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Quantum cutting in lead halide perovskites

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Ytterbium-doped lead halide perovskites are promising materials for optical and optoelectronic applications due to the stable near-infrared (NIR) emission (~1000 nm) of Yb^{3+} ions and their low nonradiative losses. In these materials, Yb^{3+} ions can enable quantum cutting (QC), where one high-energy photon absorbed by the perovskite host is converted into two NIR photons, emitted by the dopant. This process offers a potential route to improve the efficiency of silicon solar cells [1]. QC in Yb^{3+}-doped perovskites is associated with the $^2F_{5/2} \rightarrow {}^2F_{7/2}$ transition of Yb^{3+}. Although this transition is parity-forbidden for free Yb^{3+} ions, it becomes partially allowed in the perovskite lattice due to crystal-field interactions. Previous studies have shown that both QC-active and inactive Yb^{3+} species can coexist in the $CsPb(Cl_xBr_{1-x})_3$ lattice [2,3].

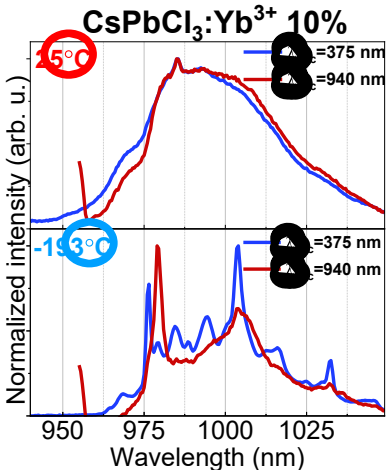

Fig. 1. PL spectra in NIR region at different temperatures of Yb-doped $CsPbCl_3$ upon 375 nm (blue) and 940 nm (red) excitation.

Here, we investigate the photoluminescence (PL) dynamics and oscillator strength of the $^2F_{5/2} \rightarrow {}^2F_{7/2}$ radiative transition for different Yb^{3+} species in $CsPb(Cl_xBr_{1-x})_3$ polycrystalline powders. Time-resolved PL measurements were performed under selective excitation of the perovskite host across its band gap and direct intra-4f excitation of Yb^{3+} ions. This approach allows us to distinguish the dynamics of Yb^{3+} species that are active and inactive in QC across different perovskite matrices.

We show that increasing temperature accelerates the PL decay and enhances the oscillator strength of Yb^{3+} ions, independently of the anion composition. However, the temperature dependence of the decay rate differs for QC-active and inactive Yb^{3+} species, indicating that their local environments and relaxation pathways are distinct. In $CsPbBr_3$ powders, where QC is strongly suppressed, the PL intensity and decay rate are governed by temperature-dependent host-to-Yb^{3+} energy transfer together with nonradiative relaxation. These results clarify the role of different Yb^{3+} centers in lead halide perovskites and provide guidelines for optimizing lanthanoid-doped materials for NIR emission and solar spectral conversion.

REFERENCES

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