Supporting Information for
"Morphology and dopant-dependent optical characteristics of novel composite 1D and 3D-based heterostructures of CdSe nanocrystals and $LaPO_4$: Re (Re = Eu, Ce, Tb) metal phosphate nanowires"

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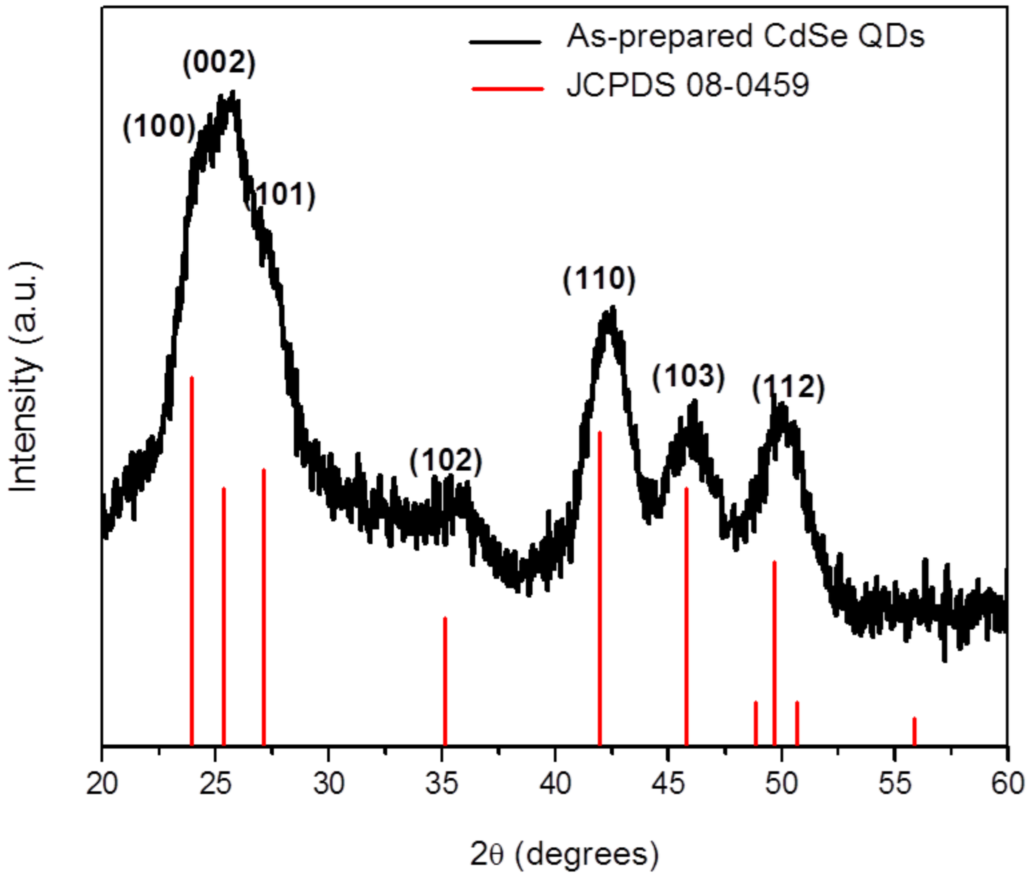


Figure S1. XRD patterns of as-prepared CdSe QDs (top, black) and the corresponding JCPDS No. 08-0459 database standard for bulk CdSe (bottom, red).

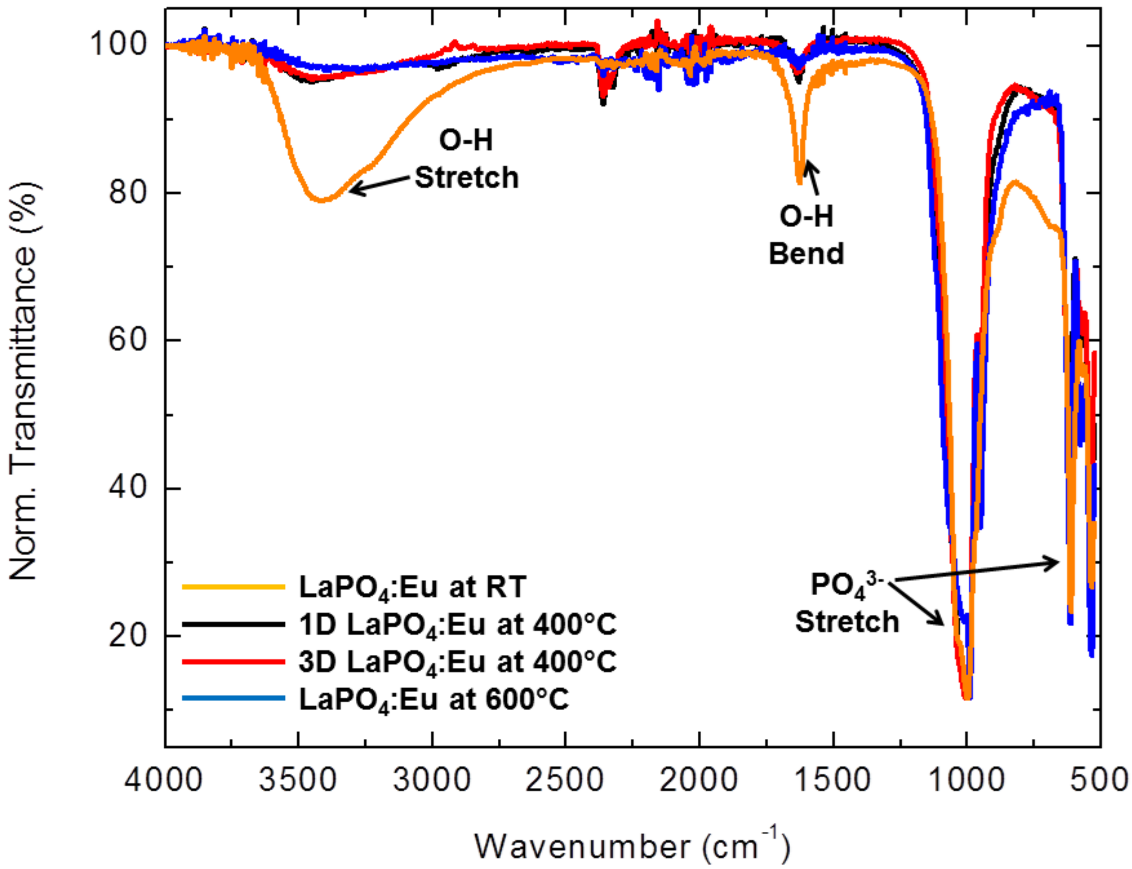


Figure S2. FT-IR spectra of $LaPO_4$: Eu nanostructures, possessing different morphologies and processed at varying post-annealing temperatures.

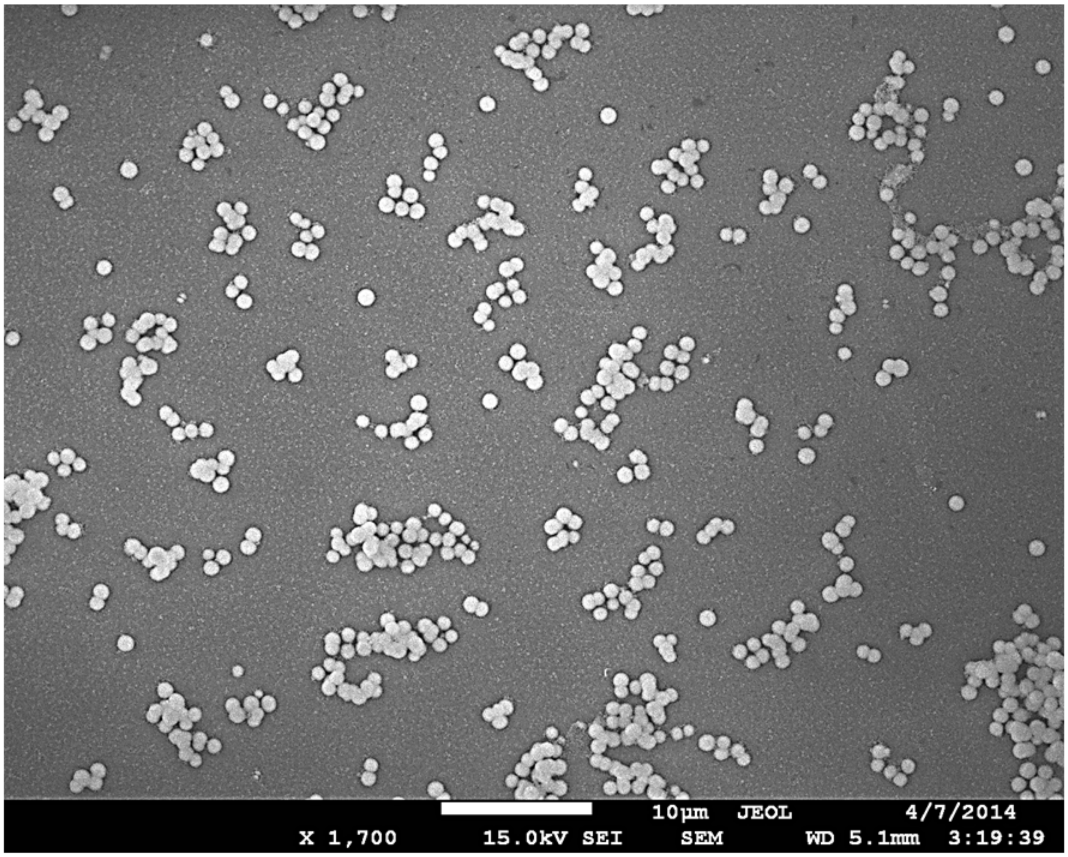


Figure S3. Representative lower magnification SEM image of $LaPO_4$: Eu 3D urchin-like architectures.

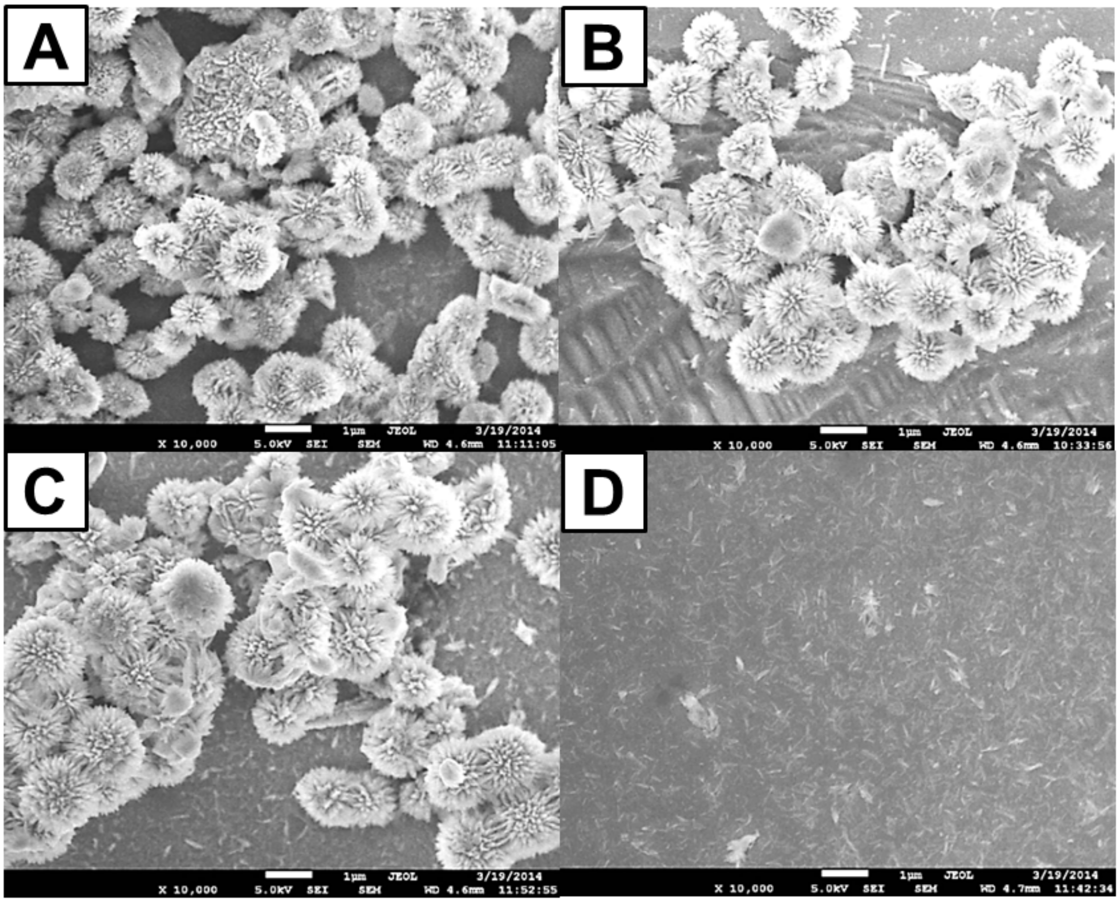


Figure S4. Representative SEM images of $LaPO_4$: Eu heterostructures, prepared by solution-precipitation protocols in the presence of varying molar precursor ratios of La/P, set at (A) 0.5, (B) 0.75, (C) 1, and (D) 1.5. Reaction times for all samples shown were held constant at 2 h.

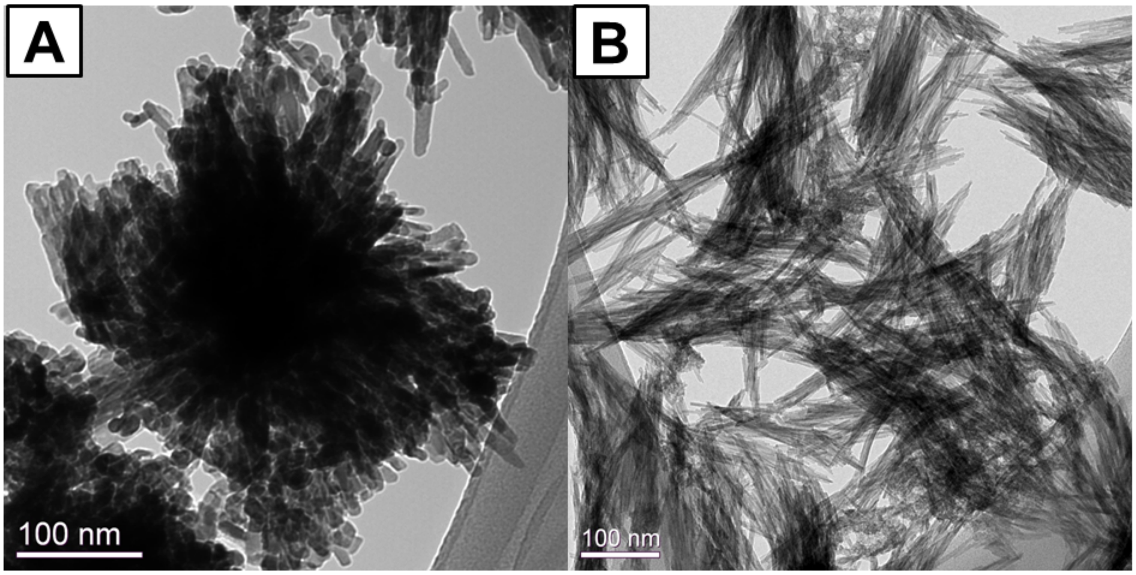
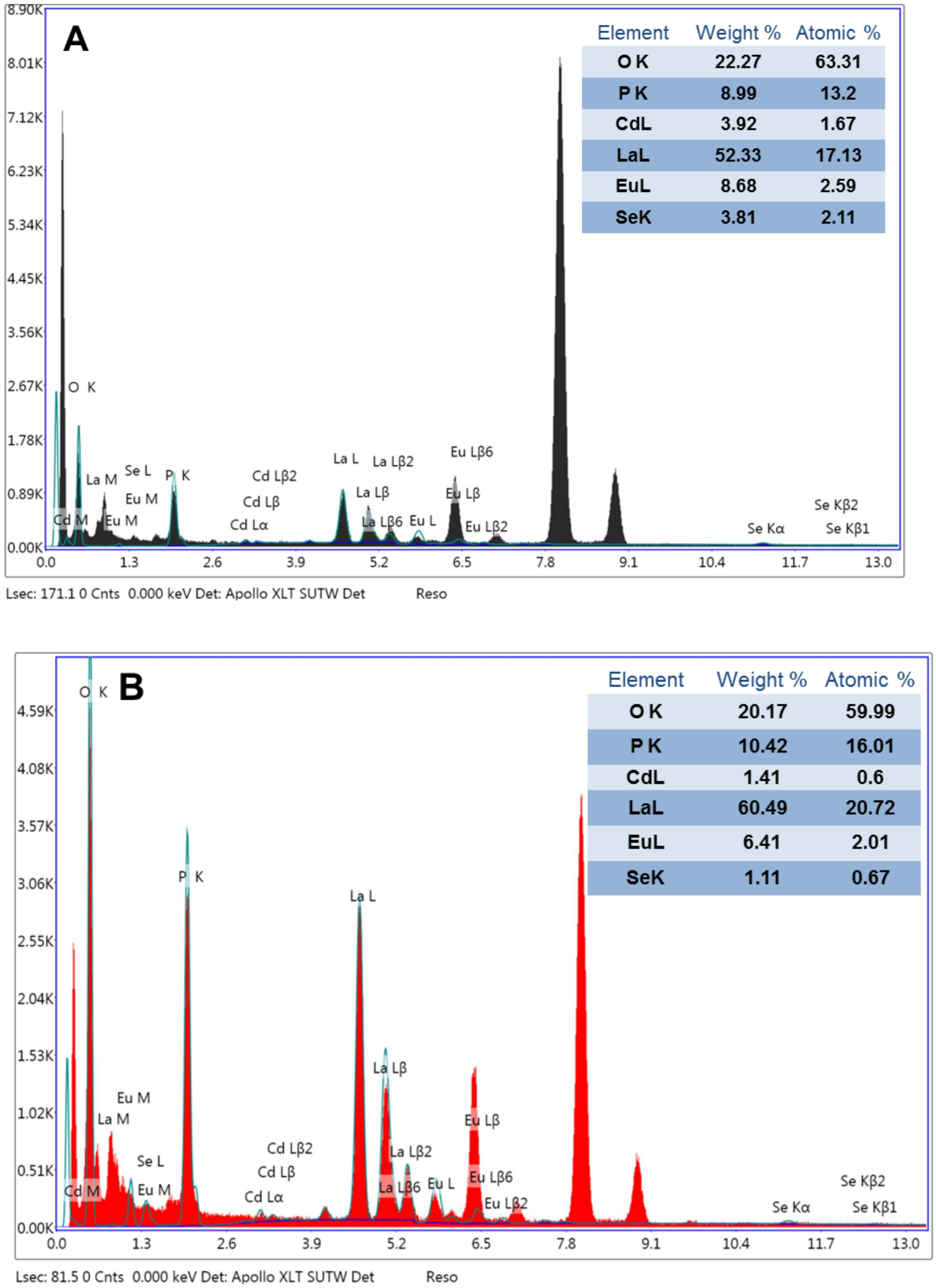


Figure S5. Representative TEM images of $LaPO_4$: Eu fabricated using a solution-precipitation approach in the presence of (A) 3-mercaptopropioic acid and (B) 11-mercaptoundecanoic acid, respectively.



Element	Weight %	Atomic %
O K	22.27	63.31
P K	8.99	13.2
CdL	3.92	1.67
LaL	52.33	17.13
EuL	8.68	2.59
SeK	3.81	2.11

Element	Weight %	Atomic %
O K	20.17	59.99
P K	10.42	16.01
CdL	1.41	0.6
LaL	60.49	20.72
EuL	6.41	2.01
SeK	1.11	0.67

Figure S6. EDS spectra and quantitative elemental analysis data for AET-capped CdSe-$LaPO_4$: Eu (A) 3D urchin-like and (B) 1D nanowire-based heterostructures.

Calculation of coverage density of CdSe QDs on 1D and 3D $LaPO_4$ structures

The number of anchored dots on either the single $LaPO_4$ nanowire or 3D structures can be estimated by the following Equation S1.

$$\frac{W_{LaPO_4}}{W_{LaPO_4} + nW_{CdSe}} \approx wt\%\ of\ LaPO_4\ in\ heterostructure \quad \textbf{(S1)}$$

wherein W_{LaPO4} = weight of either a single $LaPO_4$ nanowire or 3D $LaPO_4$ heterostructure, W_{CdSe} = weight of a CdSe QD, n = the number of QDs attached onto the underlying $LaPO_4$, and *wt% of* $LaPO_4$ *in heterostructure* are all obtained either directly or indirectly by examining the results of the EDS spectrum and corresponding EDS mapping.

Based on the EDS spectrum, the 3D-based heterostructures consist of nearly 92.3 wt % for $LaPO_4$: Eu, and 7.7 wt% for CdSe QDs (Figure S6A). The volume of one 3D-based heterostructure of $LaPO_4$: Eu is 5.1×10^{-14} cm^3 (with $r_{3D\text{-}LaPO4:Eu}$ ~ 230 nm, as obtained by TEM analysis), assuming that the 3D structure can be visualized as a perfect sphere. Hence, the weight of a single 3D $LaPO_4$ is equal to 2.63×10^{-13}g (assuming a density of $LaPO_4$ = 4.19 g/cm^3)[1]. On the other hand, the volume of a single CdSe QD is 5.03×10^{-20} cm^3 (with r_{CdSe} ~ 2.29 nm, as obtained by TEM). Assuming the density of CdSe is equal to 5.82 g/cm^3, the as-obtained weight of a single CdSe QD is 2.93×10^{-19}g. Hence, from all of these weight values, we calculate that the number of quantum dots ('*n*') attached onto a single discrete 3D $LaPO_4$: Eu structure is estimated to be 6.1×10^4 QDs, according to Equation S1.

Based on the EDS spectrum, the 1D-based heterostructures consist of nearly 97.5 wt % for $LaPO_4$: Eu and 2.5 wt% for CdSe QDs (Figure S6B). By analogy, assuming a 1D nanowire can be represented as a very thin rectangular tube with a thickness of 1 nm, the corresponding volume of 1D $LaPO_4$: Eu can be computed to be 8.03×10^{-18} cm^3, based on a nanowire length of ~1100 nm and corresponding width of 7.3 nm, as determined from TEM data. Therefore, using equation S1, we were able to calculate that ~2.94 QDs are attached onto a single individual 1D $LaPO_4$: Eu nanowire.

In order to reasonably compare coverage densities, we need to normalize for the same volume of 1D and 3D heterostructures incorporating $LaPO_4$: Eu. Since the volume of 1D $LaPO_4$: Eu (8.03×10^{-18} cm^3) is nearly four orders of magnitude smaller than that of the corresponding 3D structure (5.17×10^{-14} cm^3), upon normalization to identical volumes (i.e. to $(100\ nm)^3$) of 1D and 3D structures, we calculated that 1193 QDs (e. g. $(6.1 \times 10^4 \times (100\ nm)^3/((5.17 \times 10^{-14}\ cm^3))$ were attached onto 3D $LaPO_4$ urchin-like structures, whereas only 367 QDs (e. g. $(2.94 \times (100\ nm)^3/((8.03 \times 10^{-18}\ cm^3))$ were immobilized onto analogous 1D $LaPO_4$ nanowires under comparable reaction conditions.

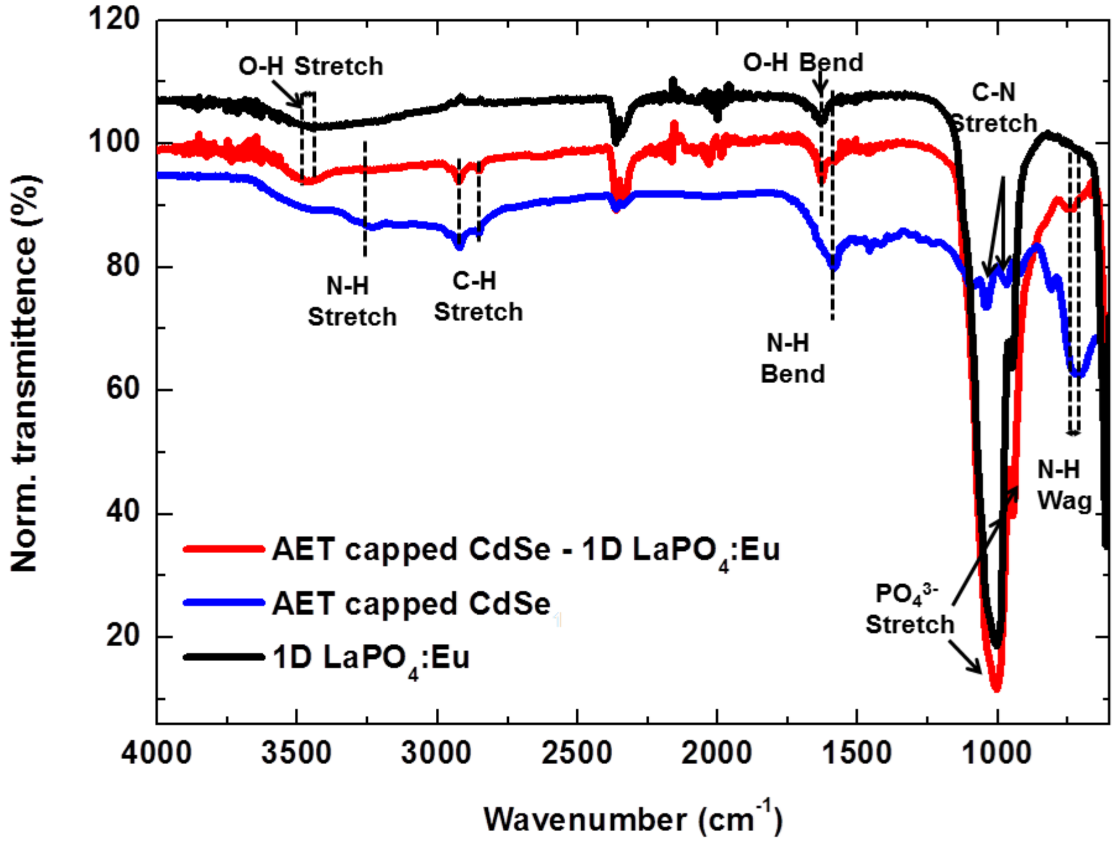


Figure S7. FT-IR spectra of $LaPO_4$: Eu 1D nanowire structures, AET capped CdSe QDs, and CdSe QD-$LaPO_4$: Eu 1D nanowire heterostructures.

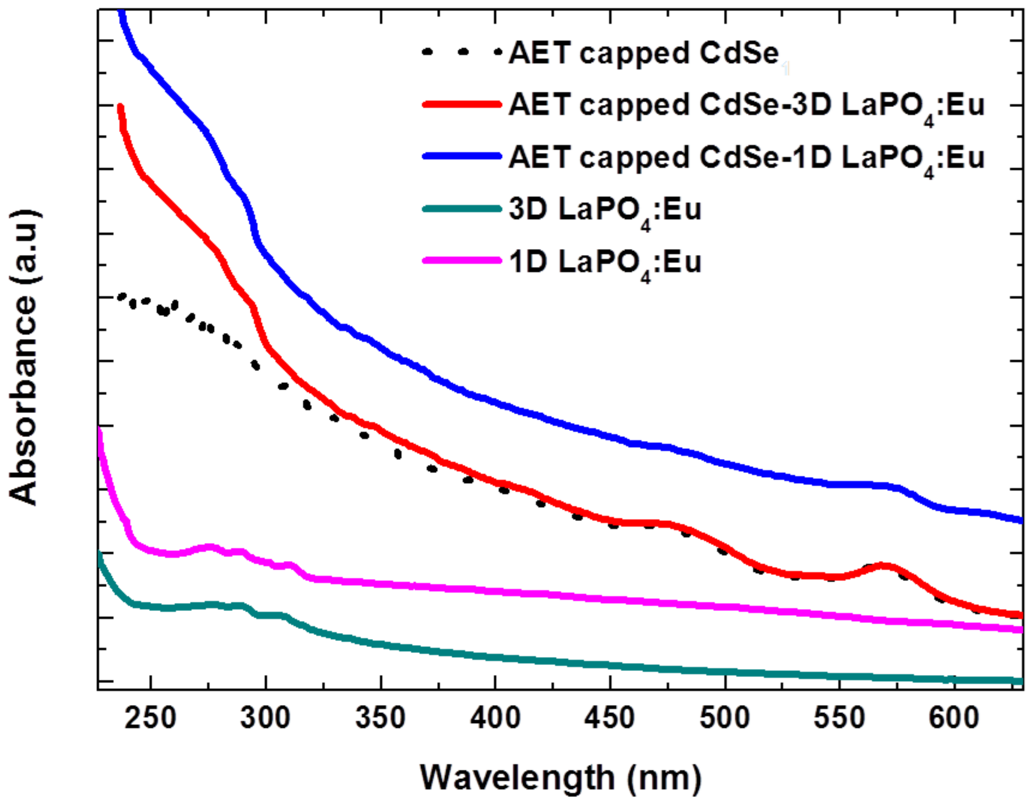


Figure S8. UV-visible spectra of AET capped CdSe QDs, $LaPO_4$: Eu 3D urchin-like structures, 1D $LaPO_4$: Eu nanowires, AET capped CdSe QD - $LaPO_4$: Eu 3D urchin-like heterostructures, and AET capped CdSe QD - $LaPO_4$: Eu 1D nanowire-based heterostructures.

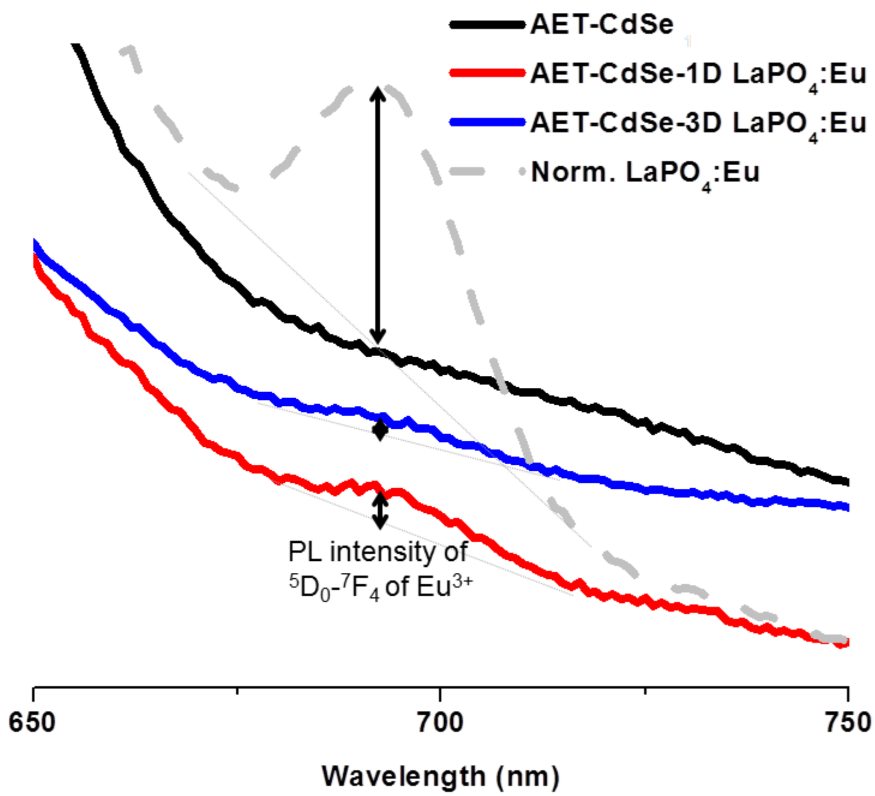


Figure S9. PL emission spectra of AET capped CdSe QDs, normalized $LaPO_4$: Eu, AET capped CdSe QD - $LaPO_4$: Eu 3D urchin-like heterostructures, and AET capped CdSe QD - $LaPO_4$: Eu 1D nanowire-based heterostructures within the magnified region of 650-750 nm under 380 nm excitation.

Table S1. Kinetic parameters and emission decay analysis associated with CdSe QDs, CdSe QD-$LaPO_4$: Eu 1D-nanowire heterostructures, CdSe QD-$LaPO_4$ 3D-based heterostructures, CdSe QD-$LaPO_4$: Eu 3D-based heterostructures, CdSe QD-$LaPO_4$: Ce 3D based heterostructures, and CdSe QD-$LaPO_4$: Tb 3D-based heterostructures.

	τ_1 (ns)	τ_2 (ns)	τ_3 (ns)	a_1	a_2	a_3	τ_{av} (ns)	χ^2
CdSe QDs	5.146	23.82	1.133	0.044	0.0041	0.1634	**7.3**	1.19
CdSe QD-1D $LaPO_4$: Eu	3.63	20.8	0.699	0.021	0.0011	0.2633	**3.2**	1.18
CdSe QD-3D $LaPO_4$: Eu	4.22	23.0	0.8615	0.034	0.0022	0.217	**5.1**	1.21
CdSe QD-3D $LaPO_4$: Ce	2.893	18.4	0.542	0.0075	0.0003	0.18	**1.8**	1.06
CdSe QD-3D $LaPO_4$: Tb	4.32	20.5	0.9183	0.0396	0.0033	0.1751	**5.7**	1.20
CdSe QD-3D $LaPO_4$	3.21	13.95	0.756	0.0266	0.0013	0.2248	**2.4**	1.16

Tri-exponential decay kinetics were noted to be satisfactory for the determination of emission lifetimes (τ_i). These values were then used to estimate the corresponding average lifetimes (τ_{av} (or $< t >$)) associated with the CdSe emission decay, using the following Equations S2 and S3.[2, 3]

$$F(t) = a_1 \exp\left(-\frac{t}{\tau_1}\right) + a_2 \exp\left(-\frac{t}{\tau_2}\right) + a_3 \exp\left(-\frac{t}{\tau_3}\right)$$ Equation S2

$$\langle t \rangle = \frac{\sum a_i \tau_i^2}{\sum a_i \tau_i}$$ Equation S3

References

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3. S. N. Sharma, Z. S. Pillai and P. V. Kamat, *The Journal of Physical Chemistry B*, 2003, **107**, 10088-10093.