Supporting Information

Anti-Stokes Photoluminescence Study on a Methylammonium Lead Bromide Nanoparticle Film

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Photoluminescence excitation spectra recorded at different temperatures

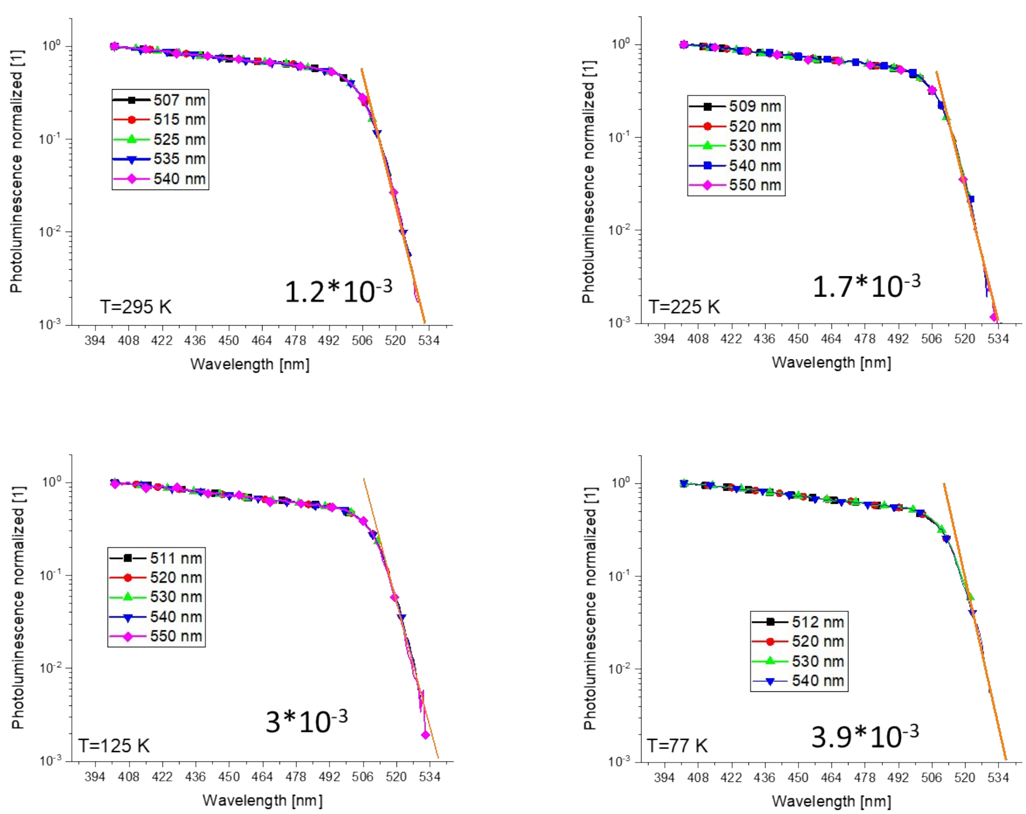

Figure S1: Photoluminescence excitation spectra recorded at different temperatures. Each figure comprises several measurements recorded at different emission wavelengths (as indicated in the figures). In the inset the ratio of absorbed photons at 532 nm and 405 nm estimated from the excitation spectra is plotted.

Temperatures dependent absorption

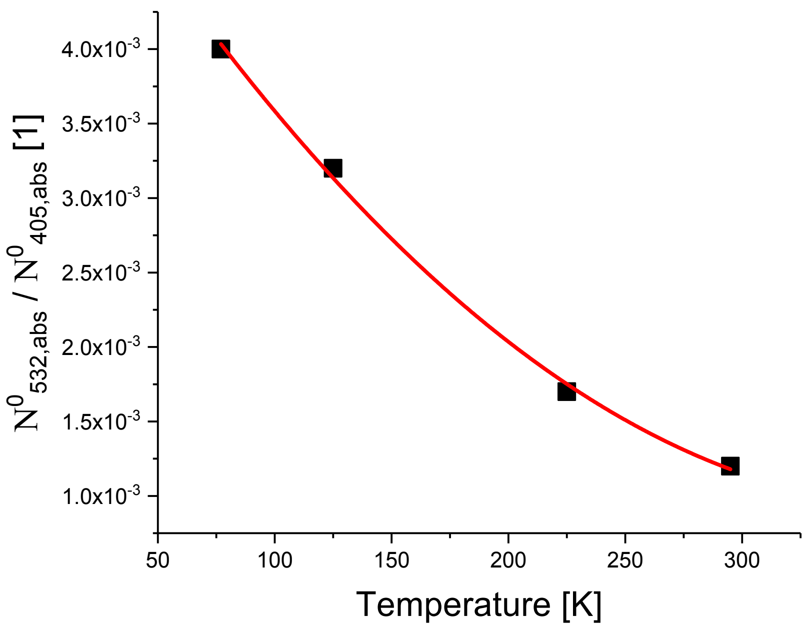

Figure S2: Ratio of absorbed photons at 532 nm and 405 nm extracted from the photoluminescence excitation spectra.

Condition for optical cooling

The minimum photoluminescence quantum yield to achieve cooling via anti-Stokes photoluminescence can be estimated by[1,2]

$$PLQY > \left(\frac{E_{em} - \Delta E}{E_{em}}\right)\left[\frac{f - f\eta_{ASPL} + \eta_{ASPL}}{\eta_{ASPL}}\right]$$

f is the fraction of subgap excitations not up-converted resulting in nonradiative heating

η_{ASPL} is an up-conversion e□ciency

ΔE is defined as the energy difference between excitation and emission

E_{em} corresponds to the photon energy at the barycenter of the photoluminescence spectrum

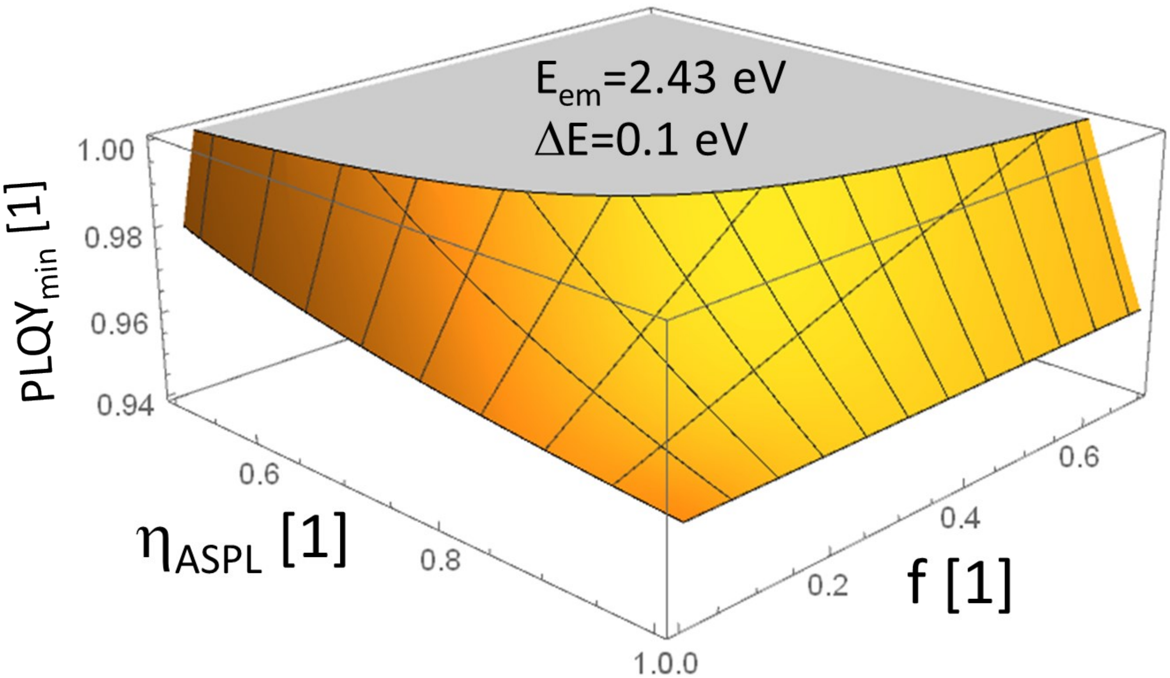

Figure S3: Minimum photoluminescence quantum yield required for photon cooling as a function of the up-conversion efficiency and the non-radiative recombination losses

References

[1] Zhang, S., Zhukovskyi, M., Jankó, B. & Kuno, M. Progress in laser cooling semiconductor nanocrystals and nanostructures. *NPG Asia Mater.* **11**, (2019).

[2] Morozov, Y. V. *et al.* Defect-Mediated CdS Nanobelt Photoluminescence Up-Conversion. *J. Phys. Chem. C* **121**, 16607–16616 (2017).