Supporting Information

High-efficient and thermal-stable broadband NIR phosphor by rationally bridging Cr^{3+}-Yb^{3+} in $LiScGe_2O_6$ for optical bioimaging

Chuanlong Wang[a], Yahong Jin[a,*], Lifang Yuan[b], Bo Wang[c], Ruiting Zhang[a], Haoyi Wu[a], Qing Yao[a], and Yihua Hu[a,*]

[a]School of Physics and Optoelectronic Engineering, Guangdong University of Technology, WaiHuan Xi Road, No. 100, Guangzhou 510006, P. R. China

[b]School of Electronics and Communications, Guangdong Mechanical & Electronical College of Technology, Guangzhou 510515, P. R. China

[c]School of Applied Physics and Materials, Wuyi University, Jiangmen 529020, P. R. China

*Corresponding authors

E-mail: yhjin@gdut.edu.cn; huyh@gdut.edu.cn

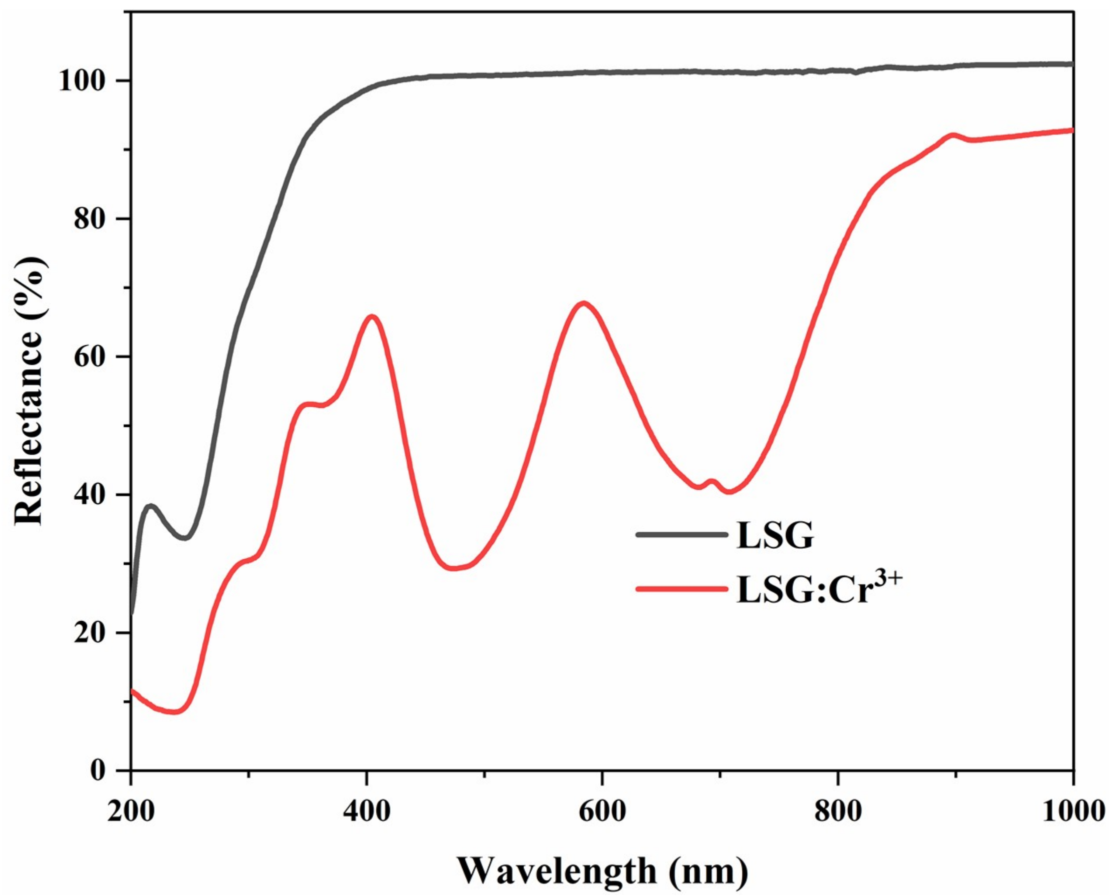

Fig. S1. DRS of LSG host and LSG:0.07Cr^{3+}.

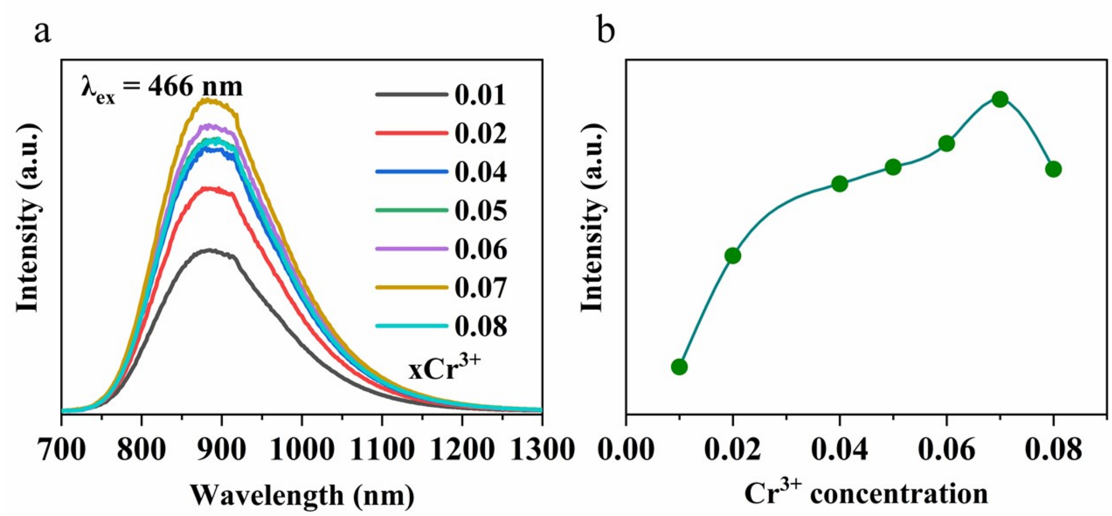

Fig. S2. (a) PL spectra of LSG:xCr^{3+} (x = 0.01-0.08). (b) Emission intensities of Cr^{3+} as a function of Cr^{3+} doping concentration.

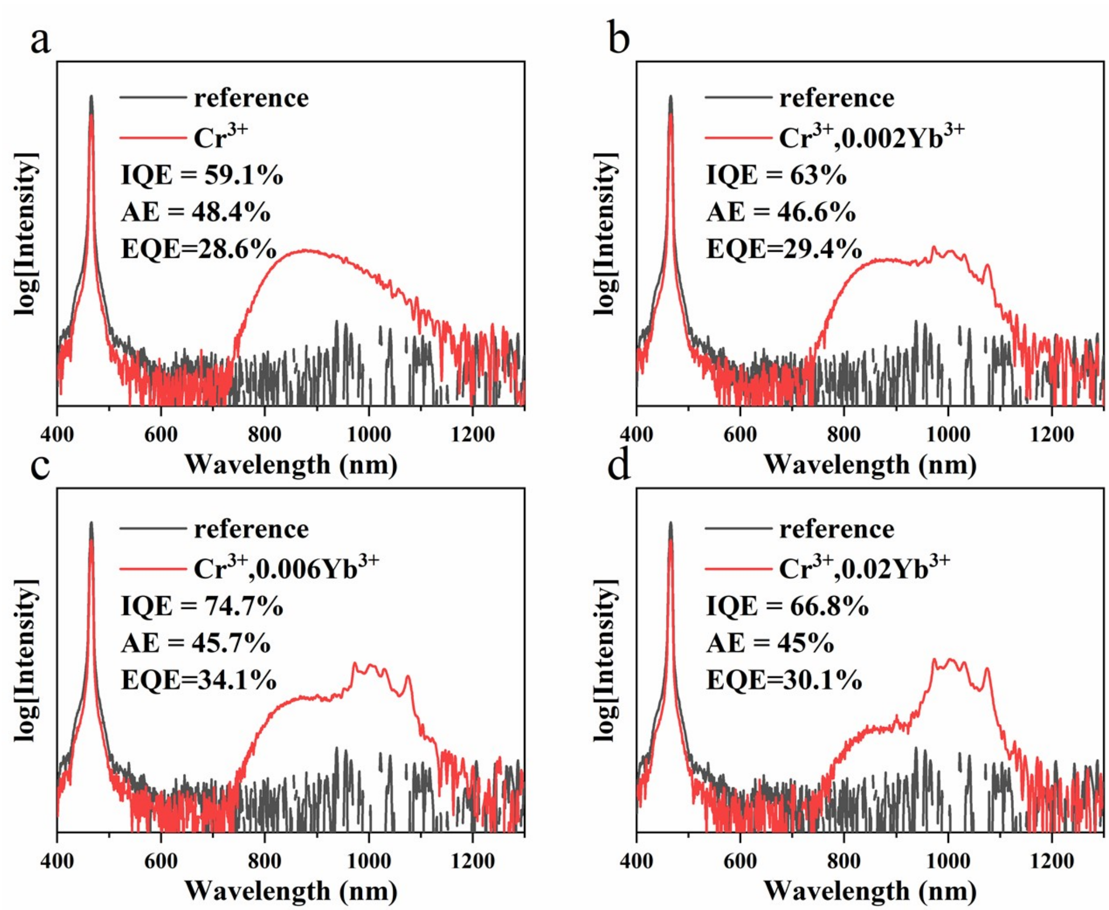

Fig. S3. IQE, AE and EQE of LSG:0.07Cr^{3+}, yYb^{3+} (y = 0, 0.002, 0.006, and 0.02).

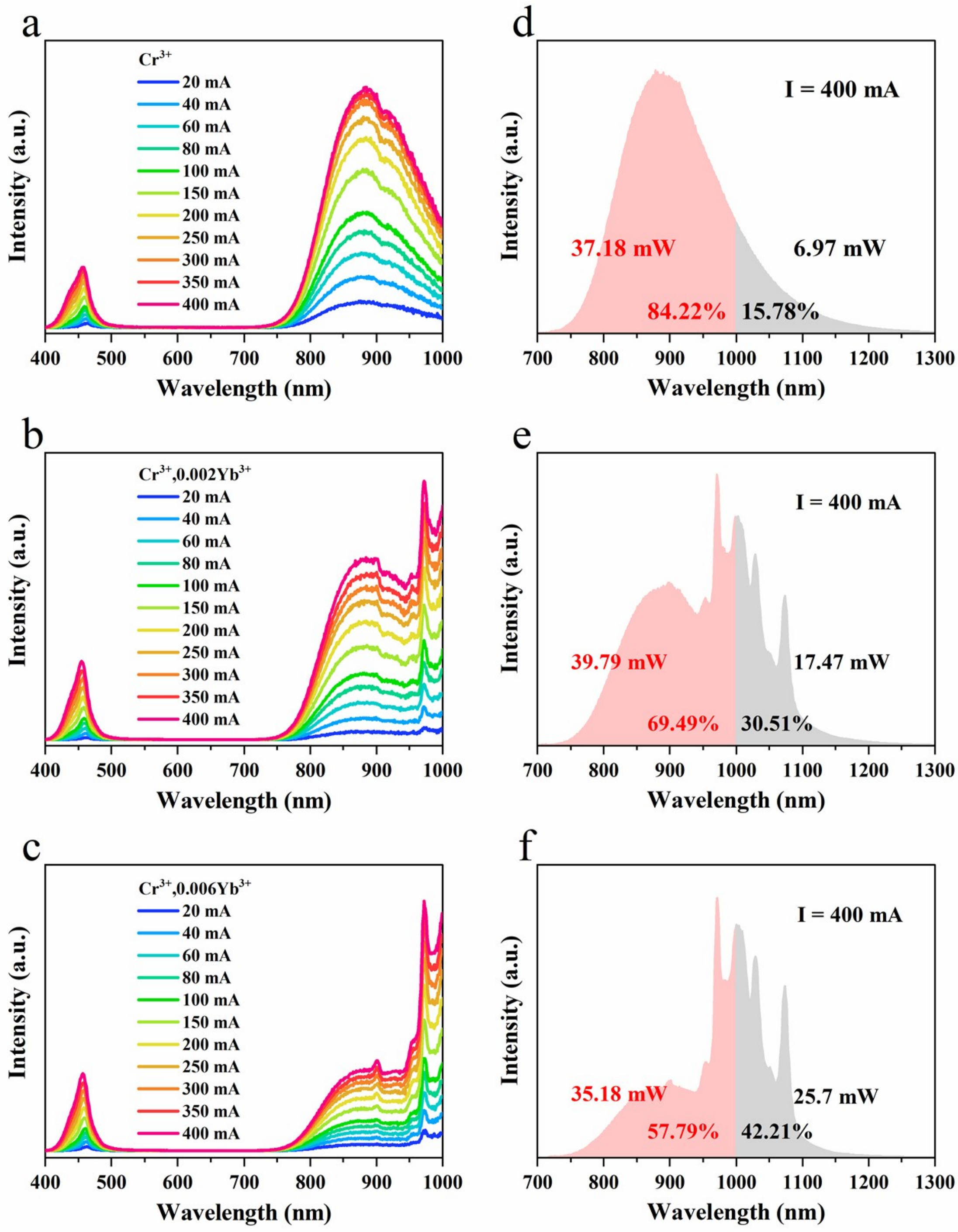

Fig. S4. (a-c) The electroluminescence spectra of the as-obtained NIR pc-LED based on LSG:0.07Cr^{3+}, yYb^{3+} (y = 0, 0.002, 0.006) at various driven currents. (d-f) The corresponding NIR output power at 400 mA based on PL spectra of LSG:0.07Cr^{3+}, yYb^{3+} (y = 0, 0.002, and 0.006). The integrated emission intensity ratios of 700-1000 nm and 1000-1300 nm of the as-obtained NIR pc-LED based on LSG:0.07Cr^{3+}, yYb^{3+} (y = 0, 0.002, and 0.006) are calculated to be 84.22:15.78, 69.49:30.51 and 57.79:42.21, respectively.

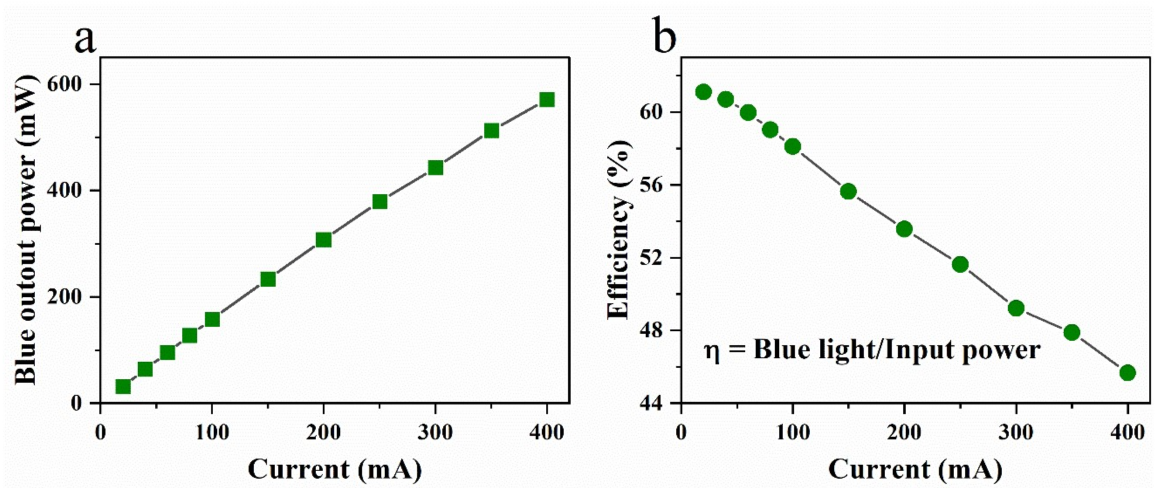

Fig. S5. (a) Output power of the 460 nm blue LED chip at different input currents. (b) Photoelectric conversion efficiency of the 460 nm LED chip as a function of driven current.

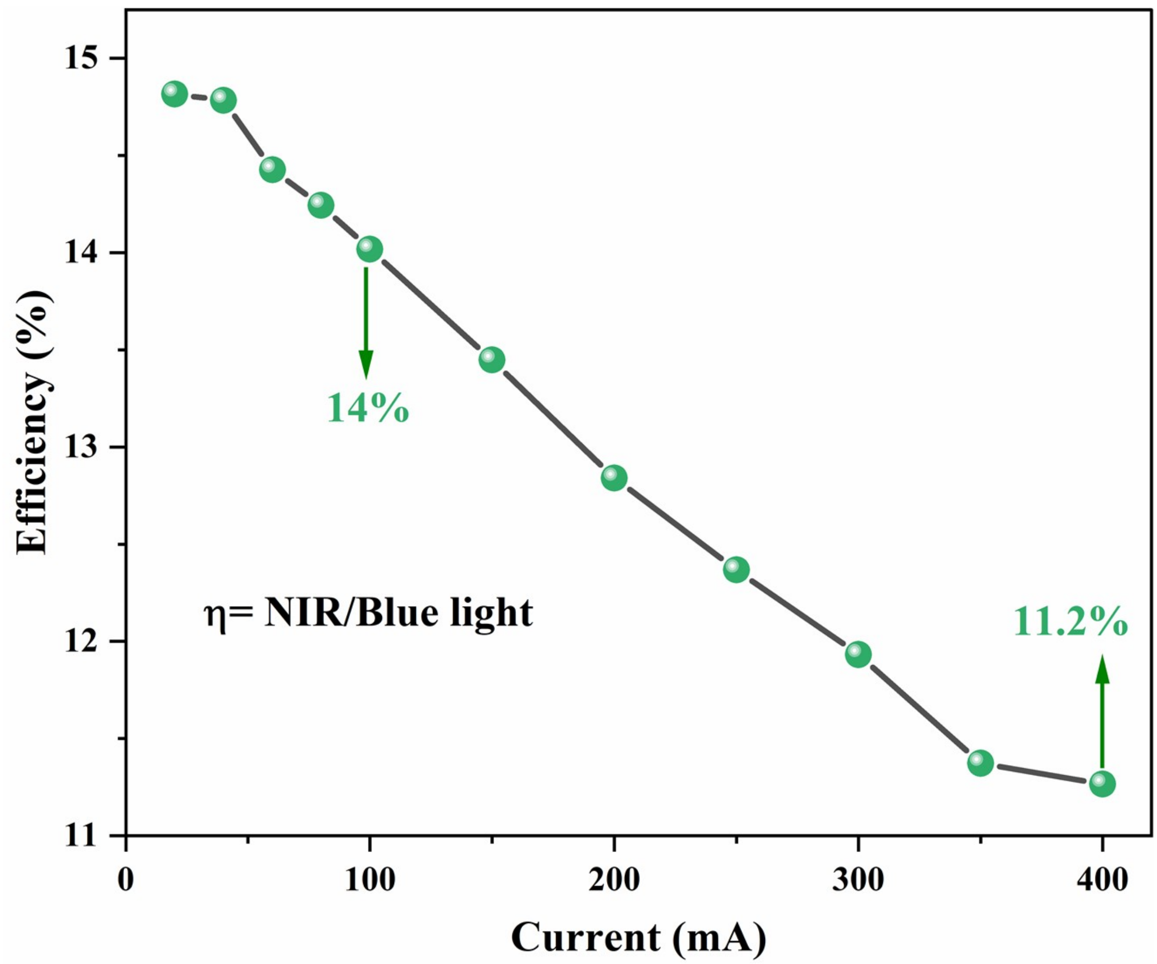

Fig. S6. The conversion efficiency of Blue to NIR light as a function of driven current.

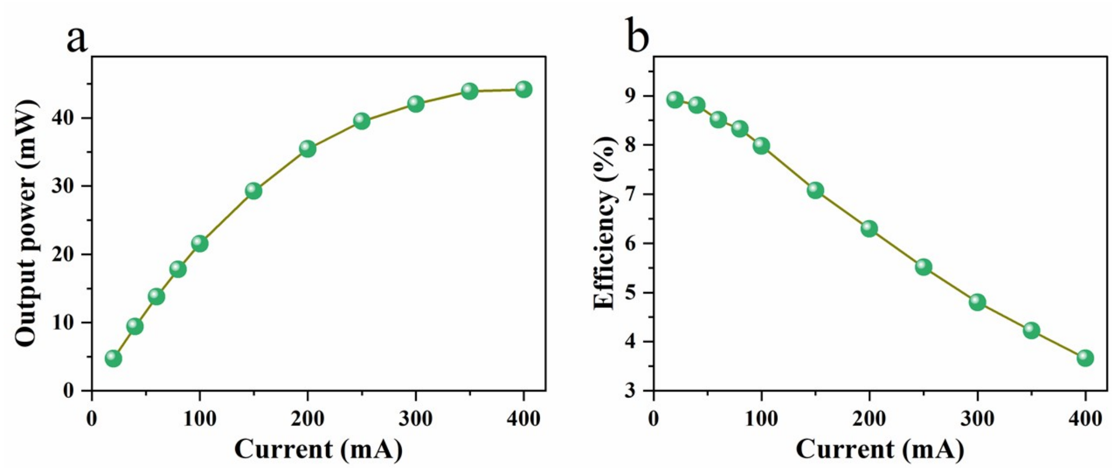

Fig. S7. (a) NIR output power and (b) photoelectric conversion efficiency of the fabricated pc-LED (by using LSG:0.07Cr^{3+} phosphor) as a function of driven current.

Table S1. IQE, EQE, thermal stability (using the percentage of remaining emission intensity at 100 ℃ (or 150 ℃) of the room-temperature value as a measure), and photoelectric parameters of some previously reported Cr^{3+}-activated and Cr^{3+}-Yb^{3+} co-activated phosphors with emission peak exceeding 830 nm.

Phosphor	Peak position (nm)	IQE (%)	EQE (%)	$I_{100℃}$ (or $I_{150℃}$) (%)	NIR output power (mW)@current (mA)@ efficiency	Ref.
$LiScGeO_4:Cr^{3+}$	1120	26	-	30_{100}	4.78@60@4.4%	1
$LiIn_2SbO_6:Cr^{3+}$	970	7	3.44	10_{100}	-	2
$CaSc_{0.85}Al_{1.15}SiO_6:Cr^{3+}$	950	30	9.3	77_{100}	-	3
$Mg_2GeO_4:Cr^{3+}$	940	48.19	16.38	-	-	4
$NaInGe_2O_6:Cr^{3+}$	900	34	-	55_{100}	25.2@120@4.5%	5
$NaScGe_2O_6:Cr^{3+}$	895	40.22	-	20_{150}	12.07@350@-	6
$LiScP_2O_7:Cr^{3+}$	880	38	20	42_{100}	19@100@7%	7
$LiInGe_2O_6:Cr^{3+}$	880	81.2	39.8	45_{100}	-	8
$Y_{0.57}La_{0.72}Sc_{2.71}(BO_3)_4:Cr^{3+}$	850	41.1	-	42_{100}	17.61@300@-	9
$Sr_9Ga_{0.2}(PO_4)_7:0.8Cr^{3+}$	850	66.3	29.9	-	19.79@150@4.23	10
$Ga_4GeO_8:Cr^{3+}$	850	60	27	73_{100}	55.94@400@3.8%	11
$La(Sc, Ga)_3B_4O_{12}:Cr^{3+}$	850	52.12	-	55_{150}	-	12
$LiGaP_2O_7:Cr^{3+}$	846	47.8	28.3	51_{100}	28.1@120@7.8%	13
$BaZrGe_3O_9:Cr^{3+}$	830	-	-	53_{150}	6.45@320@0.6%	14
$Ca_4ZrGe_3O_{12}:Cr^{3+}, Yb^{3+}$	840, 968	25.5	-	73_{100}	-	15
$LiInP_2O_7:Cr^{3+}, Yb^{3+}$	860, 1000	27.5	10.8	50_{100}	6.24@100@2.2%	16
$LiIn_2SbO_6:Cr^{3+}, Yb^{3+}$	973	10	4.76	30_{100}	2.74@180@-	2
$LSG:Cr^{3+}, Yb^{3+}$	880, 980	76.3	36.2	86_{100}	22.19@100@8.22% 31.43@150@7.59% 52.86@300@6.02% 64.26@400@5.32%	This work

Table S2. Photoelectric parameters of the fabricated NIR pc-LED with LSG:0.07Cr^{3+} under various currents.

Current (mA)	Input electrical power (mW)	NIR output power (mW) (700-1000 nm)	NIR output power (mW) (700-1300 nm)	Photoelectric conversion efficiency (%)
20	51.32	3.85	4.57	8.91
40	104.3	7.74	9.19	8.81
60	158.4	11.35	13.48	8.51
80	213.7	14.98	17.78	8.32
100	269.8	18.14	21.53	7.98
150	414	24.67	29.29	7.05
200	563.2	29.86	35.45	6.29
250	716.3	33.26	39.49	5.51
300	876.3	35.41	42.04	4.79
350	1040	36.97	43.89	4.22
400	1208	37.19	44.15	3.65

Table S3. Photoelectric parameters of the fabricated NIR pc-LED with LSG:0.07Cr^{3+}, 0.002Yb^{3+} under various currents.

Current (mA)	Input electrical power (mW)	NIR output power (mW) (700-1000 nm)	NIR output power (mW) (700-1300 nm)	Photoelectric conversion efficiency (%)
20	51.19	3.12	4.48	8.76
40	104.1	6.32	9.09	8.73
60	158.2	9.30	13.78	8.46
80	213.4	12.17	17.51	8.20
100	269.4	14.88	21.41	7.94
150	413.4	20.95	30.14	7.29
200	562.4	26.28	37.81	6.72
250	716.4	30.88	44.43	6.20
300	874.9	34.09	49.05	5.60
350	1038	37.33	53.71	5.17
400	1206	39.80	57.27	4.74

Table S4. Photoelectric parameters of the fabricated NIR pc-LED with LSG:0.07Cr^{3+}, 0.006Yb^{3+} under various currents.

Current (mA)	Input electrical power (mW)	NIR output power (mW) (700-1000 nm)	NIR output power (mW) (700-1300 nm)	Photoelectric conversion efficiency (%)
20	51.19	2.66	4.60	8.99
40	104.1	5.37	9.30	8.83
60	158.3	7.94	13.74	8.68
80	213.4	10.39	17.98	8.42
100	269.6	12.67	21.92	8.13
150	413.6	18.00	31.15	7.53
200	562.6	22.37	38.71	6.88
250	716.5	26.34	45.58	6.36
300	876	29.48	51.01	5.82
350	1038	33.4	57.80	5.56
400	1207	35.19	60.89	5.04

Table S5. Photoelectric parameters of the fabricated NIR pc-LED with LSG:0.07Cr^{3+}, 0.01Yb^{3+} under various currents.

Current (mA)	Input electrical power (mW)	NIR output power (mW) (700-1000 nm)	NIR output power (mW) (700-1300 nm)	Photoelectric conversion efficiency (%)
20	51.22	2.34	4.64	9.06
40	104.2	4.73	9.39	9.01
60	158.5	6.94	13.78	8.69
80	213.6	9.11	18.10	8.47
100	269.8	11.17	22.19	8.22
150	414.6	15.82	31.43	7.59
200	563.4	19.87	39.47	7.01
250	718.4	23.59	46.86	6.53
300	877.2	26.61	52.86	6.02
350	1041	29.37	58.34	5.60
400	1209	32.35	64.26	5.32

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