Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Supporting information - Up-conversion Quantum Yield of SrF_2:Yb^{3+}, Er^{3+} Nanoparticles Prepared by Precipitation from Aqueous Solution

S. Kuznetsov[a], Ya. Ermakova[a], V. Voronov[a], P. Fedorov[a], D. Busko[b], I.A. Howard[b,c], B.S. Richards[b,c] and A. Turshatov[b]

[a]Prokhorov General Physics Institute of Russian Academy of Sciences, , Vavilov 38, 119991 Moscow, Russia
[b]Institute of Microstructure Technology, Karlsruhe Institute of Technology, 76344 Eggenstein-Leopoldshafen, Germany
[c]Light Technology Institute, Karlsruhe Institute of Technology, Engesserstrasse 13, 76131 Karlsruhe, Germany.

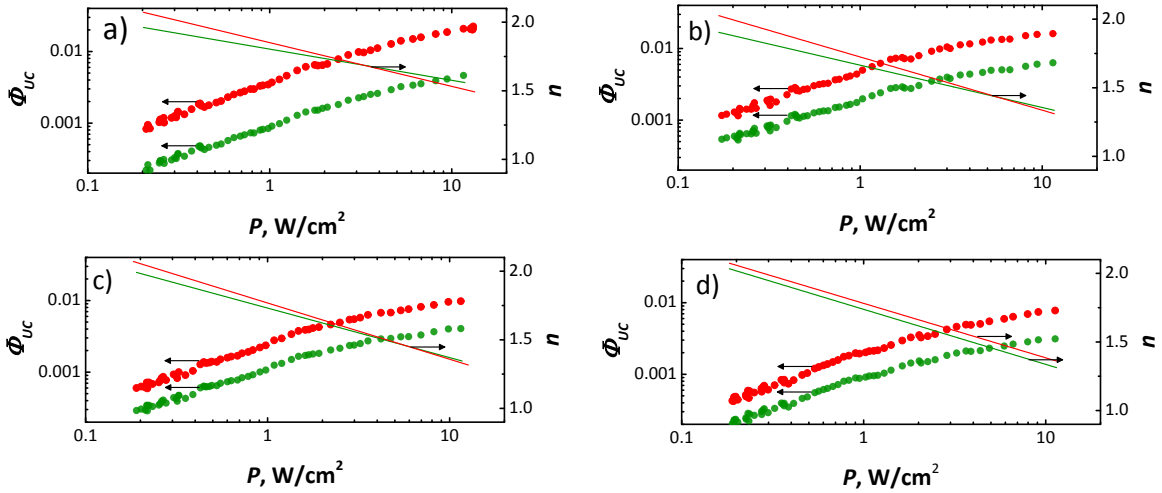


Figure S1 Dependence of UC quantum yield (Φ_{UC}) and exponential coefficient (n) as function of excitation power density (P) for emission at 544 nm (green points and lines) and at 655 nm (red points and lines). SrF_2:x%Yb^{3+},2%Er^{3+} with x = 2 (a), 5 (b), 7.5 (c) and 10 (d).

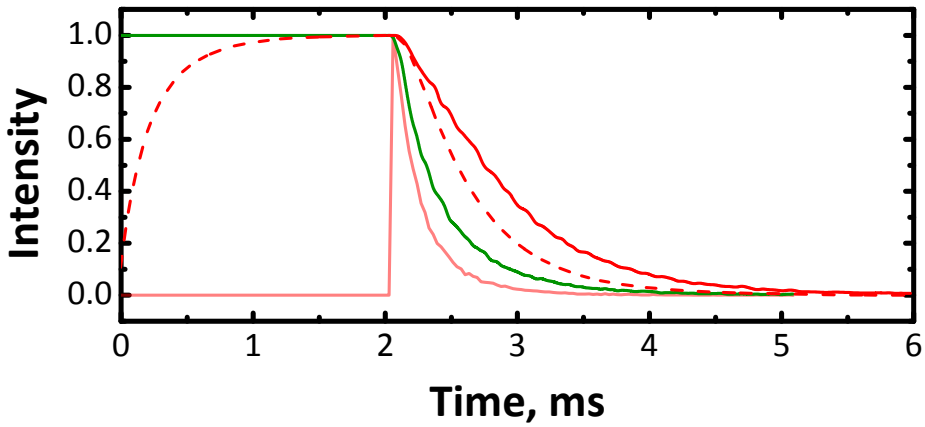


Figure S2 Convolution (dashed red line) of UC green-state decay (green solid line) and decay of the directly excited red state (rose solid line) gives faster decay then experimentally measured UC red-state decay (red solid line) for SrF_2:2%Yb^{3+},1.5%Er^{3+}.

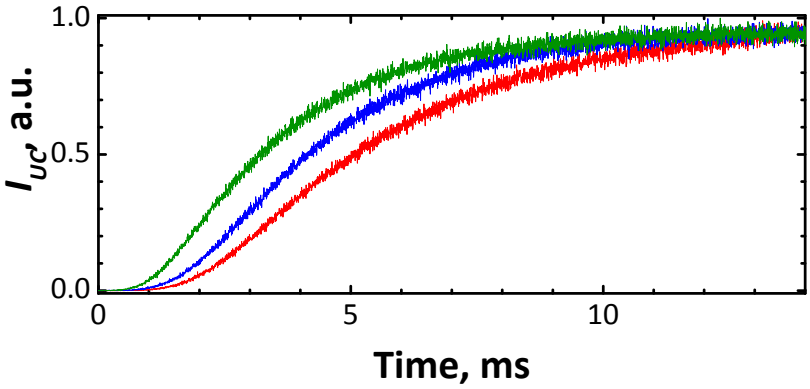


Figure S3 Population kinetics of the Er^{3+}: $^2H_{11/2}$, $^4S_{3/2}$ (green lines), Er^{3+}: $^4F_{9/2}$ (red lines) and Er^{3+}: $^2H_{9/2}$ (blue lines) states of material SrF_2:2%Yb^{3+},1.5%Er^{3+} by laser excitation with λ=980 nm and excitation power density 10 W/cm^2.

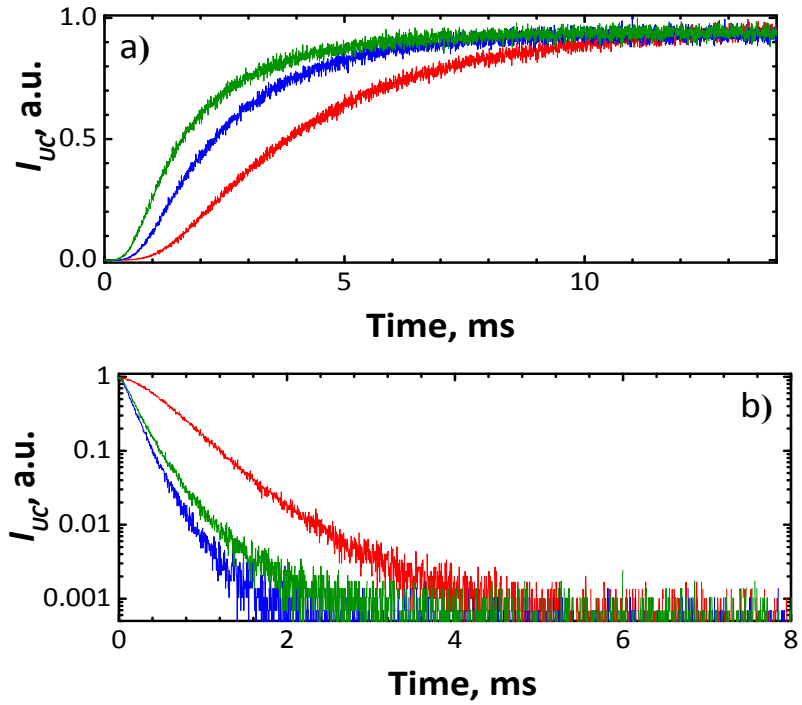


Figure S4 Population kinetics (a) and decays (b) of the Er^{3+}: $^2H_{11/2}$, $^4S_{3/2}$ (green lines), Er^{3+}: $^4F_{9/2}$ (red lines) and Er^{3+}: $^2H_{9/2}$ (blue lines) states of material SrF_2:5%Yb^{3+},1.5%Er^{3+} by laser excitation with λ=980 nm and excitation power density 10 W/cm^2

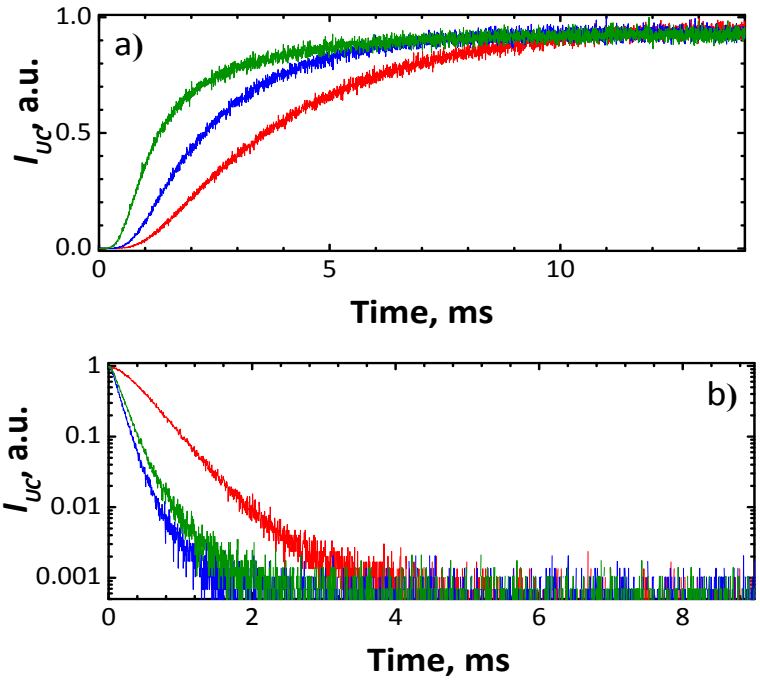


Figure S5 Population kinetics (a) and decays (b) of the Er^{3+}: $^2H_{11/2}$, $^4S_{3/2}$ (green lines), Er^{3+}: $^4F_{9/2}$ (red lines) and Er^{3+}: $^2H_{9/2}$ (blue lines) states of material SrF_2:7.5%Yb^{3+},1.5%Er^{3+} by laser excitation with λ=980 nm and excitation power density 10 W/cm²

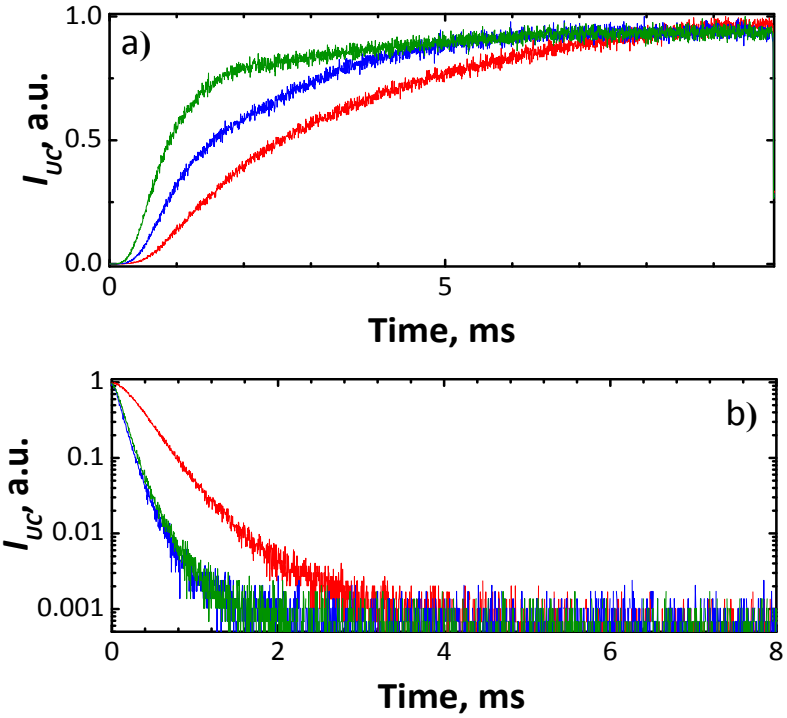
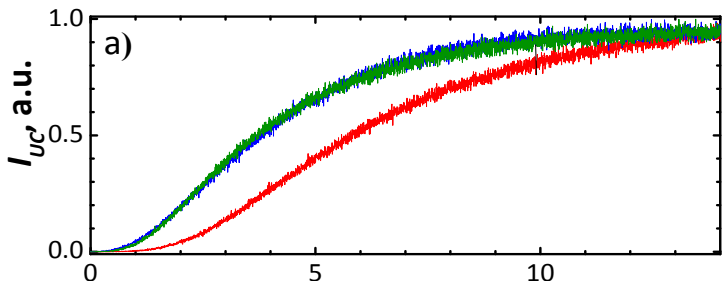


Figure S6 Population kinetics (a) and decays (b) of the Er^{3+}: $^2H_{11/2}$, $^4S_{3/2}$ (green lines), Er^{3+}: $^4F_{9/2}$ (red lines) and Er^{3+}: $^2H_{9/2}$ (blue lines) states of material SrF_2:10%Yb^{3+},1.5%Er^{3+} by laser excitation with λ=980 nm and excitation power density 10 W/cm²



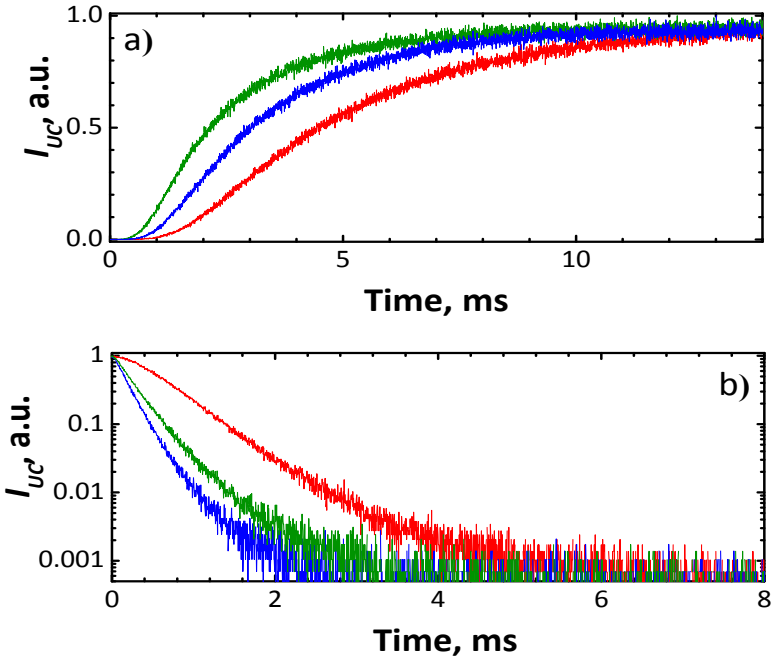


Figure S8 Population kinetics (a) and decays (b) of the Er^{3+}: $^2H_{11/2}$, $^4S_{3/2}$ (green lines), Er^{3+}: $^4F_{9/2}$ (red lines) and Er^{3+}: $^2H_{9/2}$ (blue lines) states of material SrF_2:2%Yb^{3+},5%Er^{3+} by laser excitation with λ=980 nm and excitation power density 10 W/cm^2

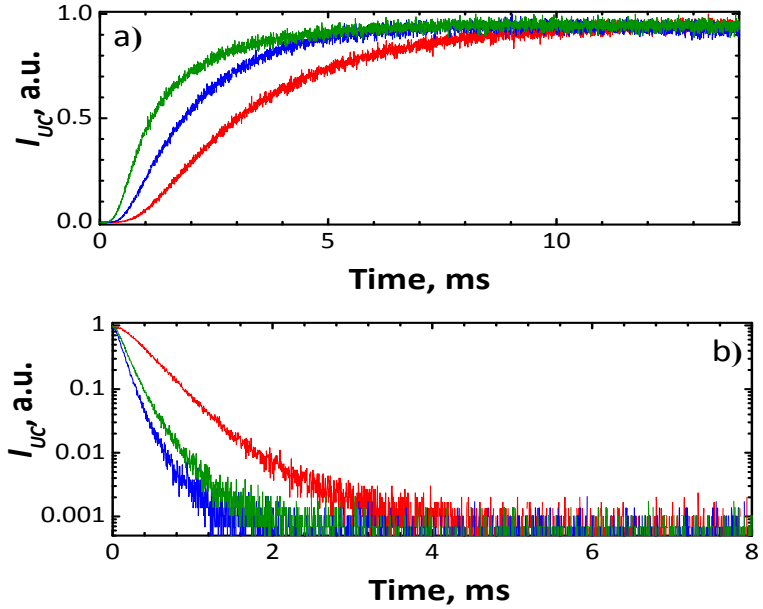


Figure S9 Population kinetics (a) and decays (b) of the Er^{3+}: $^2H_{11/2}$, $^4S_{3/2}$ (green lines), Er^{3+}: $^4F_{9/2}$ (red lines) and Er^{3+}: $^2H_{9/2}$ (blue lines) states of material SrF_2:2%Yb^{3+},7.5%Er^{3+} by laser excitation with λ=980 nm and excitation power density 10 W/cm^2

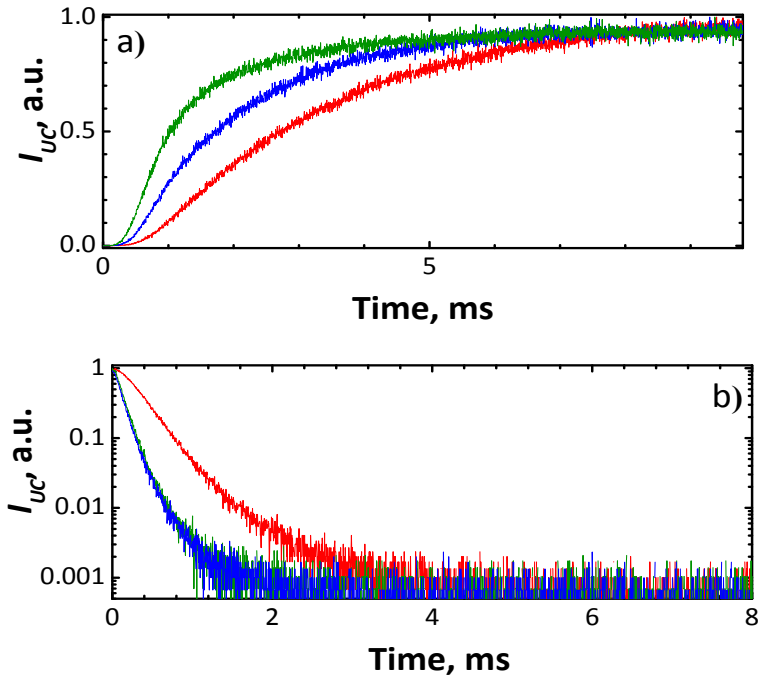


Figure S10 Population kinetics (a) and decays (b) of the Er^{3+}: $^2H_{11/2}$, $^4S_{3/2}$ (green lines), Er^{3+}: $^4F_{9/2}$ (red lines) and Er^{3+}: $^2H_{9/2}$ (blue lines) states of material SrF_2:2%Yb^{3+},10%Er^{3+} by laser excitation with λ=980 nm and excitation power density 10 W/cm^2

Table S1 UC luminescence lifetime of Er^{3+} under 980 nm excitation in SrF_2 host with different dopant concentrations.

Host	Er^{3+}/Yb^{3+} mol.%	τ_{UC} (Er^{3+}: $^4F_{9/2}$), ms	τ_{UC} (Er^{3+}: $^2H_{11/2}$, $^4S_{3/2}$), ms	τ_{UC} (Er^{3+}: $^2H_{9/2}$), ms
SrF_2	2/2	0.87	0.46	0.47
SrF_2	2/5	0.56	0.27	0.19
SrF_2	2/7.5	0.37	0.16	0.12
SrF_2	2/10	0.30	0.13	0.12

Table S2 UC luminescence lifetime of Er3+ under 980 nm excitation in SrF2 host with different dopant concentrations.

Host	Er^{3+}/Yb^{3+} mol.%	τ_{UC} (Er^{3+}: $^4F_{9/2}$), ms	τ_{UC} (Er^{3+}: $^2H_{11/2}$, $^4S_{3/2}$), ms	τ_{UC} (Er^{3+}: $^2H_{9/2}$), ms
SrF_2	1.5/2	0.73	0.36	0.25
SrF_2	1.5/5	0.46	0.20	0.17
SrF_2	1.5/7.5	0.39	0.17	0.13

SrF_2	1.5/10	0.29	0.13	0.11