Highly Improved Upconversion Luminescence in 

$\text{NaGd(WO}_4)_2: \text{Yb}^{3+}/\text{Tm}^{3+}$ 

Inverse Opal Photonic Crystals

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Figure s1: Transmittance spectra of the PMMA templates measured at $\theta = 0^\circ$. 
Figure S2: The typical UCL spectra of the IOPC and REF samples under the 980 nm NIR excitation power density (75mW/mm²) with the doping concentration of 20% Yb³⁺/2% Er³⁺.
Figure S3: The UCL and NIR emission lines of the NaGd(WO$_4$)$_2$: 20%Yb$^{3+}$/0.5Tm$^{3+}$ IOPCs with the different PSBs under the same 980 nm NIR excitation power density (75mW/mm$^2$).
Figure S4: The UCL decay dynamics of the transitions at 480nm of Tm$^{3+}$ ions in NaGd(WO$_4$)$_2$:20%Yb$^{3+}$/xTm$^{3+}$ IOPC and REF samples with the different doping concentrations of Tm$^{3+}$ ions (0.2%, 0.5%, 1% and 2%) by monitoring the UC emissions under the excitation of 980 nm laser.
Figure S5: The UCL decay dynamics of the transitions at 480nm of Tm$^{3+}$ ions in NaGd(WO$_4$)$_2$:xYb$^{3+}$/0.5%Tm$^{3+}$ IOPC and REF samples with the different doping concentrations of Yb$^{3+}$ ions (5%, 10%, 20%, 30% and 40%) by monitoring the UC emissions under the excitation of 980 nm laser.
Based on the principle of energy conservation law,

\[ \eta_{UC}(IOPC)+\eta_{DC}(IOPC)+\eta_T(IOPC) = 1 \]
\[ \eta_{UC}(REF)+\eta_{DC}(REF)+\eta_T(REF) = 1 \]

Where \( \eta_{UC} \) is the UCL efficiency, \( \eta_{DC} \) is the DCL efficiency, \( \eta_T \) is the thermal radiative efficiency. According to the experimental result of Figure 11, \( \eta_T(IOPC) > \eta_T(REF) \),

\[ \eta_{UC}(IOPC)+\eta_{DC}(IOPC) > \eta_{UC}(REF)+\eta_{DC}(REF) \]

\[ \frac{\eta_{UC}(IOPC)}{\eta_{UC}(IOPC)+\eta_{DC}(IOPC)} > \frac{\eta_{UC}(REF)}{\eta_{UC}(REF)+\eta_{DC}(REF)} \]

\[ \alpha = \frac{\eta_{UC}(IOPC)}{\eta_{UC}(IOPC)+\eta_{DC}(IOPC)} \quad \beta = \frac{\eta_{UC}(REF)}{\eta_{UC}(REF)+\eta_{DC}(REF)} \]

Where \( \alpha \) and \( \beta \) represent the ratio of UCL to UCL+DCL. According to the Equation above, the decrease of DCL in the IOPC would inevitably induce the increase of UCL.