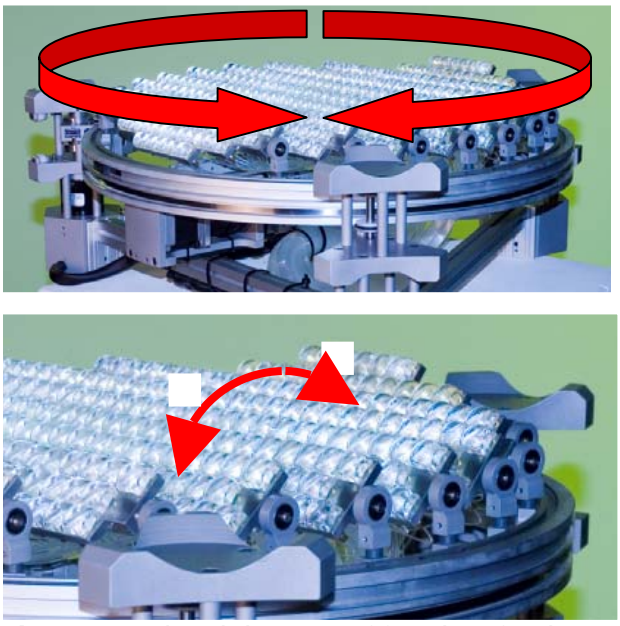

Fig. 3: Rotational degrees of freedom for the panels

Fig. 4: Sollektor complete

The 600 POF at the output end of these solar pins are bundled and can the be coupled to further guiding devices such as light tubes or luminaires. The use of fibers for transporting the light has been restricted to the parts, where flexibility is needed. The transport over longer more or less straight lines will be realized by hollow light guides giving following benefits:

- Lower loss
- Less costs
- Lower weight
- Conservation of spectral distribution i.e. colour rendering index (CRI).

Since the spectral transmission of PMMA fibers used here varies remarkably over the visual range from 380 to 780 nm, especially due to the absorption peak at around 620 nm, the longer the length of the fiber, the more evident is the change of the CRI.

Using the well known data of the spectral attenuation we calculated the colour impression of "white" light from a halogen lamp (3000 K) and sunlight (5700 K) for different lengths of the fiber As can be seen in Fig. 5, the colour impression for real (i.e. solar) white light changes only a little for fiber lengths up to 20 m, whereas the "white" halogen light in reality is yellowish and tends to green after longer lengths.

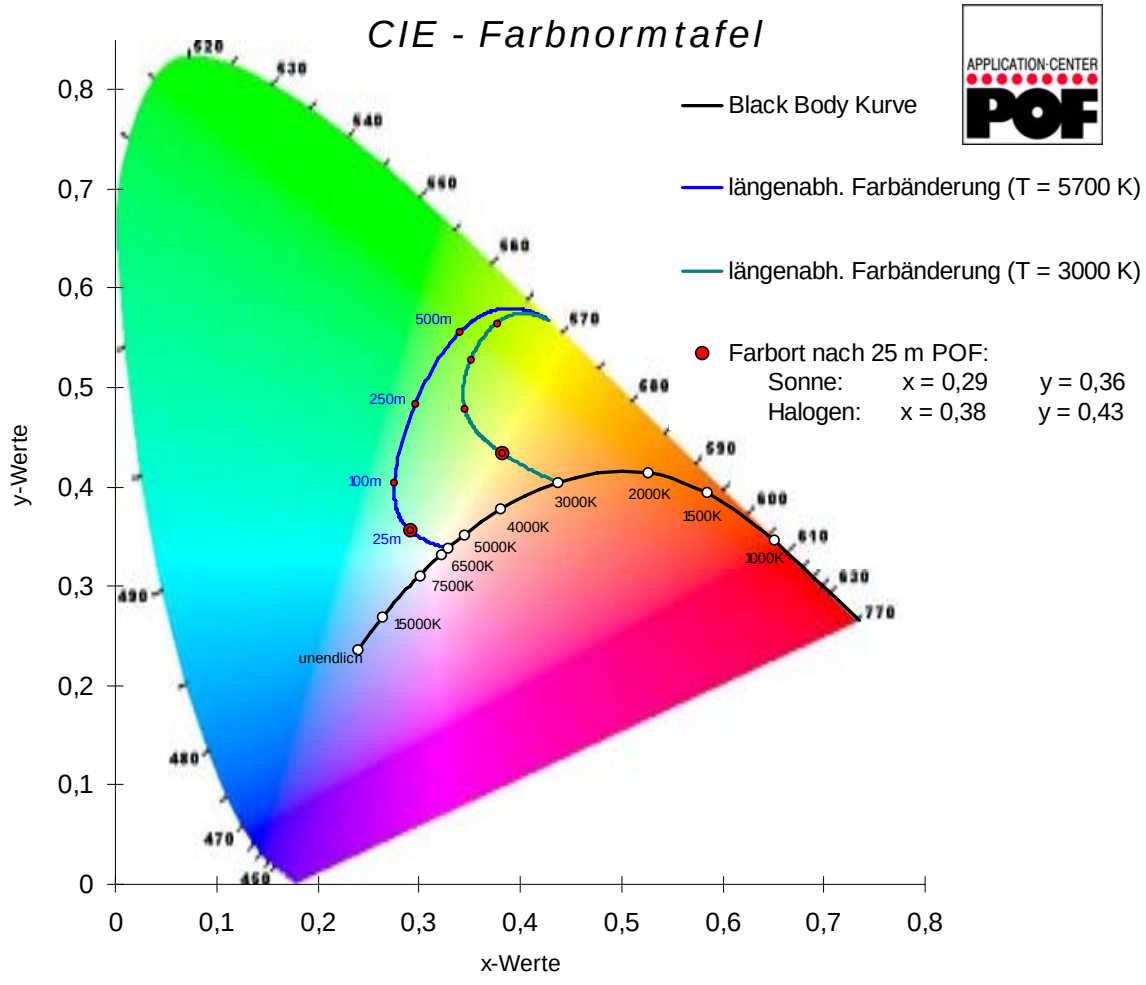

Fig. 5: Tracks for the colour impression as a function of fiber length for two different temperatures of thermal radiation sources. Numbers at the upper tracks indicate fiber length

Results

Currently we are testing the computer controlled solar tracking system and measure the loss through the system as a whole. First results show an efficiency of about 50% i.e. Given a sunny summer day in Nuernberg with 100 000 lux, we can deliver to the interior of a room typically 6000 lumen of natural light. This corresponds to the luminous flux produced by 3 halogen bulbs 100 W each but without generating heat.

Discussion

The current version of the Sollektor allows us to learn a lot about a daylight delivering system. Of course it is still a long way to become a product. But during our current project "STIF" we plan to

- increase the concentration ratio from 280 now to about 2000
- increase alignment tolerances through an improved collecting optics
- implement a sensor guided solar tracking
- simplify the mechanics to reach acceptable costs
- test the system not only in the lab but also in actual houses

Acknowledgements:

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References:

[HSL 08] http://www.sunlight-direct.com/index.php

[Him 86] www.arch.hku.hk/~kpcheung/daylight/day-4.htm

[Par 07] www.parans.com

[Poi 07] H. Poisel et al., "Daylighting with POF", 16th POF conference Turin, Sept. 10 –12, 2007