Supporting Information for

Yb^{3+} dopant concentration dependence in Yb: $CaGdAlO_4$ bulk crystals

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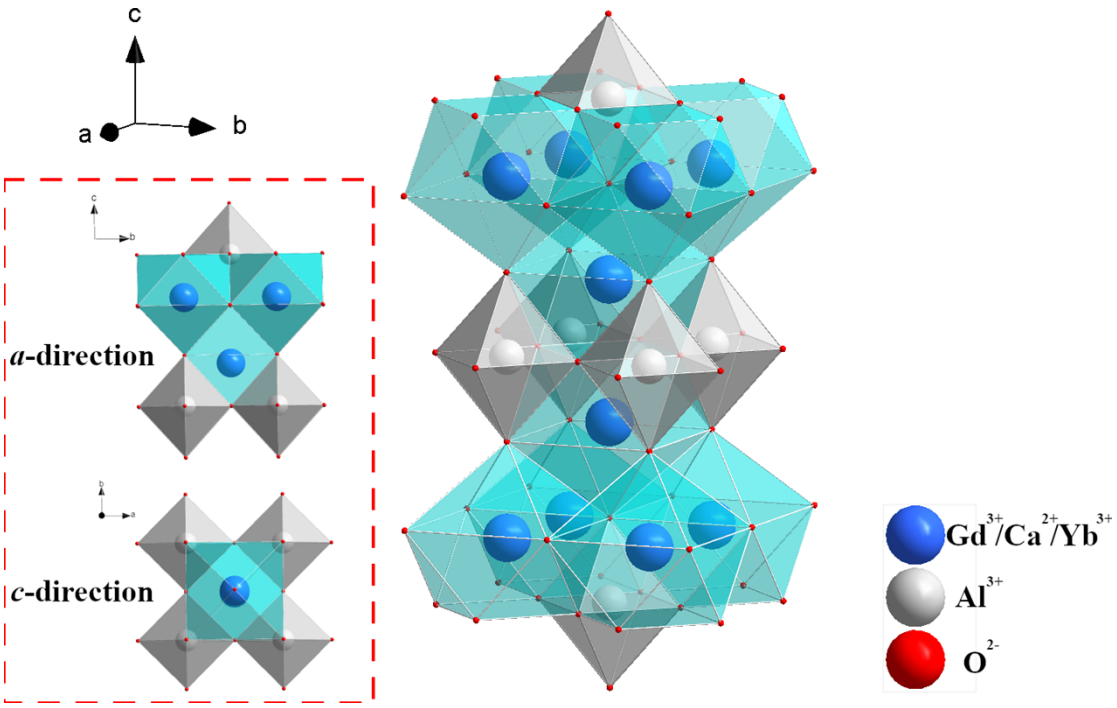

Fig. S1. The structure of Yb: CALGO crystal.

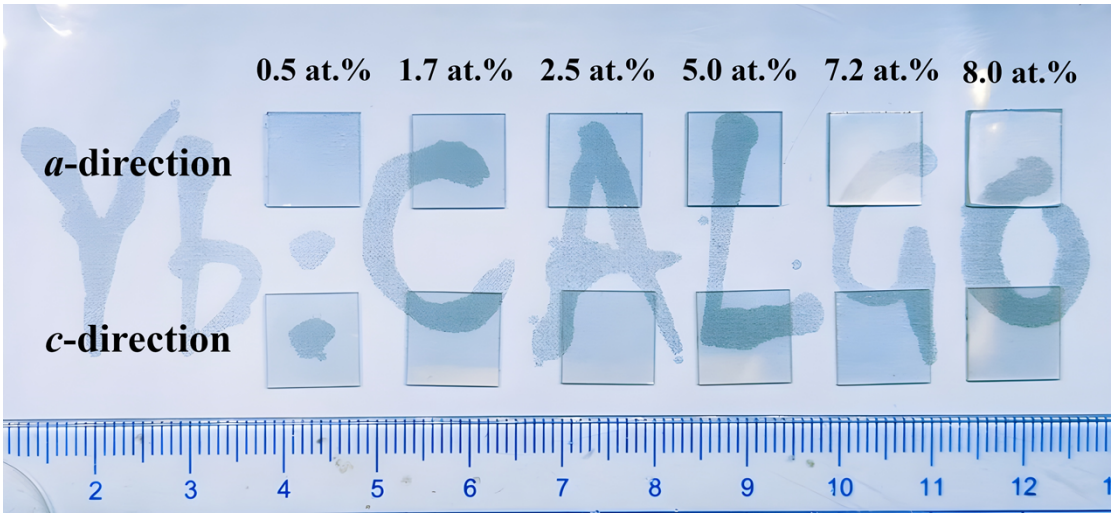

Fig. S2. The photograph of the Yb: CALGO crystal plates.

Table S1. The mass percent of Yb^{3+}, Gd^{3+}, Ca^{2+}, and Al^{3+} in Yb:CALGO crystals measured by ICP

Initial doped Yb^{3+} conc. (at.%)	The mass percent measured by ICP (%)			
	Yb^{3+}	Gd^{3+}	Ca^{3+}	Al^{3+}
1	0.29	46.41	11.65	8.48
3	0.90	47.06	12.48	8.38
5	1.26	45.44	10.49	7.85
10	3.15	53.90	16.60	9.78
12	3.65	46.02	11.23	7.90
14	4.64	49.19	12.76	9.04

Table S2. The calculated atomic coefficients of Yb, Gd, Ca, and Al in Yb:CALGO crystals when the reference atom is Gd, Ca, and Al

The reference ion	Initial doped Yb^{3+} conc. (at.%)	Yb	Gd	Ca	Al
Gd^{3+}	1	0.006	1	0.985	1.065
	3	0.017	1	1.041	1.038
	5	0.025	1	0.906	1.007
	10	0.056	1	1.245	1.109
	12	0.072	1	0.958	1.000
	14	0.086	1	1.018	1.072
Ca^{2+}	1	0.006	1.015	1	1.081
	3	0.017	0.961	1	0.998
	5	0.028	1.104	1	1.112
	10	0.045	0.803	1	0.891
	12	0.075	1.044	1	1.045

	14	0.084	0.982	1	1.053
Al^{3+}	1	0.005	0.939	0.925	1
	3	0.017	0.963	1.003	1
	5	0.025	0.993	0.900	1
	10	0.050	0.902	1.122	1
	12	0.072	0.999	0.957	1
	14	0.080	0.933	0.950	1

Table S3. The calculated segregation coefficients of the Yb^{3+} in Yb:CALGO crystals when the referent ion is Al^{3+}

Initial doped Yb^{3+} conc. (at.%)	1 at.%	3 at.%	5 at.%	10 at.%	12 at.%	14 at.%
The segregation coefficient of Yb^{3+}	0.50	0.57	0.50	0.50	0.60	0.57

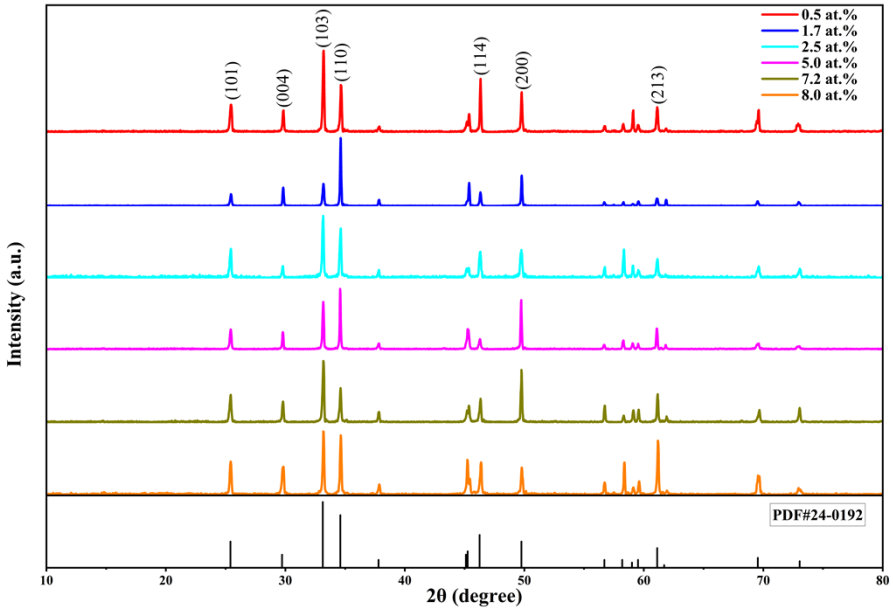

Fig. S3. XRD patterns of the as-grown Yb:CALGO single crystals.

Table S4. The calculated lattice parameters of Yb:CALGO crystals

	Samples	a (Å)	c (Å)	V (Å^3)	Ref.
Calculated lattice parameters	0.5 at.% Yb:CALGO	3.661	11.995	160.768	This work
	1.7 at.% Yb:CALGO	3.662	11.991	160.802	This work
	2.5 at.% Yb:CALGO	3.660	11.989	160.560	This work
	5.0 at.% Yb:CALGO	3.661	11.987	160.660	This work
	7.2 at.% Yb:CALGO	3.663	11.991	160.890	This work
	8.0 at.% Yb:CALGO	3.662	11.981	160.668	This work

	CALGO	3.6632	11.998	161.00157	[39]

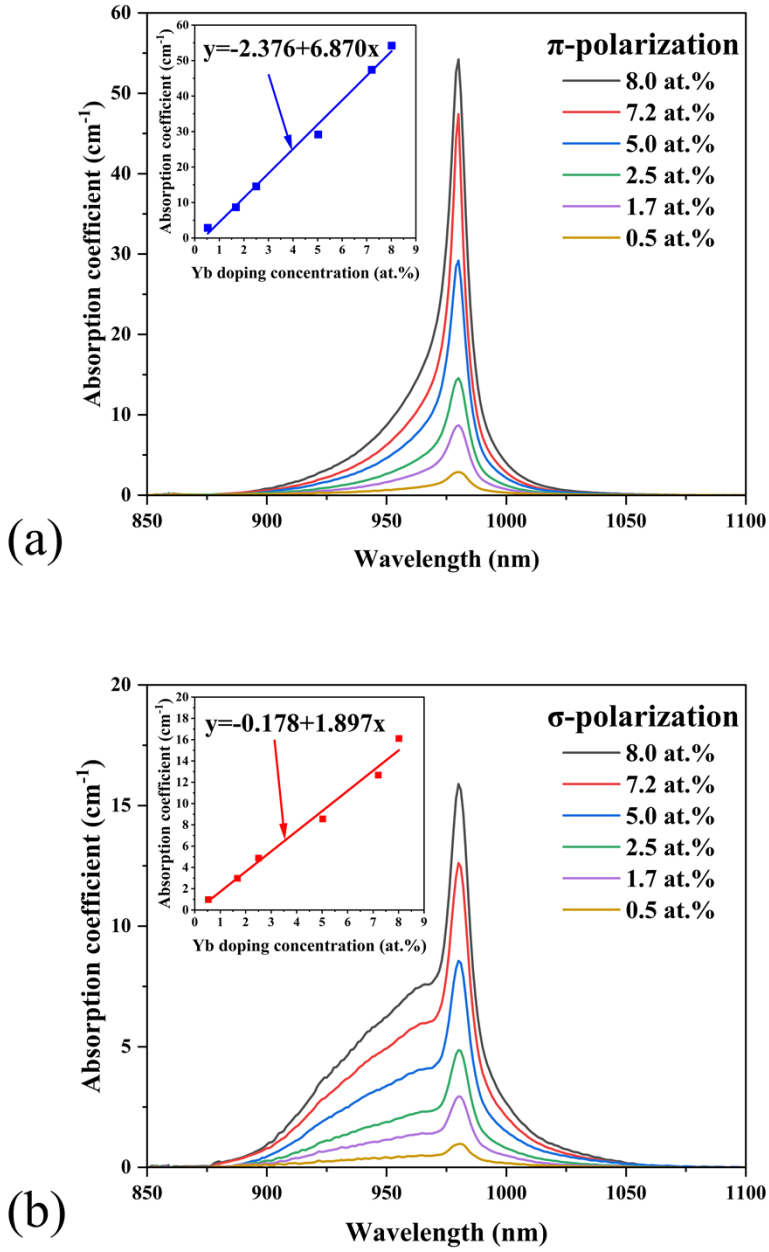

Fig. S4. (a) and (b) represent the π and σ polarized absorption spectra of Yb:CALGO, respectively. The graphs embedded within them show the dependence of the absorption coefficient at the central wavelength on the Yb^{3+} doping concentration.

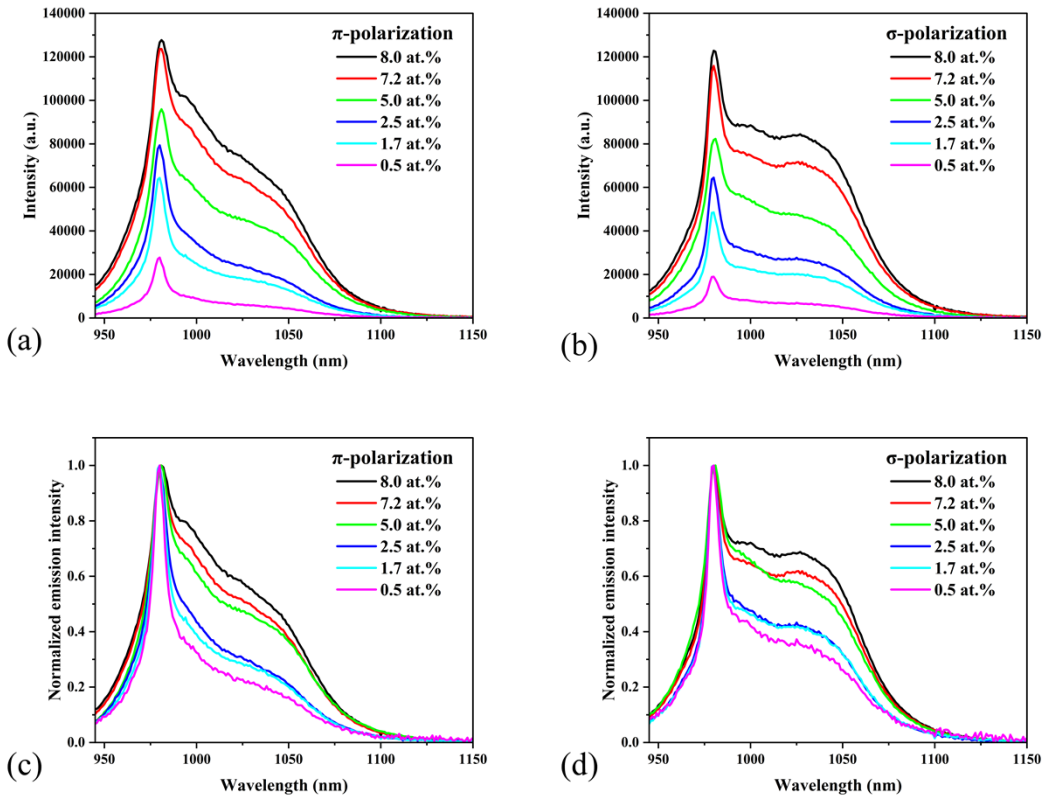

Fig. S5. (a) and (b) present the π and σ polarized emission spectra of Yb: CALGO, respectively. (c) and (d) present the normalized emission spectra relative to their peak intensity. The spectra were measured under 932 nm excitation at room temperature.

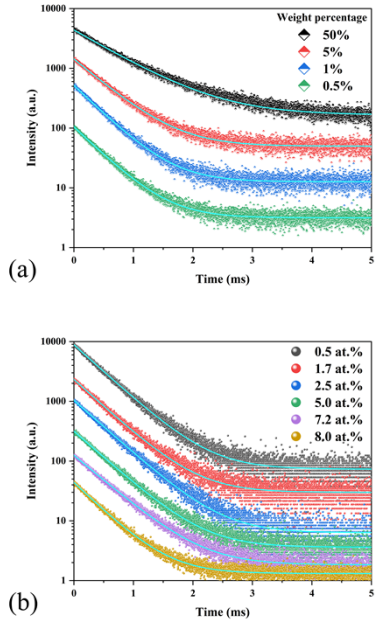

Fig. S6. (a) presents the fluorescence decay curves of samples composed of 8.0 at.% Yb:CALGO mixed with pure CALGO, with Yb:CALGO weight percentage of 50%, 5%, 1% and 0.5%, respectively. (b) presents the fluorescence decay curves of different Yb^{3+} concentration.

Table S5. The FWHMs in the π and σ polarization of the emission spectra and the fluorescence lifetime with the weight percentage of 0.5% in Yb:CALGO crystals

Yb^{3+} doping conc. (at.%)	FWHM (nm)		The fluorescence lifetime (ms)
	the π polarization	the σ polarization	
0.5	11.23	12.32	0.490
1.7	14.31	15.26	0.489
2.5	20.12	19.55	0.503
5.0	43.35	71.77	0.501
7.2	58.03	75.75	0.527
8.0	68.75	79.86	0.454

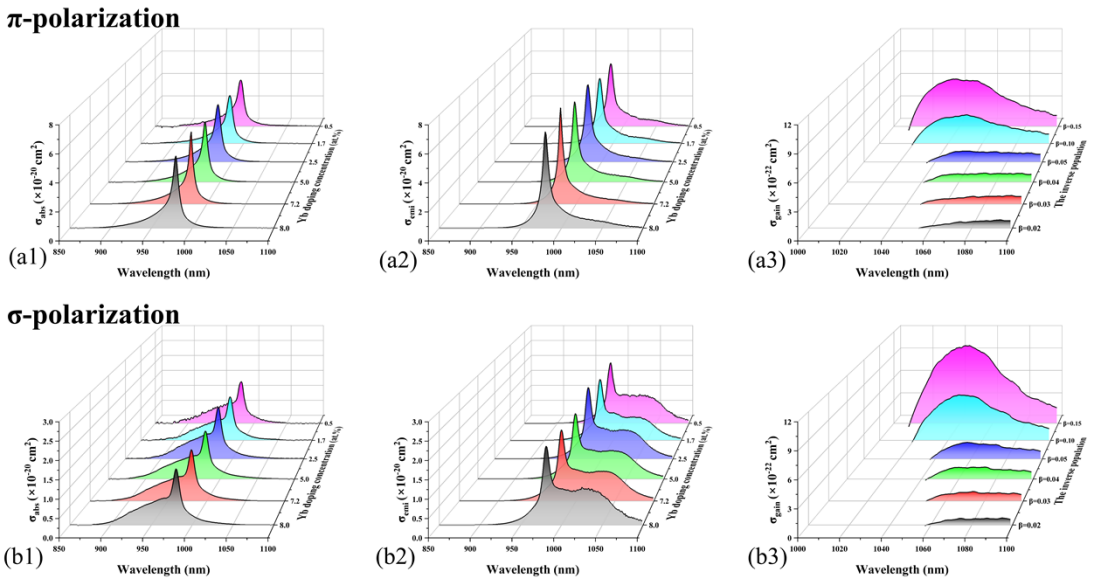

Fig. S7. (a1), (a2) and (a3) represent the absorption, emission cross-sections of a series of Yb3+ doped CALGO crystals and the gain cross-sections of 8.0 at.% Yb:CALGO crystal in π polarization , respectively. (b1), (b2) and (b3) represent the absorption, emission cross-sections of a series of Yb^{3+} doped CALGO crystals and the gain cross-sections of 8.0 at.% Yb:CALGO crystal in σ polarization , respectively.

Table S6. Comparison of the cross-sections of Yb:CALGO in this work with those of several other crystals.

Crystals	Yb conc. (at%)	Growth method	σ_{abs} (10^{-20} cm^2)		σ_{emi} (10^{-20} cm^2)		Reference
			π	σ	π	σ	
Yb:CALGO	0.5	Cz	4.07@980 nm	1.37@980 nm	5.50@ 980 nm	1.99@980 nm 0.86@1040 nm	This work
	1.7		4.05@980 nm	1.37@980 nm	5.49@ 980 nm	1.92@980 nm	

						0.73@1040 nm	
	2.5		4.65@980 nm	1.56@980 nm	6.24@ 980 nm	2.17@980 nm 0.84@1040 nm	
	5.0		4.66@980 nm	1.39@980 nm	6.23@ 980 nm	1.90@980 nm 0.79@1040 nm	
	7.2		5.35@980 nm	1.43@980 nm	7.14@ 980 nm	1.91@980 nm 0.81@1040 nm	
	8.0		5.10@980 nm	1.49@980 nm	6.81@ 980 nm	2.02@980 nm 0.90@1040 nm	
	8		2.65@ 979 nm	1.03@980 nm	2.23@979 nm	1.43 @ 980 nm	[50]
	5.4		3.8 @979.6 nm	1.4@979.6 nm	5.5 (at 980 nm	2.0@980 nm	[51]
Yb: $CaYAlO_4$	1	Cz	5.68@979 nm	1.97@ 979nm	--	0.80 (plateau)	[44]
Yb:$SrLaAlO_4$	5	Cz	2.58@980.2 nm	1.45@980.2 nm	2.88@980.2 nm	0.80 (plateau)	[52]
Yb:Lu_2O_3	3.5	TGT	1.320@976 nm, no polarization		1.165@1033 nm, 0.493@1077 nm, no polarization		[53]
Yb:$Y_3Al_5O_{12}$	2	LHPG	0.5@943 nm, no polarization		2.5@1050 nm, no polarization		[54]

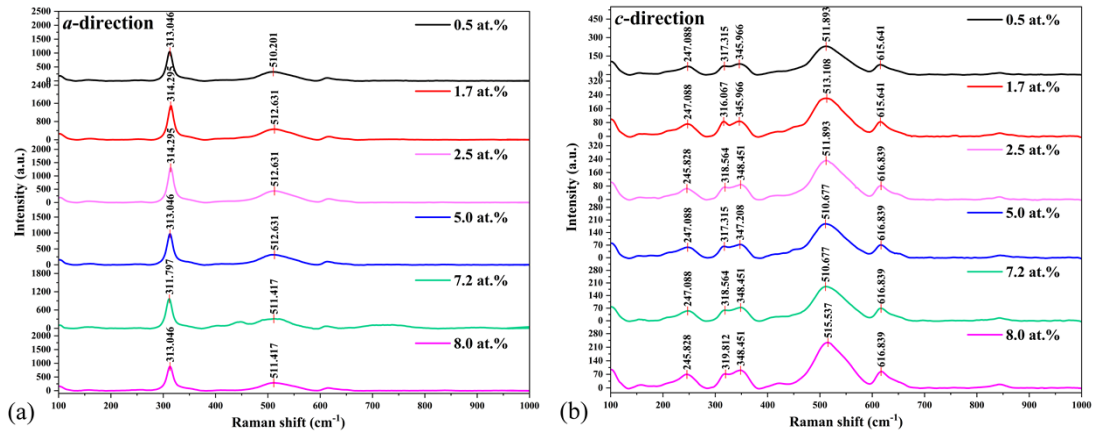

Fig. S8. (a) and (b) present the Raman spectra of Yb:CALGO crystals along the *a*-direction and the *c*-direction, respectively.