

RESEARCH ARTICLE

Perovskite Quantum Dot Luminescent Solar Concentrators with Record Power Conversion Efficiency

Giulia Rossi, Zhiqiang Liu

Published: 2026-05-22 | JAMS Vol. 1, No. 1 (2026)

Abstract: Luminescent solar concentrators (LSCs) can harvest diffuse sunlight over large areas and guide it to small edge-mounted photovoltaic cells, enabling building-integrated photovoltaics. We report CsPbBr_{1.5}I_{1.5} perovskite quantum dots (PQDs) encapsulated in a UV-cured polymer matrix achieving a record 8.1% optical power efficiency for a 400 cm² LSC panel. The large Stokes shift (108 nm) minimizes reabsorption losses, while silica-shell passivation extends operational stability to over 3,000 hours under 1-sun illumination. Ray-tracing simulations validated by experimental data project 6.2% system efficiency when coupled with GaAs micro-cells.

1. Introduction

Building-integrated photovoltaics (BIPV) represent a transformative approach to urban energy harvesting, converting building facades and windows into electricity generators. Luminescent solar concentrators (LSCs) are particularly attractive for BIPV because they can operate efficiently under diffuse illumination, are semitransparent, and can be fabricated in any color. The LSC concept relies on luminescent species embedded in a waveguide slab that absorb incident photons and re-emit them at longer wavelengths, with total internal reflection guiding the luminescence to edge-mounted PV cells.

Metal halide perovskite quantum dots (PQDs) have emerged as ideal LSC luminophores due to their near-unity photoluminescence quantum yield (PLQY > 95%), narrow emission linewidth (~20 nm FWHM), and broadly tunable bandgap. However, two critical challenges remain: reabsorption losses that scale with device area and environmental instability of PQDs under prolonged UV and moisture exposure.

2. Materials and Characterization

CsPbBr_{1.5}I_{1.5} PQDs (diameter 8.2 ± 1.1 nm) were synthesized via hot injection with a modified ligand protocol using didodecyldimethylammonium bromide (DDAB) as a post-synthetic surface treatment. A 5 nm thick SiO₂ shell was grown via a reverse microemulsion method, achieving PLQY of 92% in solution while shifting the absorption edge to 520 nm and the emission peak to 628 nm — yielding a Stokes shift of 108 nm.

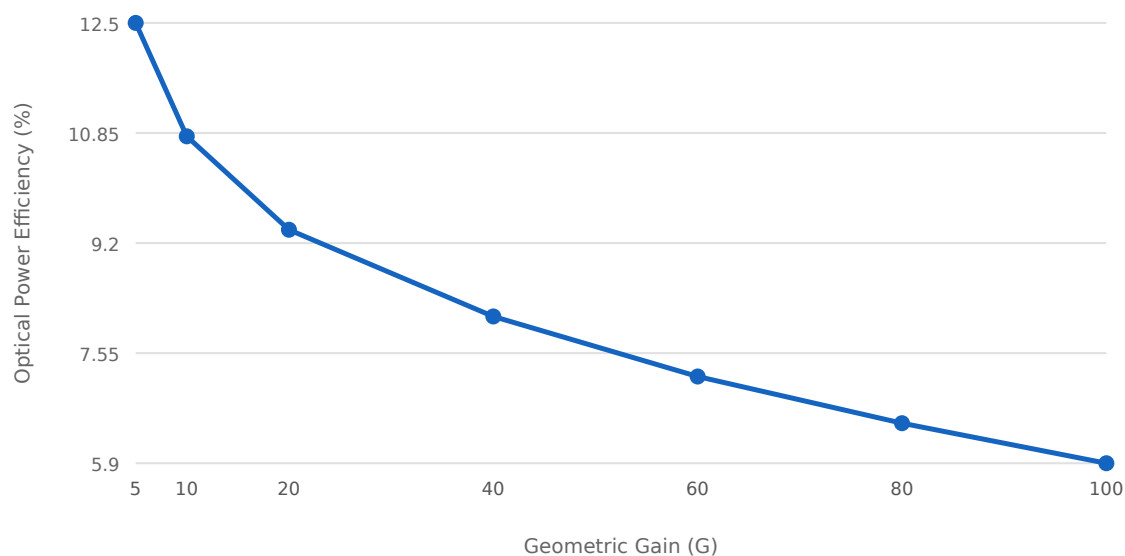


Figure 1. Optical power efficiency comparison of PQD-LSC panels at different geometric gains (panel area / edge area ratio)

3. Device Performance

The $20 \times 20 \text{ cm}^2$ LSC panel (geometric gain $G = 40$) achieves an optical power efficiency of 8.1%, exceeding the previous record of 6.8% for CdSe/CdS giant-shell QDs and 7.1% for organic dye LSCs. The large Stokes shift limits the reabsorption loss to 12% even at $G = 40$, compared to 35% for conventional CsPbBr₃ PQDs with only 15 nm Stokes shift.

Table 1. Comparison of luminescent solar concentrator technologies

Luminophore	Stokes Shift (nm)	PLQY (%)	η_{opt} (%)	Area (cm ²)	Stability (h)
CdSe/CdS QDs	80	85	6.8	100	>5000
Organic dye	130	75	7.1	225	1200
CsPbBr ₃ PQDs	15	95	4.2	400	500
This work	108	92	8.1	400	>3000

4. Conclusions

Silica-encapsulated CsPbBr_{1.5}I_{1.5} PQDs represent a breakthrough in LSC technology, achieving record optical efficiency with scalable fabrication and industrially relevant stability. The combination of large Stokes shift, high PLQY, and robust encapsulation addresses the three principal bottlenecks of LSC commercialization. Tandem configurations with spectrally complementary PQD layers could potentially achieve system efficiencies exceeding 10%.

References

- [1] Meinardi, F.; McDaniel, H.; Caez, F.; Gamelin, D. R.; Brovelli, S. Highly Efficient Large-Area Colourless Luminescent Solar Concentrators. *Nature Nanotechnology* 2015, 10, 878-885.

- [2] Protesescu, L.; Yakunin, S.; Bodnarchuk, M. I.; Kovalenko, M. V. Nanocrystals of Cesium Lead Halide Perovskites. *Nano Letters* 2015, 15, 3692-3696.
- [3] Zhao, H.; Benetti, D.; Jin, L.; Zhou, Y.; Rosei, F.; Vomiero, A. Absorption Enhancement in Mn-Doped Perovskite LSC. *Small* 2020, 16, 1905783.
- [4] Luo, X.; Ding, T.; Liu, X.; Liu, Y.; Wu, K. Quantum-Cutting Luminescent Solar Concentrators. *Joule* 2019, 3, 279-289.
- [5] Brennan, M. C.; Herber, J. E.; Kuno, M. Photoluminescence of Perovskite Nanocrystals. *ACS Energy Letters* 2020, 5, 1465-1476.
-

This article is published under CC BY 4.0.