FLSC
Fractal structures to enhance the efficiency of luminescent solar concentrators

LENS, European Laboratory for non-linear spectroscopy · Rajeshkumar Mupparapu
KTH, Royal Institute of Technology · Reza Sanatinia

Project context and objectives

Luminescent solar concentrators were invented in early seventies as an alternative to conventional solar cells. They have immense potential due to their low cost and robust concept. An LSC consists of a transparent slab doped with fluorescent molecules absorbing the solar radiation in a certain shorter wavelength range and re-emitting the light at longer wavelength range. The emitted light is partially guided towards the edges of the slab by total internal reflection and where it is captured by photovoltaic cells. LSCs have specific advantages like low cost and easy installation which make them socially acceptable. Unlike conventional solar cells, LSCs can capture both direct and diffused sunlight. However, their efficiency stands at low value even three decades after their invention on account of various losses like poor absorption and quantum yields of fluorophores, wave guiding losses, self absorption, etc. In this framework, what could be a good strategy for enhancing the efficiency of an LSC is to simultaneously achieve the absorption enhancement and good optical wave guiding.

The aim of the project is to enhance the efficiency of luminescent solar concentrators (LSCs) by patterning in the form of a deterministic fractal. In this framework, Sierpinski fractals geometry is considered to enhance the interaction of light with the structure, and at the same time, confine entire fluorescence to the slab.

Brief description of the main results

- Dispersion calculations of the Sierpinski carpet of stage 4 structure have revealed the presence of defect states in the band gap. Presence of defect states over a large range frequencies allow the maximum amount of light from out-of-plane to couple in to the slab, as a result absorption by the slab will increase.
- Electric field calculations infer that the fields can be strongly confined inside the cavities at the ferquencies corresponding to the defect states of the structure.
- K-space(wave vector dynamics) investigation has revealed that the light of frequencies in the band gap can couple in to the slab efficiently, while the light of frequencies below the band gap propagate as a general mode, and find no leaky modes to escape out the slab. Hence if emission couples to these modes, wave guiding losses can be mitigated.

Final results, potential impact and use

Matching the frequency range of the band gap with the absorption band of the fluorescent molecules, it is possible to increase their absorption. While matching the emission with the guided modes of the slab can make the light transport more efficient. Time domain and frequency domain calculations infer the presence of a regime with many defect states which increase the light coupling in to the slab, while a another regime below the gap where only the guided modes are present.

Electric field maps infer that the light can be confined inside the cavities where the fluorophores are located, hence their absorption is enhanced.

The approach provides the route to enhance the absorption at the same time efficient light wave guiding. Since the geometry proposed here is easily realizable and do not require very high resolution in fabrication, hence the approach can be scaled to larger systems.