Upconversion luminescence intensity of β-$NaYF_4$:Er^{3+},Yb^{3+} nanoparticles in magnetic fields up to 70 T

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Motivation

In literature the impact of the magnetic field on the upconversion luminescence (UCL) is non-consistent. In our work we would like to resolve a discrepancy between data reported in many research by answering the following questions:

- How does a high magnetic field affect the UCL?
- How does the change of excitation wavelength in a high magnetic field affect the UCL?
- How does a high magnetic field affect the absorption, relaxation and energy transfer pathways in β-$NaYF_4$:Er^{3+},Yb^{3+} nanoparticles?

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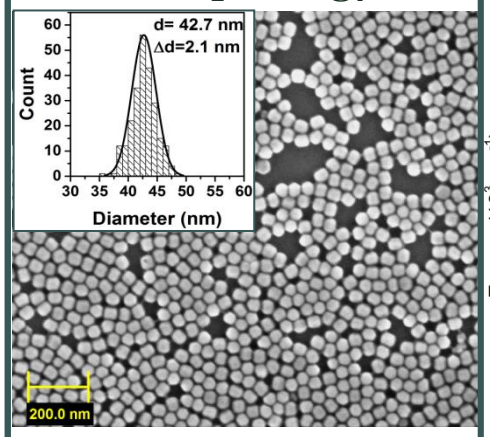
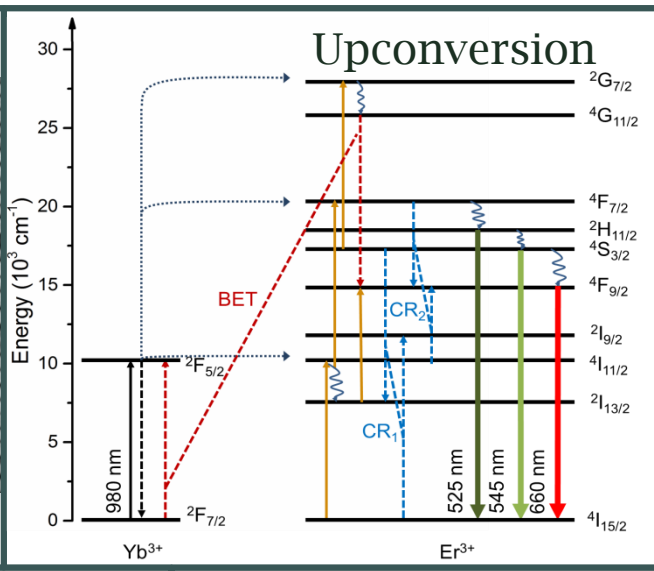
Morphology



SEM image and size distribution of UCNPs.

Upconversion



Black thin/dashed arrow – excitation/deexcitation.

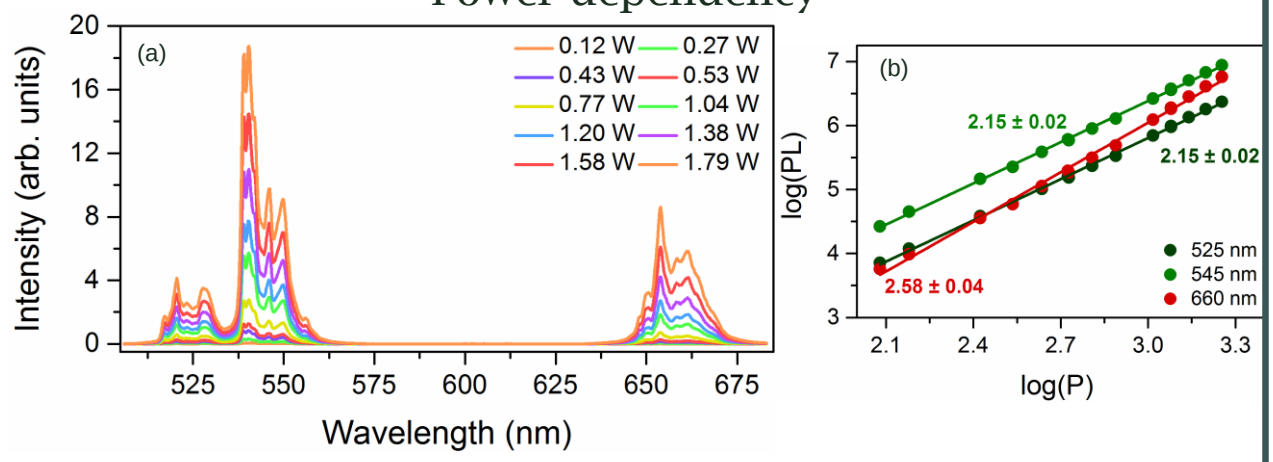
Yellow arrows – energy transfers.

Blue wavy lines – multiphonon energy relaxation.

Blue and red dashed lines – cross-relaxation (CR) and back energy transfer (BET)

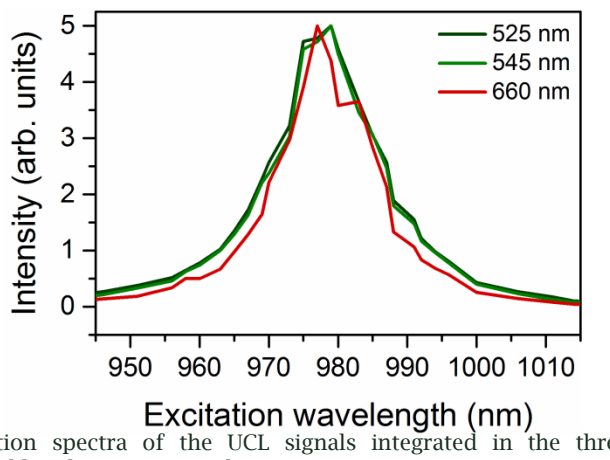
Thick green and red lines – light emission.

Power dependency



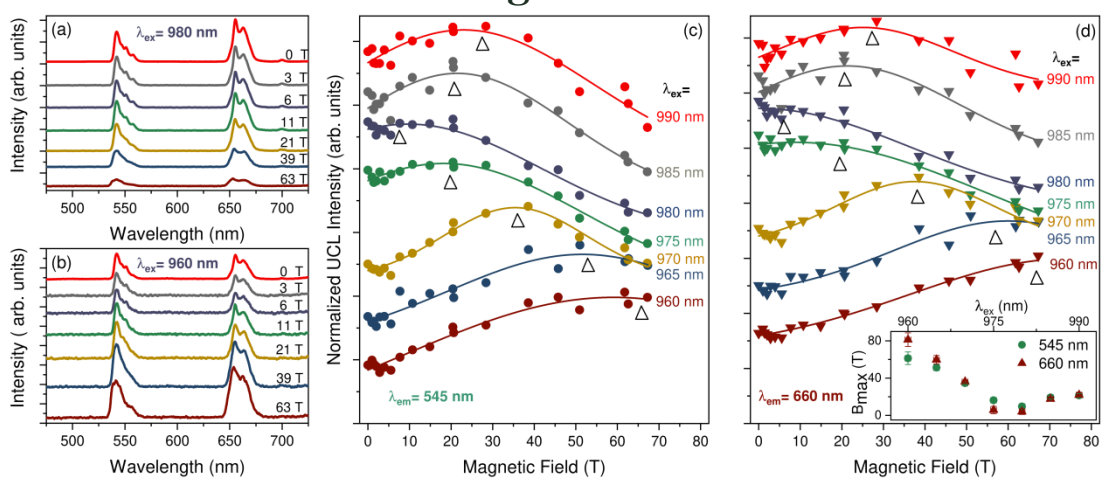
(a) UCL spectra measured for NIR excitation with various powers. (b) Double logarithmic plot of the excitation power dependence of the UCL intensity, integrated in three spectral bands: 525, 545 and 660 nm.

Excitation dependency

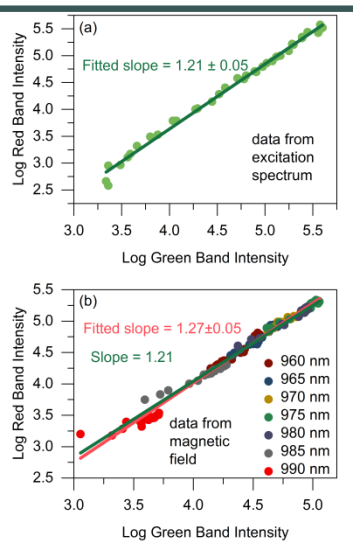


Excitation spectra of the UCL signals integrated in the three spectral bands: 525, 545 and 660 nm.

UCL in magnetic field

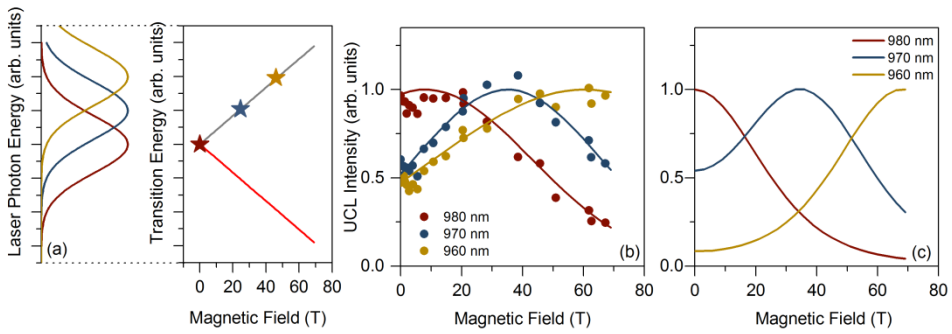


UCL measured at 100 K for various magnetic fields for two excitation wavelengths: (a) 980 nm and (b) 960 nm. Magnetic field dependence of upconverted luminescence intensities of the (c) green band and (d) red band normalized to the maximum value and shifted vertically for clarity. Points represent experimental data. Lines are guides to eye (fitted Gaussian functions). Empty triangular arrows denote positions of intensity maxima. The inset in (d) shows excitation wavelength dependence of the magnetic field B_{max}, corresponding to the maximum luminescence intensity for the two spectral bands – 545 and 660 nm.



Dependence of the red band UCL intensity on the green band UCL intensity. (a) Data from the excitation spectrum shown above. (b) Data from the UCL measurements in magnetic field for various excitation wavelengths.

Theoretical study



(a) A schematic relationship between the laser spectrum (left) and the Zeeman split absorption transitions between two spin-1/2 states. The Gaussians represent the laser spectra, the lines denote the transition energies, and the stars mark the magnetic fields of maximum excitation efficiency. (b) Green band UCL intensities for the selected excitation wavelengths. (c) Calculated UCL intensities for the selected excitation wavelengths.

Conclusions

- The magnetic field influences UCL from β-$NaYF_4$:Er^{3+},Yb^{3+} nanoparticles by modifying the excitation efficiency.
- Zeeman effect cause detuning of the absorption transition in Yb^{3+} ions from the excitation laser line. The magnitude of this detuning determines the behavior of luminescence intensity in magnetic field, which depends on the excitation wavelength.
- The magnetic field does not disrupt the energy transfer paths between the Yb^{3+} and Er^{3+} ions and the phonon relaxation rates

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