Supplementary information

Fig. S1. Experimental set-up used for Raman-photocurrent-photoluminescence mapping

Fig. S2. (a) PbI₂ film thickness as a function of concentration. (b) Raman spectra of PbI₂ thin films on glass with different thicknesses. (c) PbI₂ Raman intensity integrated between 80 cm⁻¹ and 140 cm⁻¹ as a function of film thickness. The dotted line is a polynomial fit of experimental data.
**Fig. S3.** (a) Typical J-V curves of perovskite solar cells with structure glass/ITO/NiO$_x$/CH$_3$NH$_3$PbI$_3$/PCBM/BCP/Ag using stoichiometric or 5% PbI$_2$ excess perovskite solution. (b) statistical power conversion efficiency data for 10 different devices having stoichiometric or 5% PbI$_2$ excess perovskite.

**Fig. S4.** Raman spectra of MAPbI$_3$ films on ITO/glass substrates prepared with different amounts of PbI$_2$ excess. Each spectrum is an average of 200 data points measured using laser power of 0.15 mW for 10 s.

**Fig. S5.** high and low magnification SEM top-view images of perovskite films degraded with (a-b) 0.03 mW laser power for 120 s and (c-d) 0.3 mW laser power for 120 s in air, with corresponding Energy Dispersive Spectroscopy (EDS) measurements taken at various locations along the degraded spot (b and d).