*Supporting information for*

Origin of visible and near IR upconversion in Yb3+-Tm3+-Er3+ doped BaMgF4 phosphor through energy transfer and cross-relaxation processes

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Fig. S1 Powder XRD patterns of undoped BaMgF4 sample, doped with Yb3+-Tm3+ (Yb= 10 mol%, Tm= 0.2 mol%) and Yb3+-Tm3+-Er3+ (Yb= 10 mol%, Tm= 0.2 mol%, Er= 1.6 mol%).

 

 

Fig. S2 Plot of variation in the upconversion emission intensity as a function of the excitation intensity for (a) BaMgF4:Yb,Tm (Yb= 2 mol%, Tm=0.2 mol% phosphor, (b) enlarged view of the spectra in the 300- 750 nm region and (c) BaMgF4:Yb,Tm (Tm= 0.2 mol%, Yb= 10mol%) phosphor, (d) enlarged view of the spectra in the 300- 750 nm region. The UC emission spectra were measured by changing the 980 nm excitation power from 96 mW to 1500 mW.

Table S1. Luminescence decay time calculated for BaMgF4:Yb,Tmx (Yb= 2 mol %) phosphor.

|  |  |  |  |
| --- | --- | --- | --- |
| BaMgF4:Yb,Tmx | τ (μs) @362 nm | τ (μs) @479 nm | τ (μs) @800 nm |
| 0.1 mol% | 123 | 443 | 203 |
| 0.2 mol% | 147 | 492 | 275 |
| 0.5 mol% | 178 | 460 | 311 |
| 1 mol% | 127 | 447 | 267 |
| 2 mol% | 124 | 462 | 220 |
| 3 mol% | 128 | 442 | 246 |

 

 

Fig. S3 Luminescence decay curves of BaMgF4:Yb3+,Tm3+,xEr3+ phosphor under 980 nm excitation measured for Tm3+ and Er3+ emissions at (a) 477 nm (1G4→ 3H6), (b) 540 nm (4S3/2→ 4I15/2), (c) 652 nm (Er3+: 4F9/2→4I15/2) + (Tm3+: 1G4→ 3F4) and (d) 800 nm (3H4→ 3H6), for different concentrations of Er3+ at Yb3+= 10 mol%, Tm3+= 0.2 mol%.

Table S2. Luminescence decay time calculated for BaMgF4:Yb,Tm,Erx (Yb= 10 mol%, Tm= 0.2 mol%) phosphor.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Erconcentration | τ (μs) @477 nm | τ (μs) @540 nm | τ (μs) @652 nm | τ (μs) @800 nm |
| 0.2 mol% | 286 | 134 | 359 | 254 |
| 0.4 mol% | 487  | 106  | 386 | 262  |
| 0.8 mol% | 328 | 92 | 357  | 160  |
| 1.2 mol% | 432  | 100  | 297  | 289  |
| 1.6 mol% | 516  | 105  | 390  | 295  |