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LUMINESCENT SOLAR CONCENTRATORS SUPPLYING ELECTRICITY FOR FUTURE BUILDINGS

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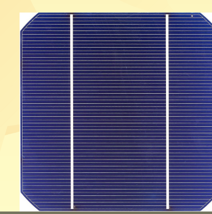
SUMMARY

We can use the surfaces of the windows, roofs and walls of the buildings for luminescent solar concentrators to produce the cheap and environment friendly energy. The ways how efficient luminescent concentrators can be materialized are proposed

Introduction

Since the shortage of fossil fuel is treating our future it became obvious that a search of alternative energy sources is of crucial importance. Photovoltaic electricity is one of the most promising solutions, however, it is still too expensive for massive uses. Luminescent solar concentrators are one of possible solutions for chipper photovoltaic electricity. Luminescent solar concentrator (LSC) has been already proposed several decades ago, after which the research stopped because of the availability of cheap fossil energy. In recent years because of the rapid increase of the cost of fuel there is a renewed great interest in solar energy and specifically in luminescent solar concentrators that will decrease significantly the amount of solar cells needed to obtain a given amount of electricity.



Theory of LSC, which is based on internal reflection of fluorescent light which is subsequently concentrated at the edges, has been discussed in detail for inorganic materials and organic dyes incorporated in bulk polymers. A transparent plate doped by fluorescent species should absorb the major part of solar spectrum. The resulting high yield luminescence is emitted at the longer wavelength part of the spectrum. Repeated reflections of the fluorescent light in a transparent matrix should carry the radiation to the edges of the plate where the light will emerge in a concentrated form. The concentration factor is the ratio of the plate surface to the plate edge. Theoretically about 75–80% of the luminescence would be trapped by total internal reflection in the plate having a refractive index of about 1.51. Photovoltaic cells can be coupled to the edges and receive the concentrated light. Such an arrangement should substantially decrease the amount of photovoltaic cells needed to produce a given amount of electricity and thus reduce the cost of the system of photovoltaic electricity. If all these ideal conditions could be realized our calculations show that the collecting efficiency, which is the amount of energy reaching he photovoltaic cell divided by the energy falling on the plate should be about 20% .

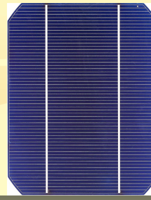
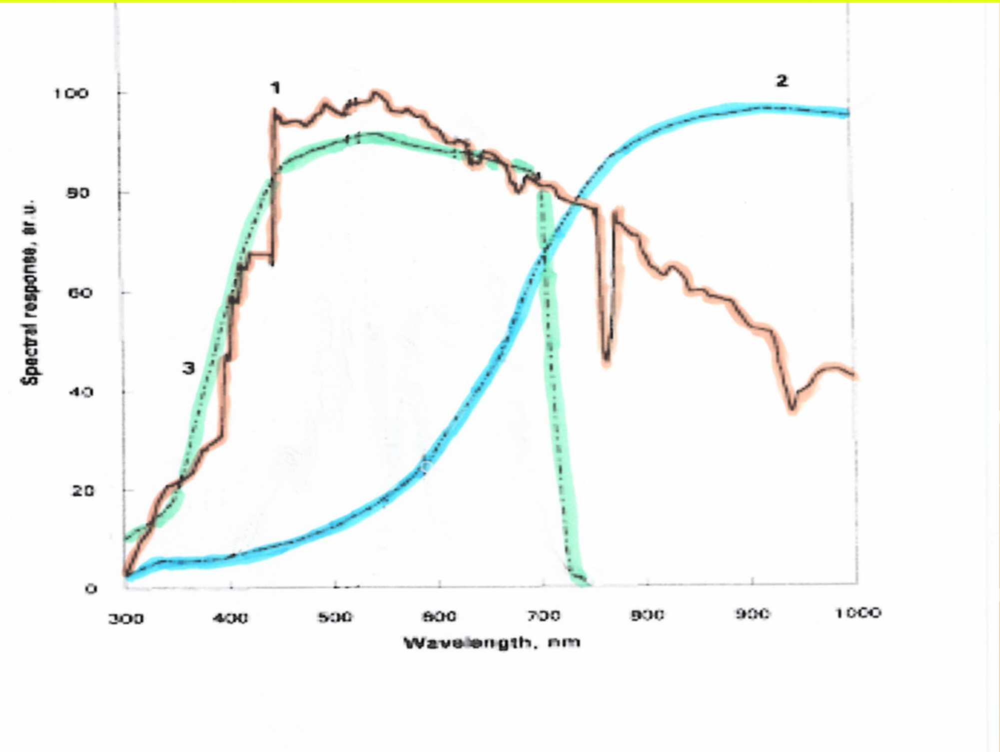
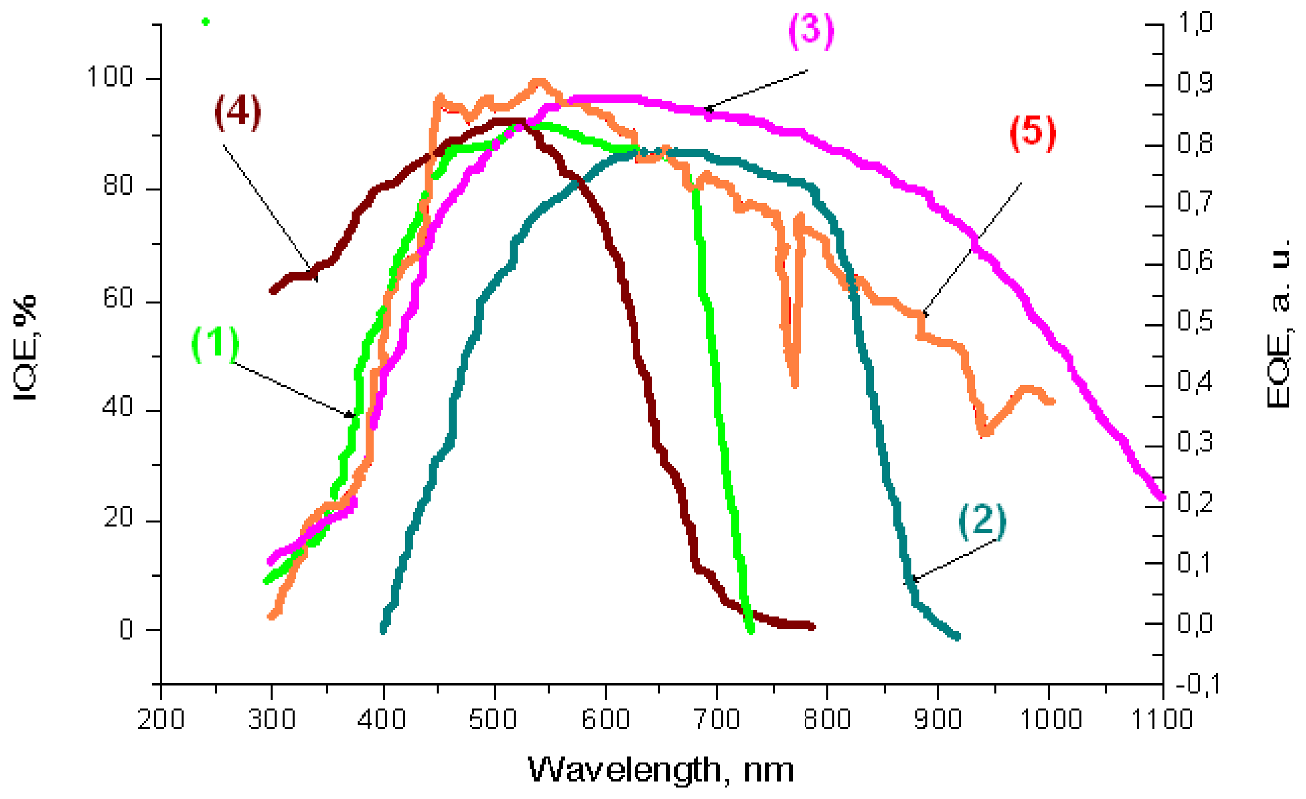


Fig. 1. (1) – Solar spectrum, (2) – sensitivity of silicon photovoltaic cell, (3) sensitivity of AlGaAs photovoltaic cell



R. Reisfeld, D. Shamrakov and C. K. Jorgensen, "Photostable solar concentrators based on fluorescent glass films" Solar Energy Materials and Solar Cells 33, 417-427 (1994).

Quantum efficiency for solar cells: AlGaAs (1); CdS/CdTe (2); Monocrystalline silicon (3), Amorphous silicon (4) and Solar spectrum (5).



The parameters determining the optical plate efficiency depend on the following factors:

a) The fraction η_{abs} which is the ratio of photons absorbed by the plate to the number of photons falling on the plate;

b) The quantum efficiency of fluorescence η_F, which is the ratio of the number of photons emitted to the number of photons absorbed;

c) The Stokes efficiency ***ηS*** which is the ratio of the average energy of emitted photons to the average energy of the absorbed photons and is given by

$$\eta_S = \nu_{em} / \nu_{abs}$$

d) The trapping efficiency $\boldsymbol{\eta_t}$ of the light trapped in the collector given by

$$\eta_t = \left(1 - 1/n^2\right)^{1/2}$$

where ***n*** is the refractive index of the light-emitting medium;

If the surrounding medium does not have a refractive index n_0 very close to 1 (such as air), the quantity ($1/n$) is everywhere replaced by the ratio (n_0/n).

A numerical examples of the trapping efficiency ηtrap are shown below:

n	=	1.414	1.556	1.743	2.000
η_{trap}	=	0.7071	0.7660	0.8191	0.8660

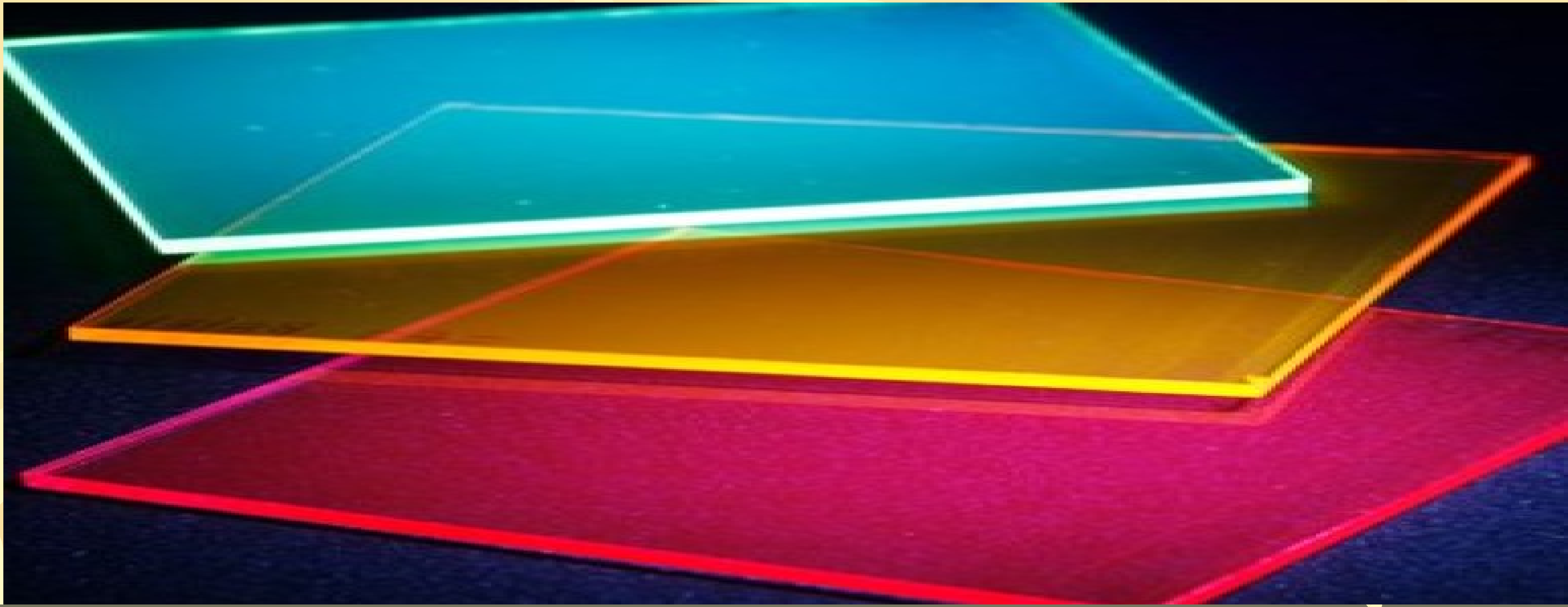
e) The transport efficiency η_{tr} which takes into account the transport losses due to matrix absorption and scattering;

f) The efficiency η_{self} due to losses arising from self-absorption of the colorants.

This efficiency is calculated by taking into account the overall absorption of the colorants in the plate, their fluorescent efficiency, the trapping efficiency (depending of the refractive index of the plate medium), and the Stock efficiency (which is the ratio of the average energy emitted to the average energy absorbed). So far the efficiency of LSC was never above 7%, one of the main reasons for the relatively low efficiency is the self-absorption of the luminescent dyes as a result of overlapping of the absorption and luminescence of the dyes. Another difficulty is the escaping of the luminescence emitted beyond the critical angle. The photostability of the colorants under solar radiation is another problem that has to have a solution.

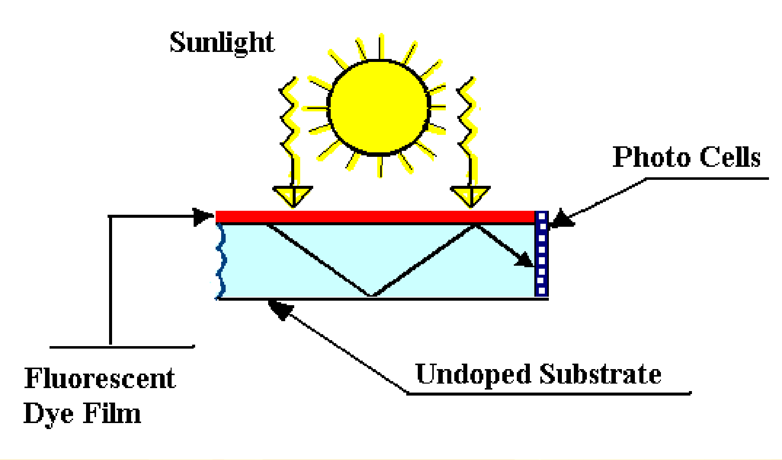
Several of the above problems have been studied in our laboratories as described in reference [1].

Our and other groups are currently studying additional aspects of luminescent solar concentrators, see [1].

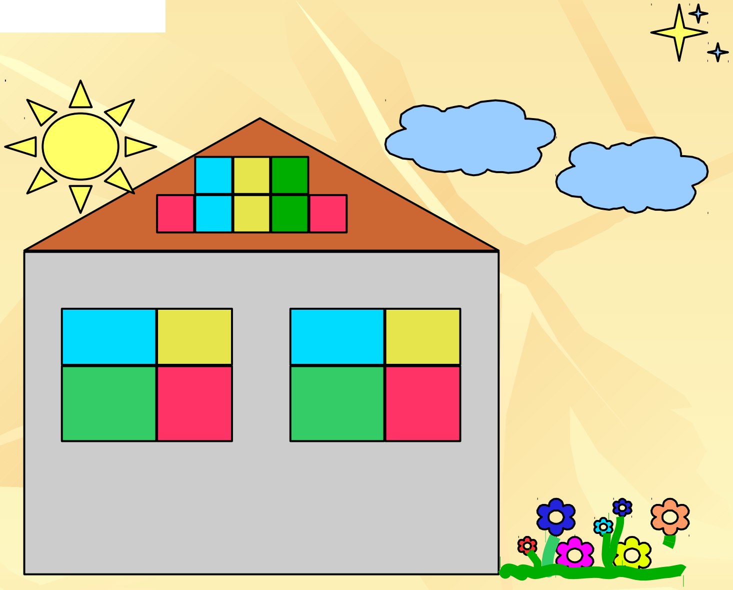


The possibility of incorporating LSC in future buildings arises from the fact that the semi-transparent glass plates can form a part of the constructions (windows, verandas, ets.) and do not need extra surfaces like the conventional solar panels. This is a specially important in big cities when the land is very expensive.

Scheme of LSC



A future building with LSCs



A schematic image including LSCs

Conclusion

For the optimum performance of luminescent solar concentrator we propose a solid film in with the emitting species having no overlapping of the fluorescence with the absorption spectrum. The film has to be attached optically to a transparent glass plate having no internal absorption. The results are of vital importance in designing luminescent solar concentrators where the self-absorption is responsible for the decrease of conversion efficiency in realistic bigger plates. The intensity of fluorescent emission is intensified by interaction with nobel metals nanoparticles and the photostability of dyes obtained by protective layer of transparent medium

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REFERENCES

Reisfeld R., Invited paper in Optical Materials 32 (2010) 850

and references there in