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Rapid and Noise-Resilient Mapping of Photogenerated Carrier Lifetime in Halide Perovskite Thin Films

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Halide perovskite materials hold significant potential for solar energy and optoelectronics. However, to enhance their efficiency and stability, it is crucial to address challenges related to lateral inhomogeneity. Photoluminescence imaging techniques are commonly used to measure their optoelectronic and transport properties¹, but achieving high precision requires longer acquisition times. Extended light exposure, due to the high reactivity of perovskites, can significantly alter these layers, compromising the quality of the data.

We propose a method to extract high-quality lifetime images from quickly acquired, noisy time-resolved photoluminescence images². Our approach employs concepts from constrained reconstruction, incorporating the Huber loss function and a specific form of Total Variation Regularisation. This method effectively mitigates local signal-to-noise ratio (SNR) limitations, allowing access to greater detail and features in the results. Through simulations and experiments, we show that our method outperforms traditional pointwise techniques. Additionally, the analysis can be extended to determine the surface recombination rate. The determination of these key parameters can offer valuable insights into the advancement and optimization of halide perovskite materials. Indeed, the mitigation of bulk and interfacial recombination stands as a central focus within the solar cell community. Finally, we identify optimal acceleration and optimization parameters tailored for decay time imaging of perovskite materials, offering new insights for accelerated experiments crucial in degradation process characterization. Importantly, this methodology has broader applications: it can be extended to other beam-sensitive materials, various imaging characterisation techniques, and more complex physical models for time-resolved decays.

1. S. Cacovich, G. Vidon, M. Degani, M. Legrand, L. Gouda, J.-B. Puel, Y. Vaynzof, J.-F. Guillemoles, D. Ory, G. Grancini. Imaging and Quantifying non-Radiative Losses at 23% Efficient Inverted Perovskite Solar Cells Interfaces. *Nature Communications* 13 (1), 1-9, 2022.
2. G. Vidon, G. Scrivanti, E. Soret, N. Harada, E. Chouzenoux, J.-C. Pesquet, J.-F. Guillemoles, S. Cacovich. Fast and Noise-Tolerant Photogenerated Carrier Lifetime Maps from Time-Resolved Photoluminescence Imaging in Halide Perovskite Thin Films. *Advanced Functional Materials*, 240234, 2024.