SOLLEKTOR – A NEW APPROACH TO AN OLD IDEA

Hans Poisel[1], Klaus Hofbeck[1], Alexander Kist[2], Sebastian Schuetz[2], Martin Bloos[1], M. Kumaravel[3]

[1] POF-Application Center, Ohm- University of Allied Sciences Nuernberg, Germany

[2] BavarianOptics, Neumarkt, Germany, [3]IIT-M, Chennai, India

1. Introduction

Even in "sunny" countries, despite the fact that an excess supply of sunlight outside, even during the daytime, windows are darkened and shut because of heat. Thus artificial light is used indoors requiring a high amount of energy. Moreover, these artificial lights are used at a very low level of efficiency only. If windows were left open, too much heat would penetrate through the windows. Thus in buildings, currently, most energy used is for air conditioning!

The efficiency of the usual way of transforming solar energy to electricity and then back to light is typically less than 1% (Fig.1), and is always linked with production of unwanted heat, whereas an efficiency of up to 50% depending on the length is achievable by direct use of sunlight e.g. with the Sollektor approach (Poisel et al.).

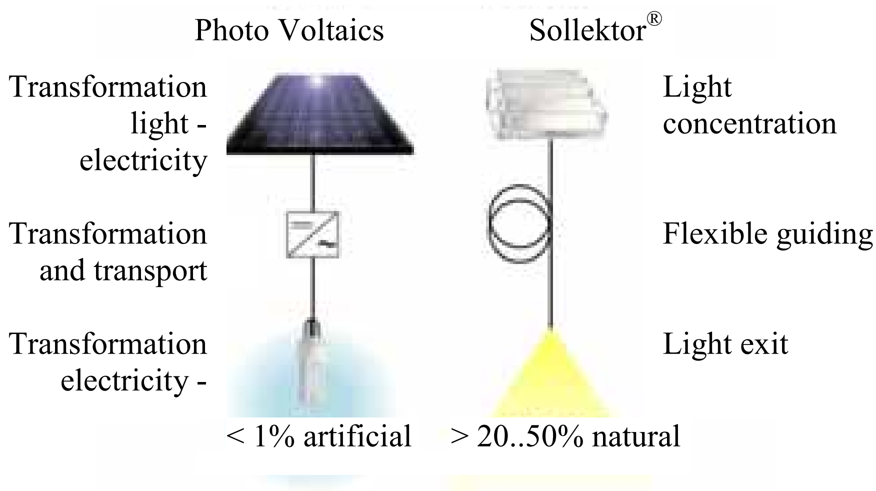

Fig. 1: Comparison electrical (left) and direct (ríght) illumination path

In addition, this light has no heat, and retains the natural spectral distribution that is most beneficial for human performance. The following benefits are linked to the use of this technology:

- Saving of energy costs through direct use of daylight and eco friendly
- Light without heat by splitting off infrared radiation
- Non visible part of radiation can be used for energy harvesting
- Natural daylight improves human performance and contributes positively to overall human well-being.

2. State of the art:

At the beginning of this century there have been EU funded projects in Europe with more or less academic character such as ARTHELIO (Arthelio) In the meantime there are also systems commercially available such as PARANS (Parans), which in the most recent version comes close to the approach of the Sollektor technology. Competing approaches can be found in:

- Egis: www.egis.org/Helio_de.html
- Solatube: http://solaglobal.com/
- Heliobus: www.heliobus.com/pages_e/frames.html
- Solux: www.bomin-solar.de/

In the USA there have been activities at the Oak Ridge National Laboratories which lead to "Sunlight Direct". In 2004 this a spin-off company started the commercialisation of the hybrid solar lighting (HSL) project, using sun-tracking parabolic mirror dishes (typ. 1 m diam) and fiber bundles, guiding the light to the interior of the building (www.sunlight-direct.com).
Maybe the most widespread commercial use has been in Japan with the Himawari system[1].

Drawbacks of the current state of the art: Apart from the Parans system, all approaches are based on bulky devices, are sensitive to environmental loads such as wind, and also not acceptable for European architectural ambitions. To our opinion this is one of the main reasons for not having been accepted so far.

3. New approach: Sollektor

As a consequence to the benchmarking of the systems mentioned above and parallel to the progress in concentrating photovoltaics we followed a more promising approach which we call "Sollektor" (= Solar Collector) which we presented at various POF conferences since 2007 (Poisel 2007 – 2010).

The Sollektor has following characteristics:

- Modular design thus fitting any size and shape
- Suitable for any roof geometry (essential for Europe, not so much in sunny belt countries such as India)
- Simple and robust mechanics with a minimum of moving parts
- To be integrated in a holistic system using the most of solar power
- Sensor assisted solar tracking
- Simple and injection moulded fault tolerant concentrating optics

The daylighting system consists essentially of three parts:

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

A key component is the coupling optics using a pin like device (Fig.2) 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. The current 2nd generation has an increased effective area and a fiber with 0.75 mm only compared to 1 mm. this increasing the concentration to about 700.

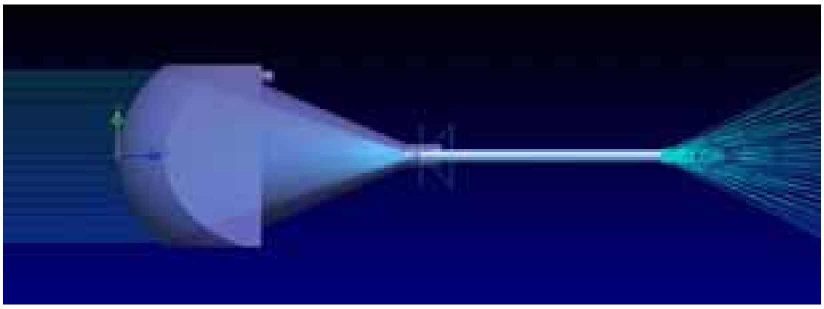

Fig. 2: Raytracing through a solar pin

---

[1] http://www.arch.hku.hk/~kpcheung/daylight/day-4.htm

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.3.

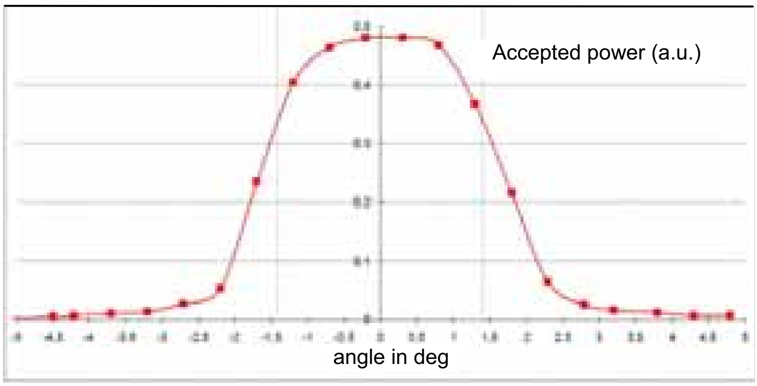

Fig. 3: Angular acceptance of solar pin with 1 mm POF

In addition to the energy saving properties of Sollektor the almost perfect colour rendering plays an important role influencing the performance of human beings. Fig. 4 shows a comparison of the spectra of different sources offering white light whereas Fig. 5 demonstrates the influence on colour rendering.

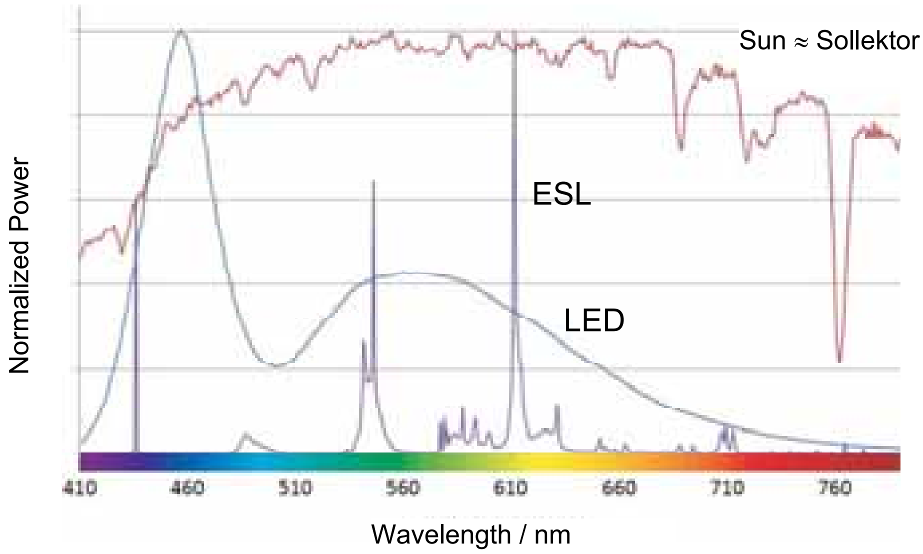

Fig. 4: Comparison of spectral distributions of white LED, Energy Saving Lamp (ESL) and sunlight

Fig. 5: Different colour rendering using different light sources; all photos taken with identical camera setting

4. Test installations

The first Sollektor had been installed at the roof top of our partner university IIT-M in Chennai / India because of their abundance of sunlight (Poisel 2009). Even though this set-up never was intended for being used under these conditions we gained a lot of experience about the behaviour of the components under very intense sunlight illumination.

The current version of Sollektor 2.1 differs from that model by increasing the concentration (700x vs. 280x), improving the tracking accuracy as a consequence and simplifying the mechanics in order to achieve a rugged system able to withstand the environmental challenges.

This set-up is shown in fig. 6.

Fig. 6: Current version of Sollektor with 8 fiber bundles carrying 108 individual POF each

The light collected by each of the four panels with 224 "lenses" is transported by 8 fiber bundles in order to distribute the light to different places such as two different hybrid luminaires (c.f. next section) located two floors underneath as well a for monitoring purposes to a control cabinet side by side to the Sollektor rack as shown in fig. 7.

Fig. 7: Current version of Sollektor with 8 fiber bundles carrying 108 individual POF each

Within this cabinet various systems are planned to be installed to measure the total amount of power, its temporal and spectral distribution, the variation of the efficiency of different individual concentrators in conjunction with other climatic parameters.

A first impression ("first light") of natural light inside the demonstration room two floors underneath is given in fig. 8.

Fig. 8: First sunlight from the Sollektor at the rooftop

5. Hybrid luminaires

The light provided by the Sollektor will be launched to two different hybrid luminaires inside the demo room one in a flat design ("slab") to be placed above the table, the other one in a tubular shape as a hollow waveguide using prismatic sheets for guiding the light. Both will use light from white LEDs in case only low or no sunlight is available. A lux-sensor will provide a signal to the control unit adjusting the LED current to make sure, that the illumination level stays within a given range.

For the slab luminaire we developed a completely new design using ray tracing techniques. Firstly the slab will act as a planar light guide (PMMA vs. air), with means to extract the light at defined locations for fulfilling its purpose as flat luminaire. As shown in fig. 9 the slab is divided in three regions: one central part where the LED light is shining through, having a diffusing part for homogenizing the light from the more or less point-like sources.

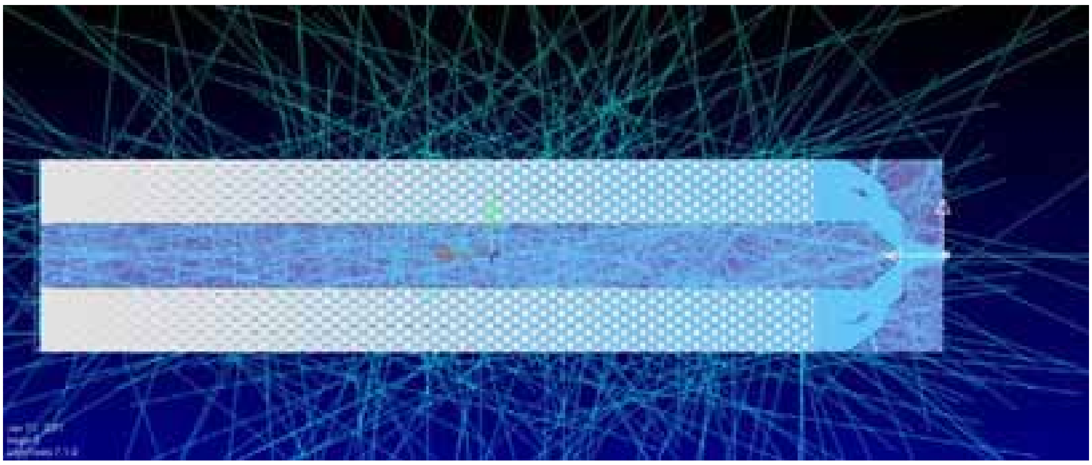

Fig. 9: Ray tracing results for slab luminaire with launching region (right), central region for LED light optionally shining through and two side regions for guiding and distributing day light

The two areas left and right will transport the Sollektor light launched at a central position at one edge of the slab (fig.10). Narrow slits in the slab will act as mirrors redirecting the light to the two outer regions and prevent it from reaching the central area. A special pattern of white dots is printed on the slab. The density of the dots varies with the distance from the launching region in order to provide a uniform illumination level.

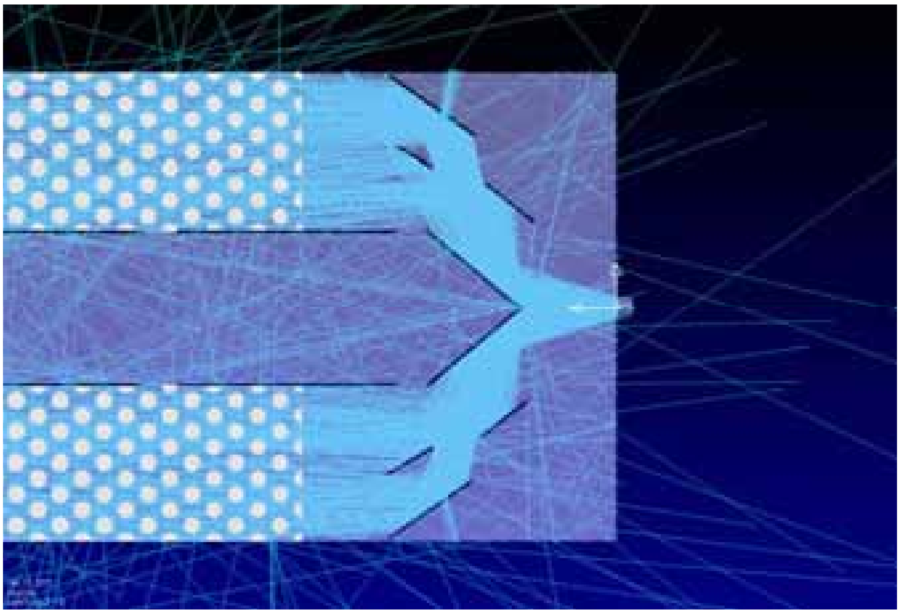

Fig. 10: Ray tracing of the slab where light is launched (center right) and redirected by totally reflecting slits

In Fig. 11 simulated rays from the printed pattern in the downwards direction are shown as well as the distribution of the illumination in the near field indicating a very satisfactory uniformity.

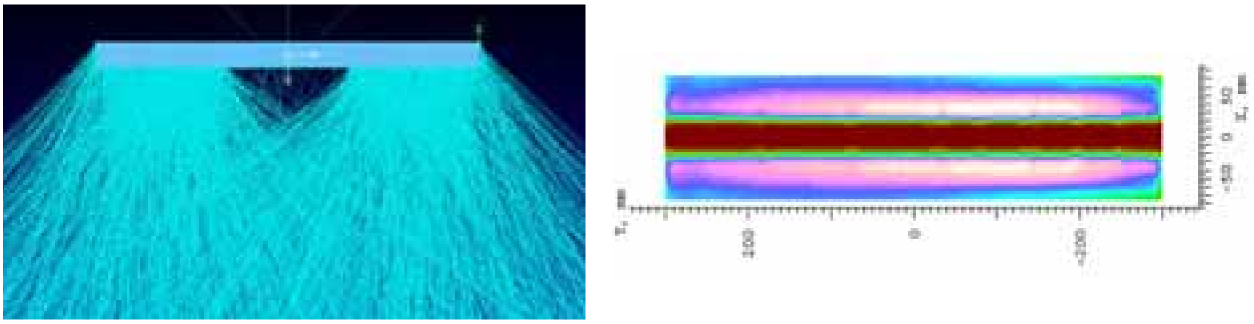

Fig. 9: Ray tracing of light scattered downwards (left) and near field distribution over the slab area (right)

6. Conclusions

Daylighting using the Sollektor approach has been demonstrated to be a viable technique with the potential to save a lot of energy, increase human´s well being and providing the right colours.

Mainly for sunny belt countries, the energy saving aspect is the most important one demanding a cost effective design of the complete system. This is one of the main activities for the next future. Sollektor is now on its way from the laboratory to commercial applications. A spin-off company called Bavarian Optics has been founded in March 2010, first samples have already been ordered.

7. Acknowledgement

This work has been funded by the German Federal Ministry of Education and Research (BMBF) within the AiF program profUnt, project "STIF", FKZ 1780X08. The start-up company "BavarianOptics" has also been funded by BMBF within the EXIST framework FKZ 03EGSBY152. We greatly appreciate this support.

8. References

Arthelio, http://www.tuilmenau.de/fakmb/fileadmin/template/fglt/publikationen/ 2001/LuxJun2001.pdf

Parans, http://www.parans.com

Poisel , H. Poisel et al., "Daylighting with POF", 16th POF conference Turin/Italy, Sept. 10 –12, 2007

H. Poisel et al., "Sollektor–Transporting Daylight with POF" 17th POF conf., S. Clara/USA, Aug. 25-28, 2008

H. Poisel et al., 2009, Progress with fiber optic daylighting system Sollektor, Proc. 18th POF conference, Sydney (Australia), Sept. 10 –12, 2009

H. Poisel et al., "Sollektor: Progress on its way to a product , 19th POF conference, Yokohama / Japan, Oct. 19-21, 2010