Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Supporting Information

Ultra-Broadband Optical Amplification at Telecommunication Wavelengths Achieved by Bismuth-Activated Lead Iodide Perovskites

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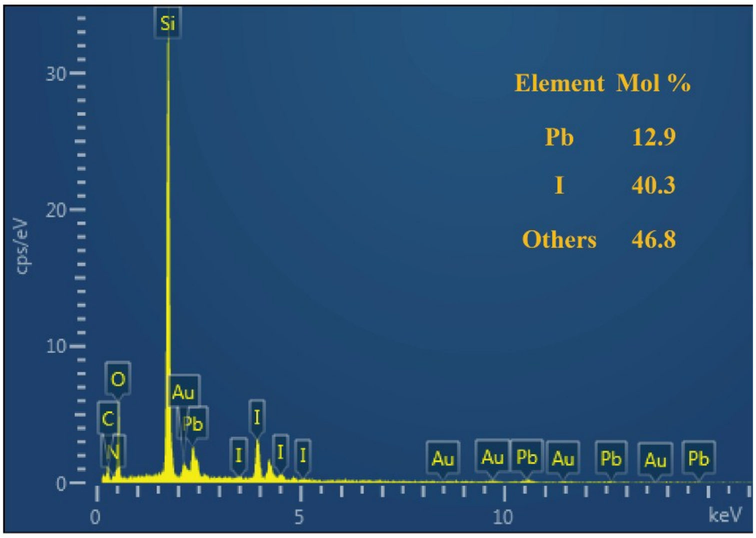

Figure S1. Energy dispersive X-ray spectroscopy (EDX) of the $PbAc_2$-derived film.

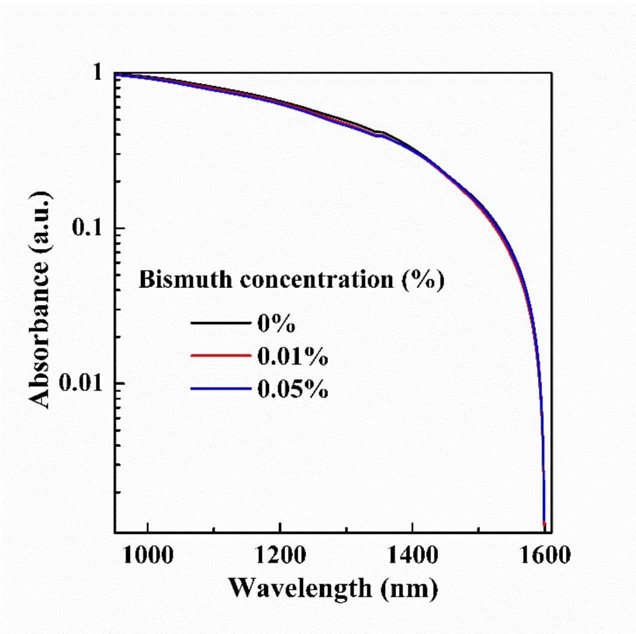

Figure S2. Absorption spectra of the pristine, 0.01% and 0.05% Bi-doped films. We note that in the NIR region, no obvious absorption bands occur. Note that we took the absorption spectra in this range by a a UV-vis-NIR spectrophotometer (Cary 5000, Agilent), because our PDS measurement cannot extend to such wavelengths.

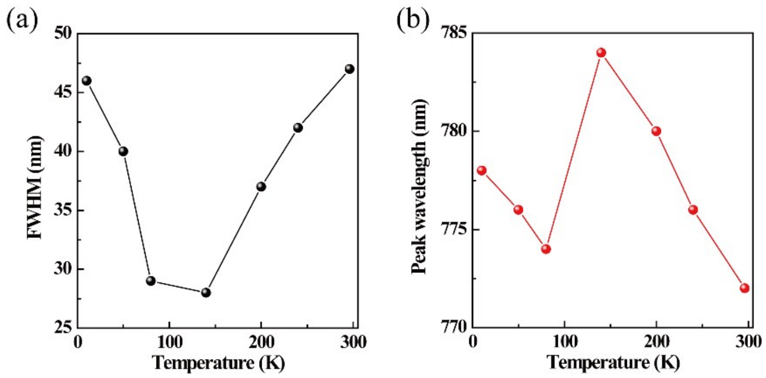

Figure S3. (a) FWHMs and (b) PL peak of the PL spectra taken at different temperatures for the $PbAc_2$-derived film.

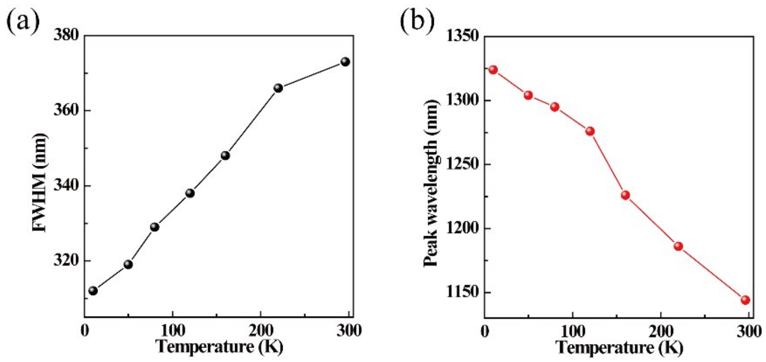

Figure S4. (a) FWHMs and (b) PL peak of the NIR PL spectra taken at different temperatures for the $PbAc_2$-derived film.

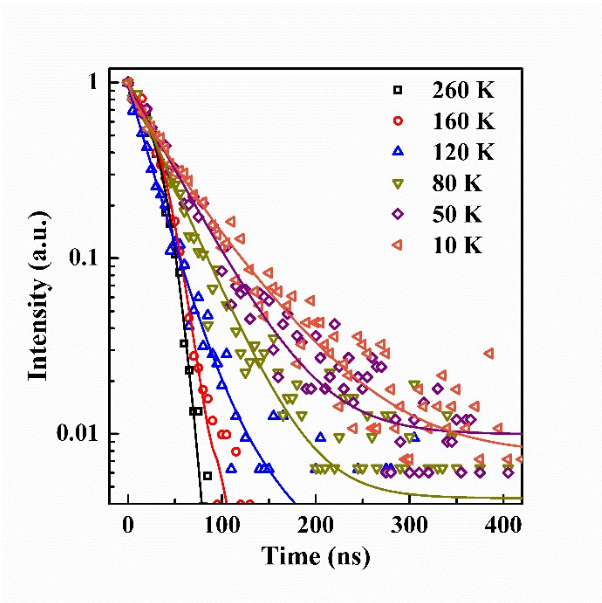

Figure S5. Time-resolved PL dynamics measurements at different temperatures for the $PbAc_2$-derived film. The solid line was drawn to guide the eye.

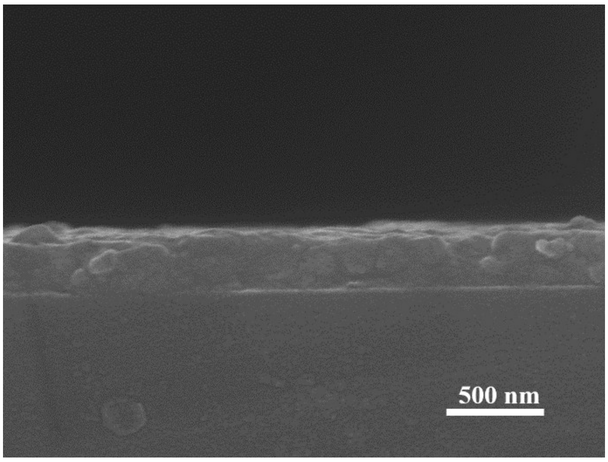

Figure S6. Cross-section SEM image of the $PbAc_2$-derived film.

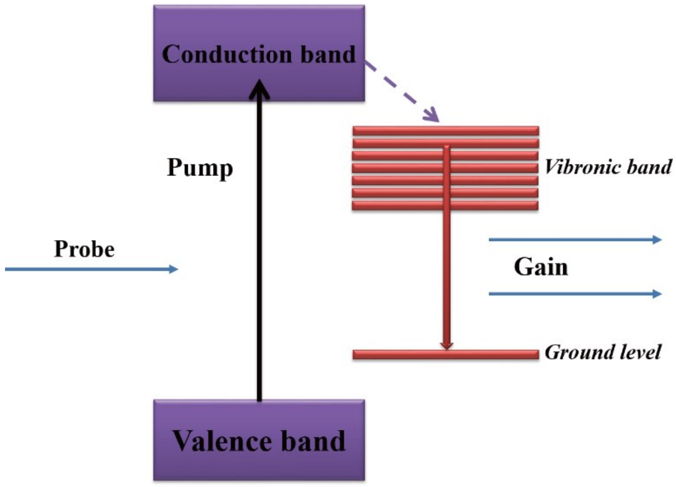

Figure S7. Schematic of the experimental setup for the light amplification experiment.

Table S1. The calculated average lifetimes of the $PbAc_2$-derived film at different temperatures. The emission wavelengths are the PL peak of the NIR PL spectra.

Temperature (K)	260	160	120	80	50	10
Emission wavelength (nm)	1165	1226	1276	1295	1304	1324
Average lifetime[a] (ns)	19	22	32	49	66	76

a. Average lifetime (τ_{ave}) is calculated by: $\tau_{ave} = \frac{\int_0^\infty tI(t)dt}{\int_0^\infty I(t)dt} = \frac{\int_0^\infty t exp\left(-\frac{t}{\tau}\right)dt}{\int_0^\infty \exp\left(-\frac{t}{\tau}\right)dt}$.

Table S2. Comparison of optical amplification results using different Bi-activated materials as gain media.

Sample	Laser source (nm)	Pumping power (W)	Emission wavelength (nm)	Thickness (mm)	Max.gain coefficient (cm^{-1})	Reference
$1Bi_2O_3$-$7Al_2O_3$-$92SiO_2$ glass	810	1	1307.5	1	0.62	2
$1Bi_2O_3$-$7Al_2O_3$-$91SiO_2$-Li_2O glass	808	0.97	1315	1	0.32	3
$1Bi_2O_3$-$5Al_2O_3$-20SrO-$75GeO_2$ glass	808	1.12	1272	1	1.03	4
$82P_2O_5$-$17Al_2O_3$-$1Bi_2O_3$-$3.5Yb_2O_3$ glass	980	1	1272	1	2.62	5
$PbAc_2$-derived perovskites (77 K)	450	1.18×10^{-3}	1310	3.07×10^{-4}	1.2×10^{5}	This work
PbAc2-derived perovskites (296 K)	450	1.20×10^{-2}	1310	3.07×10^{-4}	7.1×10^{3}	This work

Table S3. PL QEs of the $PbAc_2$-derived film at cryogenic temperatures.

Temperature (K)	296	220	160	120	80	50	10
PL QE (%)	0.019	0.089	0.28	2.17	5.57	7.87	9.93

References

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