Electronic Supplementary Information

Y_2O_3-YAG:Ce composite phosphor ceramic with enhanced light extraction efficiency for solid state laser lighting

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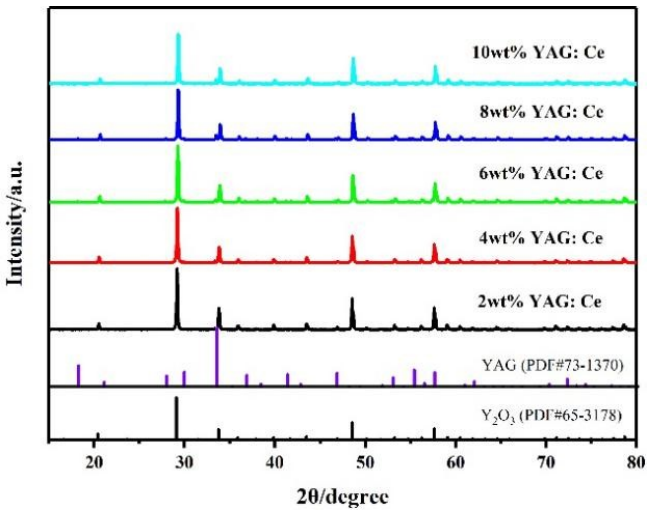

Figure S1 XRD pattern of Y_2O_3-YAG:Ce composite phosphor ceramics with different YAG:Ce phosphor contents.

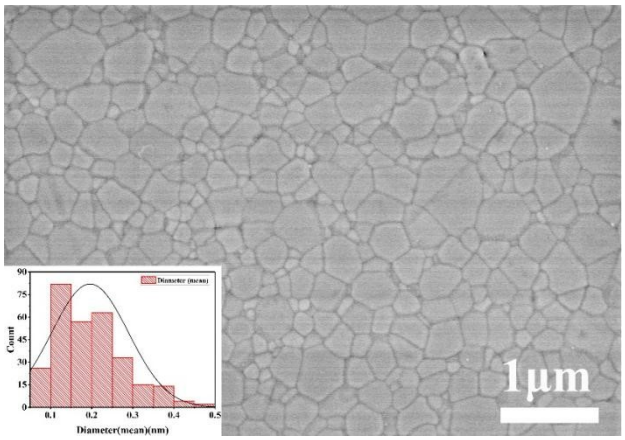

Figure S2 The surface SEM image of Y_2O_3-YAG:Ce composite phosphor ceramic after thermal etching and the result of the grain size distribution shows in inset.

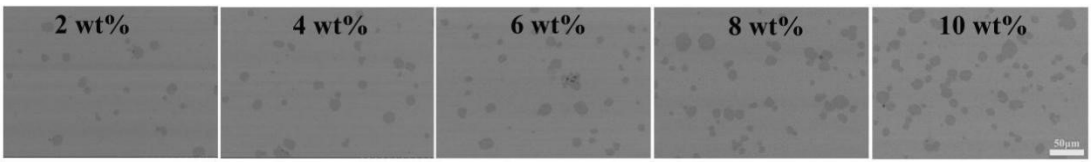

Figure S3 The backscattered SEM images of Y_2O_3-YAG:Ce composite phosphor ceramics with different YAG:Ce phosphor contents.

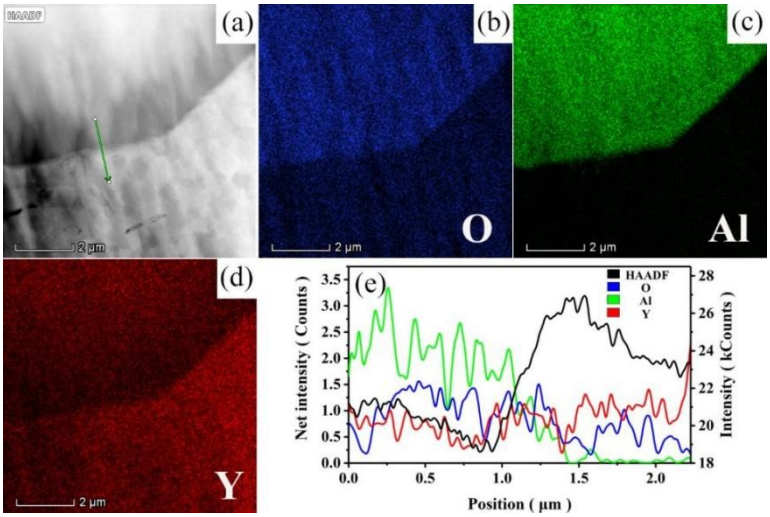

Figure S4 TEM image (a) of the composite phosphor ceramic with 6 wt% YAG:Ce phosphor and the EDS element mapping images from (b) to (d). The HAADF curves (e) of different element according to the green straight line from the phosphor particles to the polycrystalline Y_2O_3 matrix.

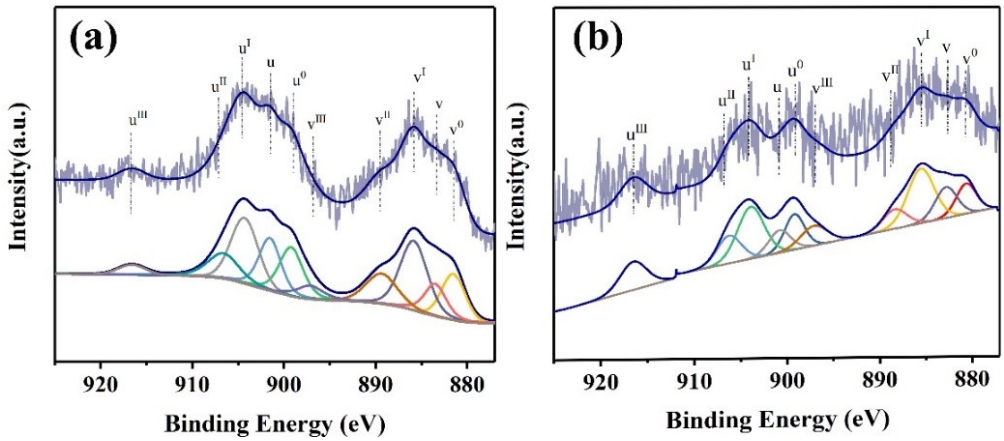

Figure S5 X-ray photoelectron spectroscopy (XPS) spectra of Ce $3d_{3/2,5/2}$ in (a) YAG:Ce phosphor and (b) Y_2O_3-YAG:Ce composite phosphor ceramic and corresponding fitting curves.

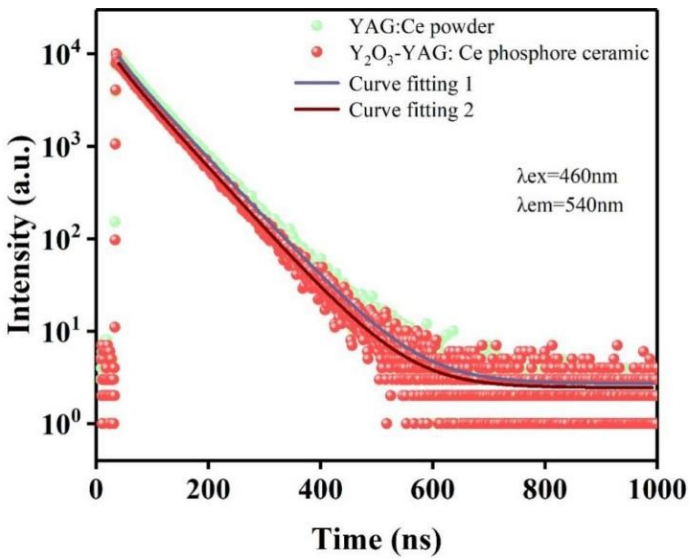

Figure S6 The YAG:Ce fluorescence decay curves of YAG:Ce phosphor and Y_2O_3-YAG:Ce phosphor ceramic and corresponding fitting curves, the fitting curve 1 is for YAG:Ce phosphor, fitting curve 2 is for Y_2O_3-YAG:Ce phosphor ceramic. The excitation wavelength and emission wavelength were 460 nm and 540 nm, respectively.

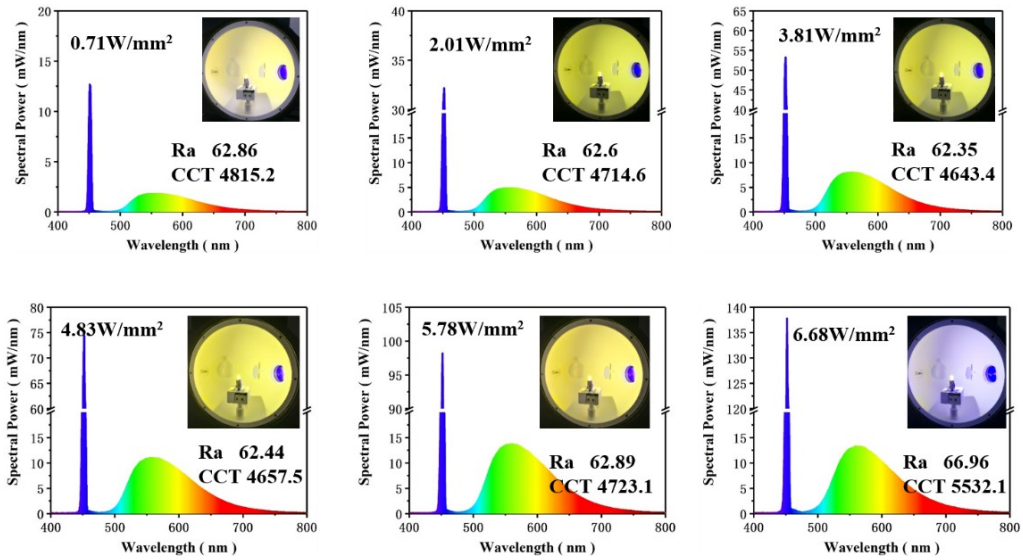

Figure S7 Luminescence spectra and corresponding color rendering index (CRI), correlated color temperature (CCT) and physical images of Y_2O_3-YAG:Ce phosphor ceramic with 8 wt% concentration under 450 nm blue lasers with different power densities.

Table S1. The core excitation binding energy (eV) of Ce 3d and the corresponding atomic relative area are collected from Ce^{4+} and Ce^{3+} in YAG:Ce phosphor and Y_2O_3-YAG:Ce phosphor ceramic with 20 wt% phosphor contents.

	Ce: YAG	Peak/eV	Area/a.u.	Relative perc/%	Phos Cera	Peak/eV	Area/a.u.	Relative perc/%
Ce^{4+} 3d	$3d_{3/2}$	901.55	1930.21	43.51%	$3d_{3/2}$	900.80	792.80	45.81%
	$3d_{5/2}$	883.49	1252.54		$3d_{5/2}$	882.81	1100.76	
	$3d_{3/2}$	906.61	1386.52		$3d_{3/2}$	906.23	1068.92	
	$3d_{5/2}$	889.36	1535.88		$3d_{5/2}$	888.36	750.65	
	$3d_{3/2}$	916.57	409.54		$3d_{3/2}$	916.50	1200.97	
	$3d_{5/2}$	897.16	696.69		$3d_{5/2}$	897.09	845.47	
Ce^{3+} 3d	$3d_{3/2}$	899.22	1965.08	56.49%	$3d_{3/2}$	899.21	1129.65	54.92%
	$3d_{5/2}$	881.51	1657.74		$3d_{5/2}$	880.62	987.20	
	$3d_{3/2}$	904.32	2708.86		$3d_{3/2}$	903.91	2218.43	
	$3d_{5/2}$	885.85	3031.41		$3d_{5/2}$	885.54	2336.19	

Table S2. The luminous flux (LF), LE, CCT, CRI and the CIE color coordinates (x, y) of Y_2O_3-YAG:Ce composite phosphor ceramic with different YAG:Ce phosphor contents under 450 nm blue laser light radiation with 4.24 W mm^{-2} powder density.

Sample	CCT	CRI	CIE color coordinates (x , y)	LF (lm)	LE (lm W^{-1})
2 wt% YAG: Ce	8314	73	(0.2987, 0.2839)	489.47	147.02
4 wt% YAG: Ce	5335	66	(0.3364, 0.3453)	538.22	161.66
6 wt% YAG: Ce	5564	66	(0.331, 0.3286)	549.53	165.06
8 wt% YAG: Ce	4638	62	(0.357, 0.3664)	593.28	178.20
10 wt% YAG: Ce	4884	63	(0.3477, 0.3474)	545.29	163.79

Table S3. Saturation power densities, LF and LE for the reported LDs adopting phosphor in glass,

transparent ceramic and CPCs as color converters.

Composition	Saturation Power Density (W/mm^2)	LF (lm)	LE (lm/W)	Reference
YAG:Ce phosphor in silica glass (PiSG)	3.46	—	—	*1*
Single-phase YAG:Ce transparent ceramic	11.94	700	123.3	*2*
	—	—	170	*3*
$Y_{3-x}Mg_xAl_{5-2x}Si_xO_{12}$:0.5%Ce（x=0.005）transparent ceramic	~4.0	~650	223	*4*
Al_2O_3-YAG:Ce CPCs	20.1	1367	135.3	*2*
	—	1200	165	*5*
	32	—	305	*6*
$BaAl_2O_4$-YAG:Ce CPCs	—	479	37	*7*
MgO-YAG:Ce CPCs	32.2	3979	292	*8*
AlN-YAG:Ce CPCs	—	639	266	*9*
YAG-YAG:Ce CPCs	9.60	—	142	*10*
Y_2O_3-YAG:Ce CPCs	6.14	805	178.4	**This work**

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