

## Supporting Information

### Bi<sup>3+</sup>-Sensitized La<sub>2</sub>Zr<sub>2</sub>O<sub>7</sub>: Er<sup>3+</sup> Transparent Ceramics with Efficient Up/Down-Conversion Luminescence Properties for Photonic Applications

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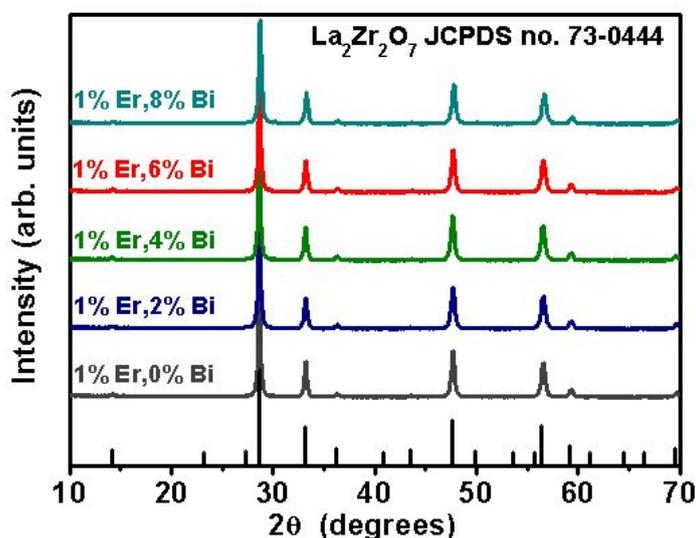
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## Experimental Section

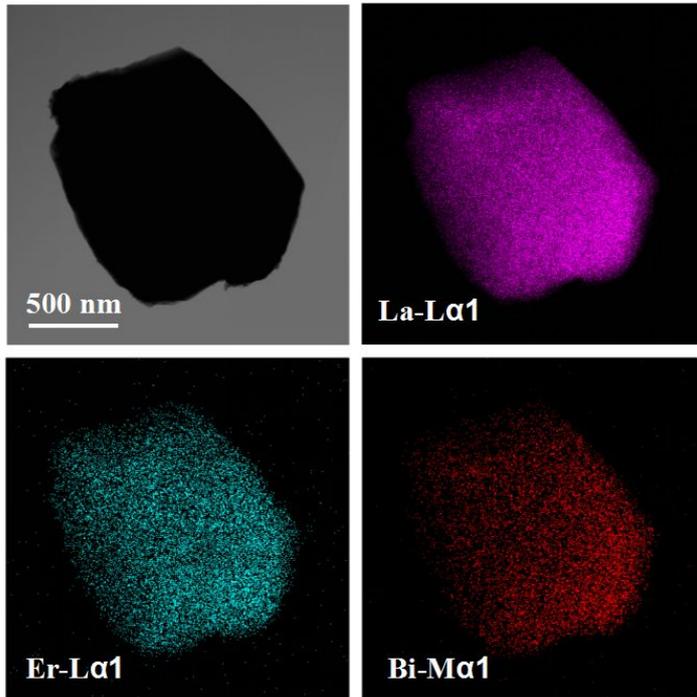
In a typical synthesis, the nano-sized La<sub>2</sub>Zr<sub>2</sub>O<sub>7</sub> powders were prepared via a hydrothermal-assisted method. The starting materials, a certain amount of Bi(NO<sub>3</sub>)<sub>3</sub>·5H<sub>2</sub>O and Er(NO<sub>3</sub>)<sub>3</sub>·6H<sub>2</sub>O, were firstly dissolved in 1.5 mL concentrated nitric acid and subsequently mixed with La(NO<sub>3</sub>)<sub>3</sub>·6H<sub>2</sub>O and Zr(NO<sub>3</sub>)<sub>4</sub>·5H<sub>2</sub>O aqueous solution stoichiometrically (the molar ratios (La<sup>3+</sup>+Er<sup>3+</sup>+Bi<sup>3+</sup>):Zr<sup>4+</sup>=0.01 mol/L:0.01 mol/L=1:1). Then, 1.5×10<sup>-3</sup> mol/L CTAB as a surfactant was blended with above-mixed solution under continuous magnetic stirring until it became a clear solution. This obtained solution was added into 50 mL 2 mol/L NaOH solution to form a homogeneous white suspension. After that, the mixture was introduced into a Teflon autoclave and heated under 200°C for 24 h. The obtained precipitates, which were washed by distilled water and ethanol, were dried and further sieved through a 200 mesh screen. Afterword, pure LZO: Er, Bi nano-powders were synthesized by calcinating the precursor powders at 1000°C for 5 h. The as-synthesized powders were pressed into pellets (Φ10×1.5 mm) and then cold isostatically pressed at 250

MPa. Finally, after sintered at 1850°C for 10 h in a vacuum (vacuum level: around  $10^3$  Pa) and subsequently annealed at 1200°C for 4 h in air, LZO: Er, Bi transparent ceramics were obtained.

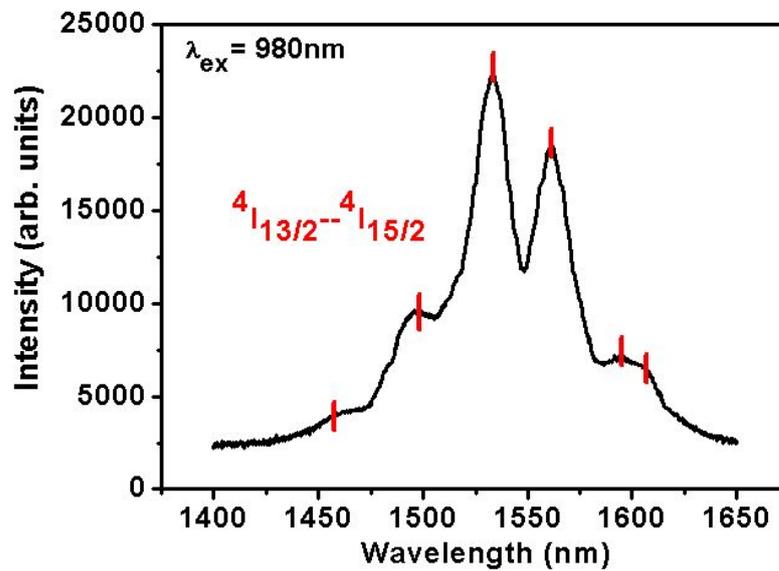
Sample compositions and phase structures were identified from an X-ray powder diffractometer (XRD, Dx-2700, Dandong Fangyuan Instrument Co., Ltd, Liaoning, China). The morphology of precursor powder was characterized by scanning electron microscopy (SEM, Model S-4800, Hitachi, Japan) and their microstructure properties were monitored and analyzed by Transmission electron microscopy (TEM, Tecnai G2 F20 S-TWIN, FEI, Hillsboro, OR). The transmittance of the LZO:Er,Bi ceramics were measured using a UV/Vis/NIR spectrophotometer (Lambda-750, Perkin-Elmer). Up-conversion and infrared emission spectra and fluorescence lifetime of LZO transparent ceramics were obtained from a fluorolog-3 spectrofluorometer (Horiba JobinYvon) equipped with a 980 nm laser as the excitation source as well as a CCD (Synapse) and a PMT (H10330-75) as the detector. The luminescence spectra of ceramics were measured using a fluorescence spectrophotometer (F-7000, Hitachi, Japan) with a xenon lamp as the excitation source. All measurements were performed at room temperature.



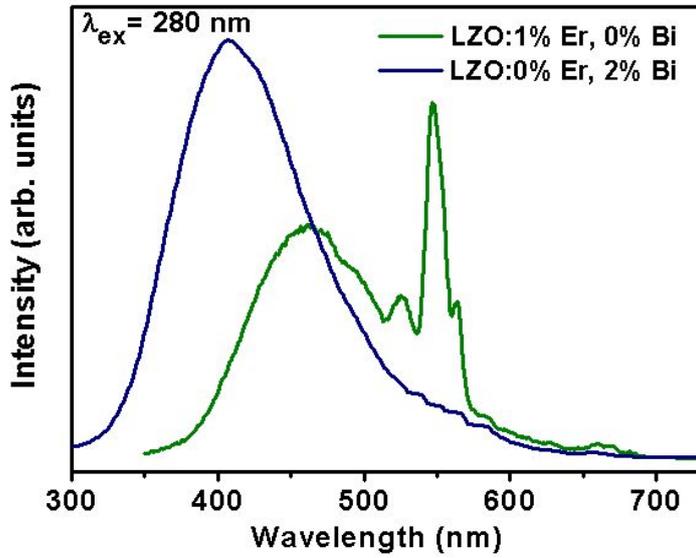
**Figure S1.** XRD patterns of as-prepared powders with different  $\text{Bi}^{3+}$  concentrations calcinated at 1000°C.



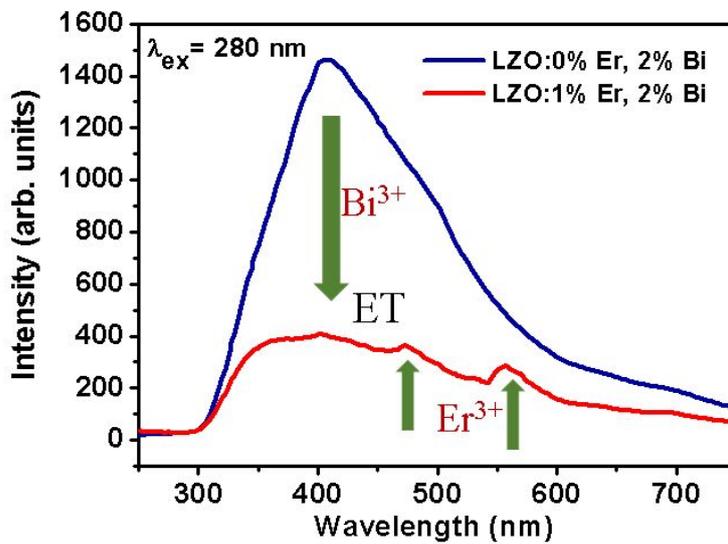
**Figure S2.** TEM image and EDS mapping images of LZO: 1% Er, 2% Bi ceramics.



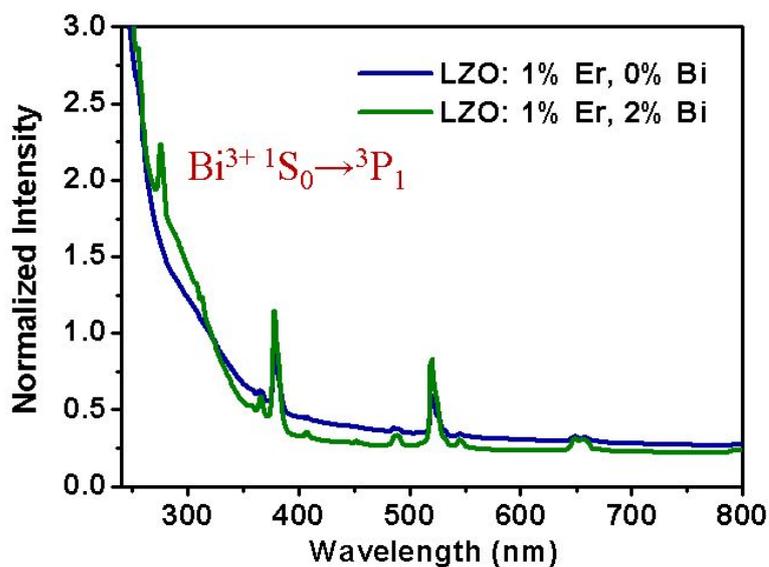
**Figure S3.** Infrared emission peaks of LZO: 1% Er, 6% Bi ceramic under 980 nm laser excitation.



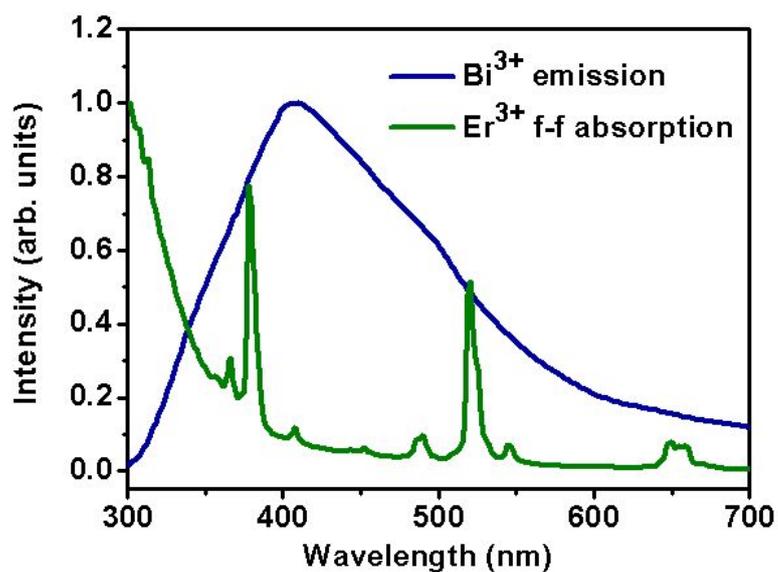
**Figure S4.** The photoluminescence spectra of LZO: 2% Bi and LZO: 1% Er ceramics under the excitation of 280 nm.



**Figure S5.** The photoluminescence spectra of LZO: 2% Bi and LZO: 1% Er, 2% Bi ceramics under the excitation of 280 nm. The  $\text{Er}^{3+}$  emission is enhanced at the expense of the  $\text{Bi}^{3+}$  emission centered at 402 nm in Er/Bi codoped LZO ceramics.



**Figure S6.** The absorption spectrum of LZO: 1% Er and LZO: 1% Er, 2% Bi.



**Figure S7.** The emission spectrum of  $\text{Bi}^{3+}$  and f-f absorption spectrum of  $\text{Er}^{3+}$  in LZO ceramics.

**Table S1.** The lattice parameter of as-prepared LZO powders doped with different  $\text{Bi}^{3+}$  concentrations calcinated at  $1000^\circ\text{C}$ .

Samples	LZO:1% Er	LZO:1%Er,2%Bi	LZO:1%Er,4%Bi	LZO:1%Er,6%Bi	LZO:1%Er,8%Bi
Lattice parameter (Å)	10.788	10.791	10.796	10.799	10.802

**Table S2.** The results of EDS analysis of LZO: 1% Er, 2% Bi.

Element	wt%	at%
O	19.45	63.32
Zr	34.45	19.67
Bi	1.73	0.43
La	43.50	16.31
Er	0.88	0.27

**Table S3.** The fitting parameters for luminescence decay curves of LZO: 1% Er, x% Bi (x=0, 2, 4, 6, 8) ceramics under the excitation of 980 nm.

Sample	A <sub>1</sub>	τ <sub>1</sub> [μs]	A <sub>2</sub>	τ <sub>2</sub> [μs]	τ [μs]
LZO:1% Er	0.87	76.96	0.13	603.97	361.41
LZO:1% Er,2% Bi	0.92	86.38	0.08	845.94	435.72
LZO:1% Er,4% Bi	0.91	93.68	0.09	830.31	437.78
LZO:1% Er,6% Bi	0.91	92.11	0.09	829.06	439.18
LZO:1% Er,8% Bi	0.91	89.57	0.09	841.96	452.05

**Table S4.** The fitting parameters for the infrared luminescence decay curves of LZO:1% Er and LZO:1% Er, 6% Bi under the excitation of 980 nm.

Sample	A <sub>1</sub>	τ <sub>1</sub> [μs]	A <sub>2</sub>	τ <sub>2</sub> [μs]	τ [μs]
LZO:1% Er	0.14	1.23	0.86	4.75	4.61
LZO:1% Er,6% Bi	0.79	8.02	0.21	2.20	7.62

**Table S5.** The fitting parameters for luminescence decay curves of LZO: 2% Bi and LZO: 1% Er, 2% Bi under the excitation of 280 nm.

Sample	$A_1$	$\tau_1$ [ $\mu$ s]	$A_2$	$\tau_2$ [ $\mu$ s]	$\tau$ [ $\mu$ s]
LZO:2% Bi	0.82	4.32	0.18	23.56	14.80
LZO:1% Er,2% Bi	0.86	3.69	0.14	19.55	11.03