# Simultaneous Broadening and Enhancement of $Cr^{3+}$ Photoluminescence in $Ba_3ZrTa_4O_{15}$ by Chemical Unit Cosubstitution

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**Table S1**. Atomic parameters obtained from Rietveld refinement of $Ba_3ZrTa_4O_{15}$: $Cr^{3+}$ and $Ba_3Al_{0.5}Ta_{4.5}O_{15}$: $Cr^{3+}$.

| Samples | Atom | x | y | z | Multiplicity & Wyckoff | Occ | Uiso |
|---|---|---|---|---|---|---|---|
| $Ba_3ZrTa_4O_{15}$: $Cr^{3+}$ | Ba1 | 0.00000 | 0.00000 | 0.39378 | 2a | 1 | 0.012 |
| | Ba2 | 0.17165 | 0.67165 | 0.40490 | 4c | 1 | 0.028 |
| | Zr1 | 0.00000 | 0.50000 | 0.87563 | 2b | 0.2 | 0.002 |
| | Ta1 | 0.00000 | 0.50000 | 0.87563 | 2b | 0.8 | 0.002 |
| | Zr2 | 0.07552 | 0.21384 | 0.89881 | 8d | 0.2 | 0.007 |
| | Ta2 | 0.07552 | 0.21384 | 0.89881 | 8d | 0.8 | 0.007 |
| | O1 | 0.00000 | 0.50000 | 0.45260 | 2b | 1 | 0.079 |
| | O2 | 0.28106 | 0.78106 | 0.92480 | 4c | 1 | 0.022 |
| | O3 | 0.07270 | 0.21049 | 0.36082 | 8d | 1 | 0.004 |
| | O4 | 0.34297 | 0.01190 | 0.83636 | 8d | 1 | 0.044 |
| | O5 | 0.14239 | 0.06733 | 2.23864 | 8d | 1 | 0.035 |
| $Ba_3Al_{0.5}Ta_{4.5}O_{15}$: $Cr^{3+}$ | Ba1 | 0.00000 | 0.00000 | 0.40240 | 2a | 1 | 0.029 |
| | Ba2 | 0.1722 | 0.67220 | 0.37949 | 4c | 1 | 0.030 |
| | Al1 | 0.00000 | 0.50000 | 0.87605 | 2b | 0.2 | 0.011 |
| | Ta1 | 0.00000 | 0.50000 | 0.87605 | 2b | 0.8 | 0.011 |
| | Al2 | 0.07508 | 0.21315 | 0.89932 | 8d | 0.2 | 0.002 |
| | Ta2 | 0.07508 | 0.21315 | 0.89932 | 8d | 0.8 | 0.002 |
| | O1 | 0.00000 | 0.50000 | 0.46334 | 2b | 1 | 0.062 |
| | O2 | 0.28163 | 0.78163 | 0.95045 | 4c | 1 | 0.025 |
| | O3 | 0.07258 | 0.20606 | 0.34494 | 8d | 1 | 0.006 |
| | O4 | 0.35763 | 0.01105 | 0.86803 | 8d | 1 | 0.065 |
| | O5 | 0.15222 | 0.06925 | 0.87630 | 8d | 1 | 0.010 |

**Table S2**. Distances in octahedra of $Ba_3ZrTa_4O_{15}$: $Cr^{3+}$ and $Ba_3Al_{0.5}Ta_{4.5}O_{15}$: $Cr^{3+}$.

| **Octahedra** | **$Ba_3ZrTa_4O_{15}$: $Cr^{3+}$** | **$Ba_3Al_{0.5}Ta_{4.5}O_{15}$ : $Cr^{3+}$** | **Octahedra** | **$Ba_3ZrTa_4O_{15}$: $Cr^{3+}$** | **$Ba_3Al_{0.5}Ta_{4.5}O_{15}$: $Cr^{3+}$** |
|---|---|---|---|---|---|
| $Ba1O_{12}$ | 2.82665(4) | 2.75362(4) | $Ba1O_{15}$ | 2.66585(3) | 2.57820(3) |
| | 2.82665(4) | 2.75362(4) | | 2.66585(3) | 2.82079(4) |
| | 2.82665(4) | 2.75362(4) | | 2.74315(3) | 2.82079(4) |
| | 2.82665(4) | 2.75362(4) | | 2.85641(4) | 2.88340(4) |
| | 2.82775(4) | 2.81283(4) | | 3.04814(4) | 2.88340(4) |
| | 2.82775(4) | 2.81283(4) | | 3.04814(4) | 2.97631(4) |
| | 2.82775(4) | 2.81283(4) | | 3.08500(5) | 3.07689(5) |
| | 2.82775(4) | 2.81283(4) | | 3.27080(4) | 3.22218(4) |
| | 2.89070(4) | 2.95387(4) | | 3.27080(4) | 3.22218(4) |
| | 2.89070(4) | 2.95387(4) | | 3.28468(5) | 3.23687(5) |
| | 2.89070(4) | 2.95387(4) | | 3.28468(5) | 3.23687(5) |
| | 2.89070(4) | 2.95387(4) | | 3.37916(4) | 3.23757(4) |
| | | | | 3.37916(4) | 3.23757(4) |
| | | | | 3.44562(5) | 3.43675(5) |
| | | | | 3.44562(5) | 3.43675(5) |
| **(**Zr/Al/Ta)$1O_6$ | 1.68868(3) | 1.62910(3) | (Zr/Al/Ta)$2O_6$ | 1.84504(4) | 1.76154(4) |
| | 2.00367(3) | 1.79402(3) | | 1.99362(3) | 1.97001(3) |
| | 2.00367(3) | 1.79402(3) | | 2.00192(3) | 2.00509(3) |
| | 2.00367(3) | 1.79402(3) | | 2.01176(3) | 2.05293(3) |
| | 2.00367(3) | 1.79402(3) | | 2.06841(3) | 2.11648(4) |
| | 2.30318(4) | 2.31822(5) | | 2.14838(4) | 2.19035(4) |

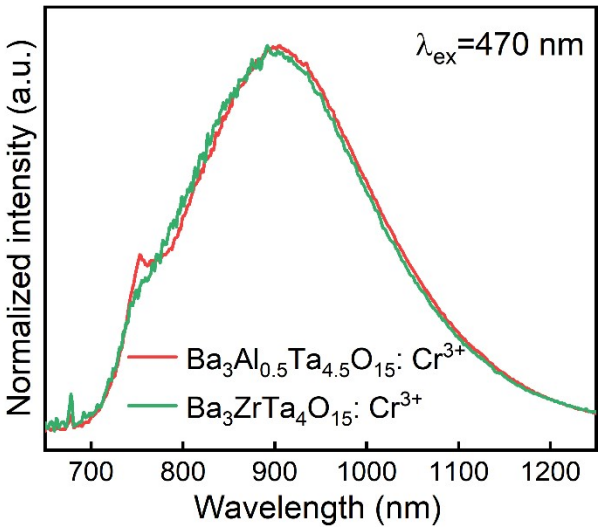


**Figure S1.** Normalize emission spectra of $Ba_3ZrTa_4O_{15}$: $0.04Cr^{3+}$ and $Ba_3Al_{0.5}Ta_{4.5}O_{15}$: $0.04Cr^{3+}$. $Ba_3ZrTa_4O_{15}$: $0.04Cr^{3+}$ and $Ba_3Al_{0.5}Ta_{4.5}O_{15}$: $0.04Cr^{3+}$ phosphors were synthesised via a solid-state reaction method. High-purity starting materials, including $BaCO_3$ (AR), $Al_2O_3$ (AR), $ZrO_2$ (AR), $Cr_2O_3$ (AR), and $Ta_2O_5$ (AR), were weighed according to the stoichiometric ratios of the respective chemical formulae. The thoroughly mixed reactants were sintered at 1400 °C for 5 h. The resulting products were subsequently cooled to room temperature, ground into fine powders, and ultimately obtained as the final phosphor materials.

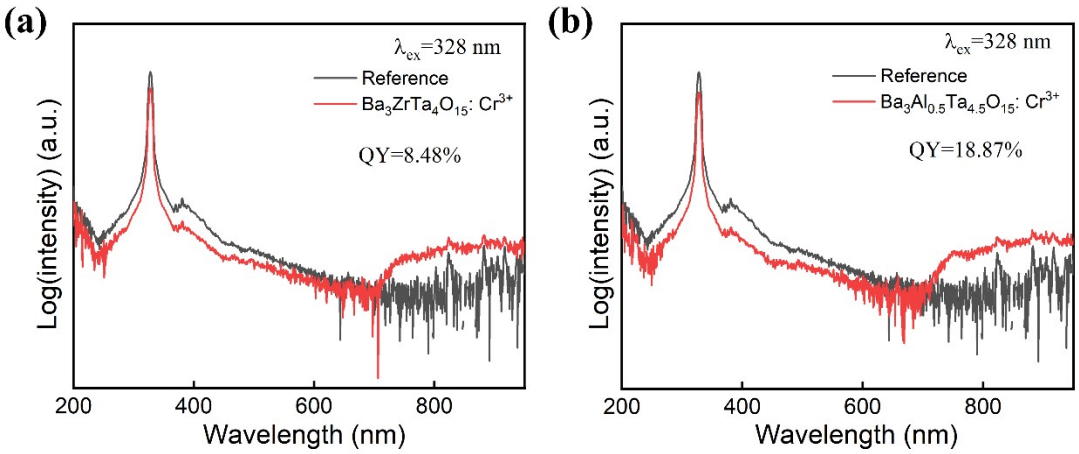


**Figure S2.** The quantum yield (QY) spectra of $Ba_3ZrTa_4O_{15}$: $Cr^{3+}$ and $Ba_3Al_{0.5}Ta_{4.5}O_{15}$: $Cr^{3+}$.

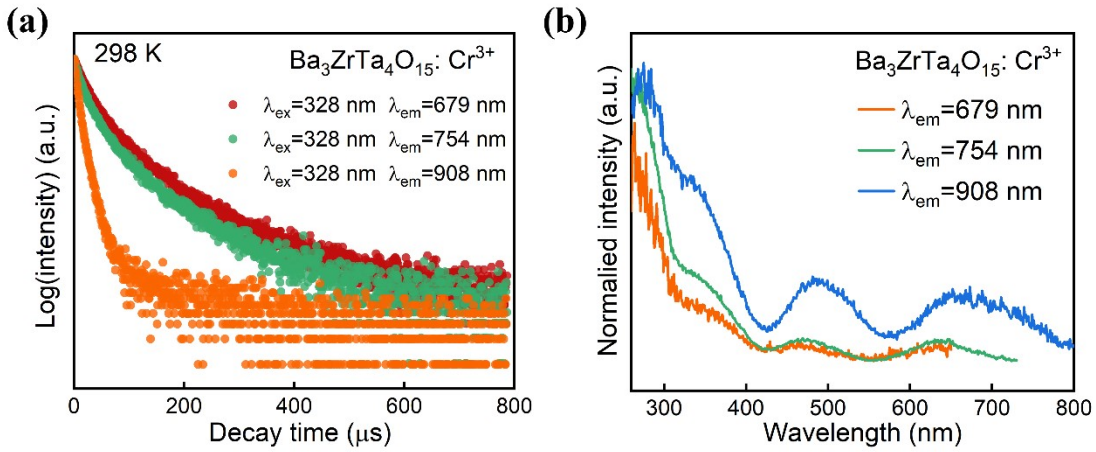


**Figure S3.** (a) Decay curves of $Ba_3ZrTa_4O_{15}$: $0.04Cr^{3+}$ at different monitoring wavelengths (b) The excitation spectra of $Ba_3ZrTa_4O_{15}$: $Cr^{3+}$ at different monitoring wavelengths.

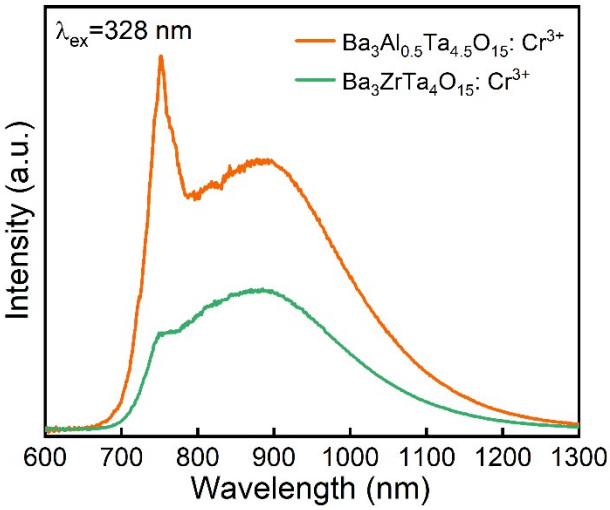


**Figure S4.** Emission spectra of $Ba_3ZrTa_4O_{15}$: $0.005Cr^{3+}$ and $Ba_3Al_{0.5}Ta_{4.5}O_{15}$: $0.005Cr^{3+}$.

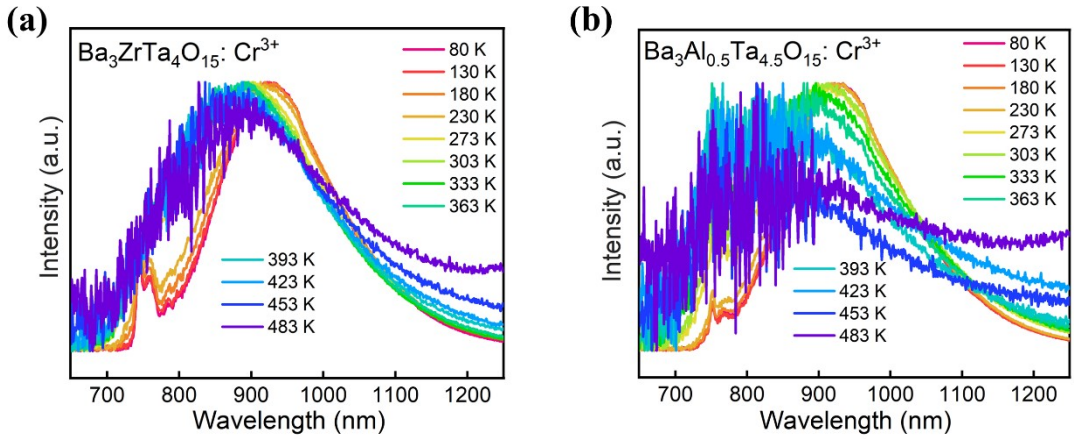


**Figure S5.** Normalized temperature-dependent emission spectra of (a) $Ba_3ZrTa_4O_{15}$: $0.04Cr^{3+}$ and (b) $Ba_3Al_{0.5}Ta_{4.5}O_{15}$: $0.04Cr^{3+}$.