

# Diffuse light concentration in free space with down-conversion CsPbCl<sub>3</sub>:Yb<sup>3+</sup> nanocrystals

Mathis Van de Voorde\*, Tim Bekius, Jelle Westerhof, Lisanne Einhaus and Rebecca Saive

MESA+ Institute for Nanotechnology, Inorganic Materials Science, University of Twente, 7522NB Enschede, Netherlands

\* [m.a.n.vandevoorde@utwente.nl](mailto:m.a.n.vandevoorde@utwente.nl)

Free-space luminescent solar concentrators (FSLSCs) are optical structures that can enhance photovoltaic yield by efficiently concentrating diffuse light into a small cone in free space. To achieve net étendue reduction, a luminophore-doped waveguide captures the incoming light, and down-shifts the photons to a wavelength range which can escape the waveguide through a specific emission cone. The emission cone is tuned via a nanophotonic coating, consisting of multiple aperiodic bilayers of high and low refractive index materials deposited on top of the waveguide. A proof-of-concept FSLSC device using organic down-shifters yielded a concentration factor of 1.18 [1]. However, the non-ideality of the dye (i.e., photon reabsorption with non-unity quantum yield) severely cripples the output of the FSLSC. We aim to enhance the concentration of the device by leveraging the excellent optical properties of down-conversion luminophores such as CsPbCl<sub>3</sub>:Yb<sup>3+</sup> nanocrystals. This material is able to tackle the shortcomings of its organic counterpart due to its large Stokes shift (~600 nm) and therefore limited photon reabsorption. Furthermore, such down-converters are capable of achieving quantum yields above unity by splitting the localized absorbed photon energy and sensitizing multiple neighboring luminescent centers (i.e., Yb<sup>3+</sup> ions). Detailed balance simulations predict that, under realistic conditions and assuming perfect spherical symmetry, concentration factors up to 2 are achievable with luminophores exhibiting quantum yields of 150%. To explore this potential, we synthesize CsPbCl<sub>3</sub>:Yb<sup>3+</sup> nanocrystals via a two-step solvent-assisted mechanochemical process and integrate them into a functional FSLSC device. The device performance is assessed using a custom-built goniometer setup to extract the spectro-angular emission profile and resulting concentration factor. This work advances our understanding of photon management in FSLSCs by harnessing the unique photophysical properties of down-conversion CsPbCl<sub>3</sub>:Yb<sup>3+</sup> nanocrystals, and thereby supports the development of more efficient solar harvesting technologies.

[1] L. M. Einhaus, G. C. Heres, et al., (2023). Free-Space Diffused Light Collimation and Concentration. *ACS Photonics*, 10, 508–517. <https://doi.org/10.1021/acsp Photonics.2c01652>