Supporting information

Band structure and Near infrared quantum cutting investigation of $GdF_3:Yb^{3+}$, Ln^{3+} (Ln=Ho, Tm, Er, Pr, Tb) nanoparticles

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The ICP-AES results of a series of samples with different kinds of doping Ln^{3+} ions are shown in the following Table 1. It can be seen from the table that the molar ratio of Gd, Yb and Ho (Er /Tm/Pr/Tb) in GdF_3:10%Yb, 0.5%Ho (Er /Tm/Pr/Tb) is very close to the theoretical value.

Table 1 ICP-AES results of a series of samples with different kinds of doping Ln^{3+} ions

Gd: 10%Yb: 0.5%Ln (Ln=Ho,Tm,Er,Pr,Tb)	Gd/Yb/Ho	Gd/Yb/Tm	Gd/Yb/Er	Gd/Yb/Pr	Gd/Yb/Tb
Measured Mass ratio	62.8%/6.81%/0.32%	50.75%/6.3%/0.25%	51.28%/6.31%/0.42%	52.19%/6.5%/0.279%	50.28%/6.35%/0.311%
Measured molar ratio	100:9.85:0.485	100:11.27:0.45	100:11.2:0.76	100:11.38:0.6	100:11.48:0.612
Theoretical molar ratio	100:11.17:0.56	100:11.17:0.56	100:11.17:0.56	100:11.17:0.56	100:11.17:0.56

Fig. S1 shows SEM images of a series of samples with different concentrations of Yb^{3+} ions. It can be seen that the morphology and size hardly change with increasing Yb^{3+} concentration.

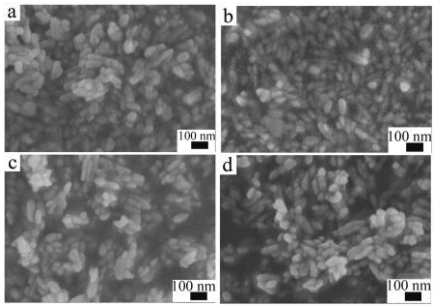

Fig. S1 SEM images of GdF_3:0.5%Ho^{3+},x%Yb^{3+} ($0 \le x \le 15$) nanoparticles: x=0 (a); x=5 (b); x-10 (c); x=15 (d)

The impurity contents of a series of GdF_3:0.5%Ho^{3+},x%Yb^{3+} ($0 \le x \le 15$) nanoparticles were characterized by Fourier-transform infrared (FT-IR) spectra, as shown in the following Fig. S2. It is found that the spectra shape of these samples with different concentrations of Yb^{3+} from 0 to 15% are nearly identical, and the absorption intensity of the surface contaminants OH groups (~3410cm^{-1}) and CO groups (~1641cm^{-1}) were measured to be the same basically with increasing concentrations of Yb^{3+}.

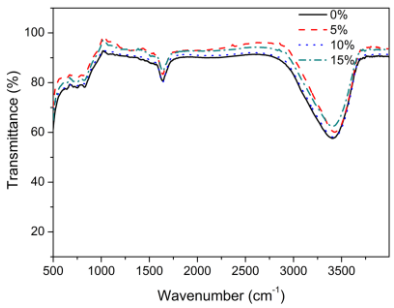

Fig. S2 FT-IR spectra of GdF_3: 0.5%Ho^{3+},x%Yb^{3+} ($0 \le x \le 15$) nanoparticles

Fig.S3 shows decay curves of Ho^{3+} for $^5F_5 \rightarrow {}^5I_8$ emission under excitation of 448 nm. It can be seen that the decay time of Ho^{3+}:$^5F_5$ state quickly decreases from 78.4μs to 6.2μs with the concentration of Yb^{3+} increasing from 0% to 20%.

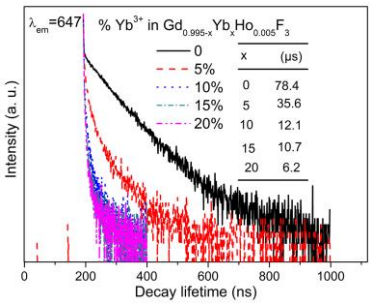

Fig. S3 Decay curves of Ho^{3+} for $^5F_5 \rightarrow {}^5I_8$ emission under excitation of 448 nm