Advanced Fluorescent Concentrators

J. C. Goldschmidt, S. W. Glunz, A. Gombert, G. Willeke

Fraunhofer Institute for Solar Energy Systems, Heidenhofstr. 2 79110 Freiburg, Germany

The concept of fluorescent concentrators was investigated intensively in the early eighties [1]. In a fluorescent concentrator dyes in matrix absorb radiation and emit light with a longer wavelength. Most of the emitted light is internally total reflected and therefore trapped and guided to the sides of the concentrator, where it can be utilised by solar cells. Research of those days aimed for cost saving by replacing expensive solar cells by eventually cheap fluorescent material. However, several problems led to diminishing research interest. The used organic dyes were instable under longterm illumination and had only narrow absorption bands. Although relatively high quantum efficiencies of the absorption and reemission process above 90% could be achieved in the visible range of the spectrum, efficiencies remained at 50% and lower in the infrared. Reabsorption of the emitted light because of overlapping absorption and emission spectra reduced efficiency further [2]. A principal problem is the escape cone of the internal reflection which causes losses of around 30% of the emitted light. Additionally no efficient solar cells whose spectral response matched the emission spectra of the dyes were available in those days.
Under the light of 20 years of progress in the development of solar cells and fluorescent dyes and with some new ideas at hand, we would like to propose a reinvestigation of the potential of fluorescent concentrators. We therefore suggest an advanced concept, which aims for higher efficiencies by utilisation of the full solar spectrum. Figure 1 summarises the concept.

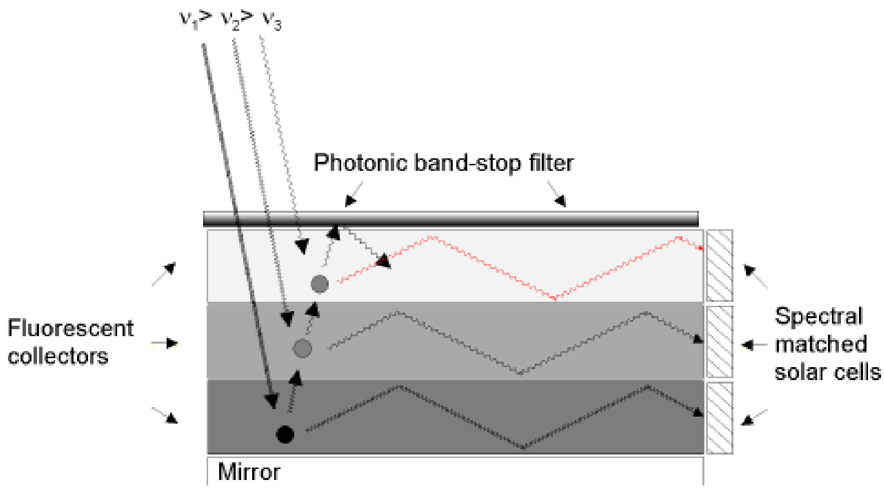

Figure 1: The advanced fluorescent collector concept. Dyes in a matrix absorb radiation of a specific spectral range and emit light with a longer wavelength. The light is guided by internal reflection to the side of the concentrator, where it is utilised by spectral matched solar cells. The full spectrum can be used with a stack of fluorescent collectors with different dyes. The stack configuration allows for "recycling" of emitted photons that are lost in one collector but can be absorbed in another one, which is sensitive for lower energy photons. A photonic structure helps to minimise losses due to the escape cone of internal reflection, but does not affect the incoming light in the usable wavelength range.

One major improvement of the advanced fluorescent concentrator concept is the use of a photonic structure to reduce the losses due to the escape cone of the total internal reflection.

The photonic structure acts as a bandstop reflection filter. It allows the light in the absorption range of the dyes to enter the collectors, but reflects the light in the emission range. Therefore a larger amount of light is trapped in the collector and guided to the solar cells at the side. The idea of a photonic bandstop was first proposed for a different system configuration in [3].
Another progress is that solar cells on different materials are available. As shown in figure 2, a broad spectrum of light can be utilised with high efficiencies with the solar cells produced at our institute.

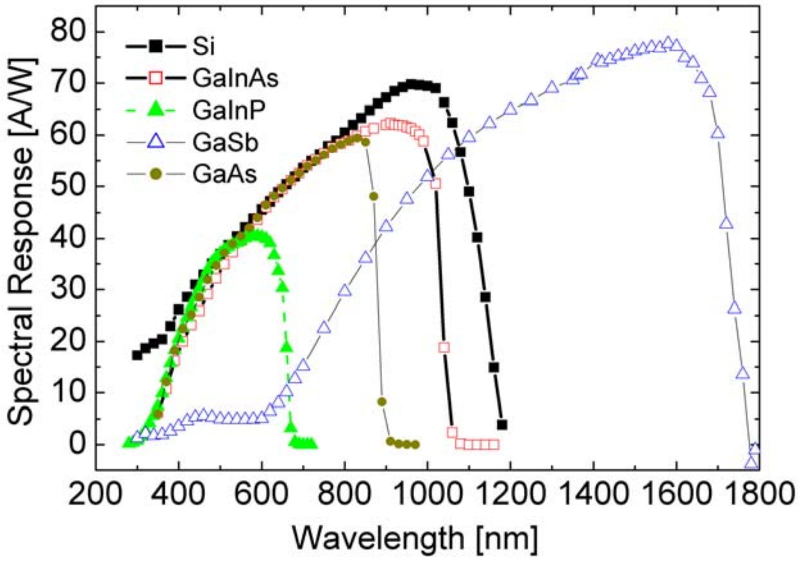

Figure 2: Spectral response of solar cells on different materials produced at Fraunhofer ISE. The full solar spectrum can be converted with high efficiencies.

One important asset of the fluorescent concentrator is the ability to concentrate diffuse light without the need for a tracking system. This gives the concept a high application relevance for use in conditions like central Europe with extensive periods with low illumination intensities and a high diffuse fraction. Moreover the stack design with the matched solar cells at the side means a high degree of freedom for cell interconnection, which is a clear advantages over tandem cell concepts with the need for tunnel diodes and current limitation problems.
To assess the potential of the advanced fluorescent concentrator the concept is currently subject to first experiments and thermodynamical calculations. One of the first identified remaining issues is the availability of dyes that are stable and have high conversion efficiencies in the infrared and UV part of the spectrum. Quantum structures, such as luminescent nanocrystals of CdSe [4] could be applicable [5]. Their major advantage is the tunable absorption and emission range, which gives hope to control problems like the reabsorption problem.

[1] V. Wittwer, K. Heidler, A. Zastrow, A. Goetzberger , "*Theory of fluorescent planar avail*
[2] A. Zastrow, „*Physikalische Analyse der Energieverlustmechanismen im Fluoreszenz-kollektor*", Dissertation (1981)
[3] U. Rau, F. Einsele, G. C. Glaeser "*Efficiency limits of photovoltaic fluorescent collectors*"
[4] V. Babentsov, J. Riegler, J. Schneider, O. Ehlert, T. Nann, M. *Fiederle "Deep level defect luminescence in cadmium selenide non-crystals films*" J. of Crystal Growth 280 p.502-58 (2005)
[5] A . J. Chatten, K.W. Barnham, B.F. Buxton, N.J. Ekins-Daukes, M.A. Malik, „*The quantum dot concentrator: Theory and results*", Proc. of the 3rd World Conference of Photovoltaic Energy Conversion Osaka (2003)