Pressure Dependence of Lanthanide-based Upconverting Nanomaterials

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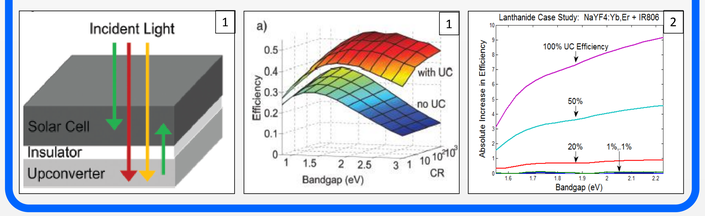
Purpose

To explore the pressure dependence of the upconverting capabilities of $NaYF_4$:Er^{3+},Yb^{3+} nanoparticles, thereby gaining insight into the structure of the material and elucidating its most effective optimization routes

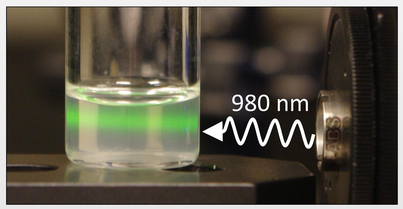
Upconversion Basics

Upconversion (UC) describes the process through which **two or more low-energy photons** are converted into a **single high-energy photon**

PV Applications



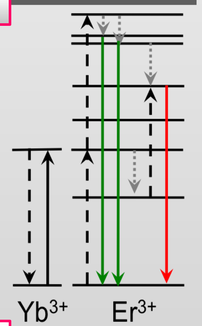
UC with $NaYF_4$:Er^{3+},Yb^{3+}



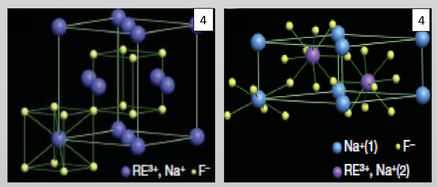
$NaYF_4$ doped with trivalent erbium and ytterbium is **the most efficient lanthanide-based upconverter to date**[3]

Terminology

- Er^{3+}, the **emitter**: chosen for its regularly-spaced energy levels and long-lived excited states
- Yb^{3+}, the **sensitizer:** chosen for its relatively large absorption band and energy resonance with Er^{3+}
- $NaYF_4$, the **host**: chosen for its chemical stability and low phonon energies



Phase Effects



$NaYF_4$ is stable in both a cubic and a hexagonal phase at STP – **the latter yields 10x greater UC efficiencies**[4]

Limitations

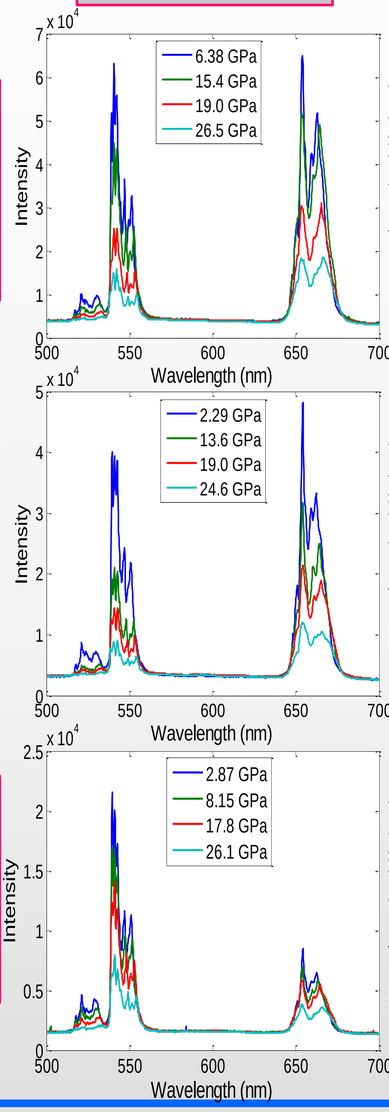
- **Low efficiencies (<1%)**
- Narrow absorption width
- Weak emission intensities

Unknowns

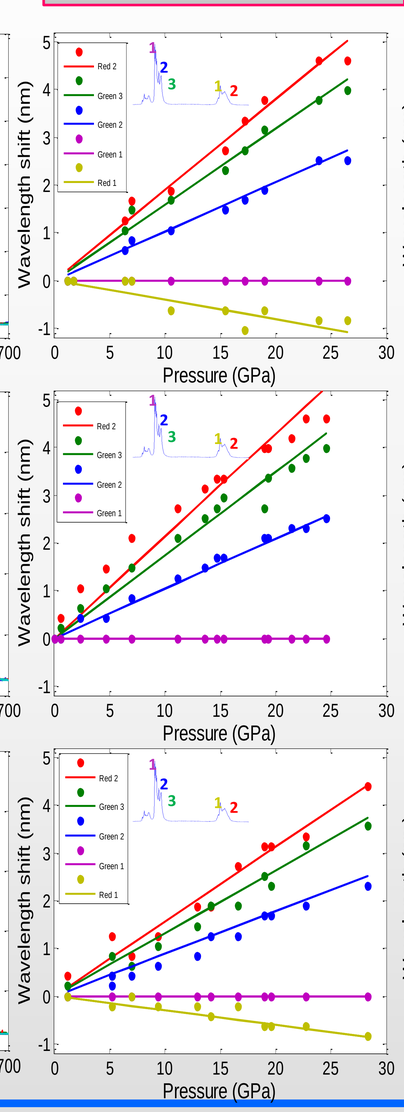
- **Dopant ion positions**
- Optimal particle size
- **Ideal crystal field**

Results

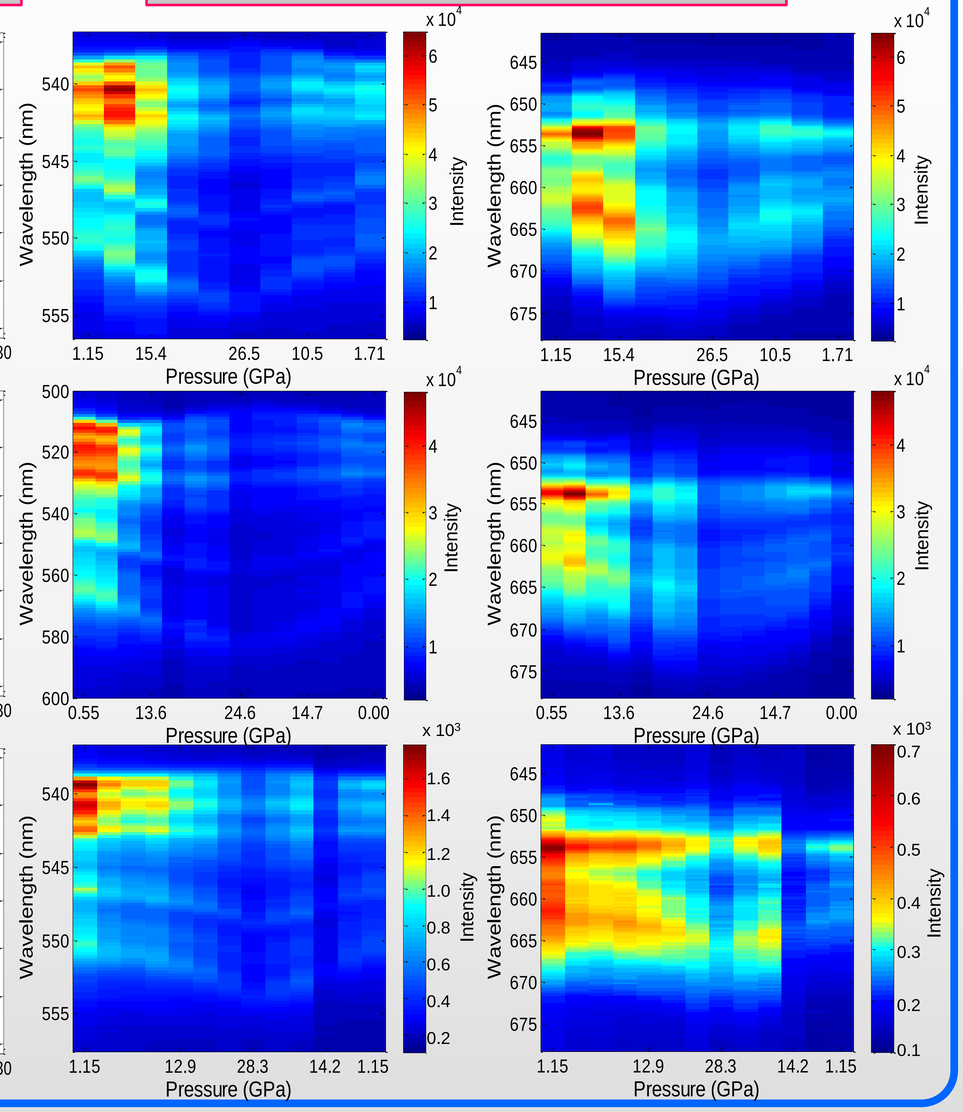
UC Spectra



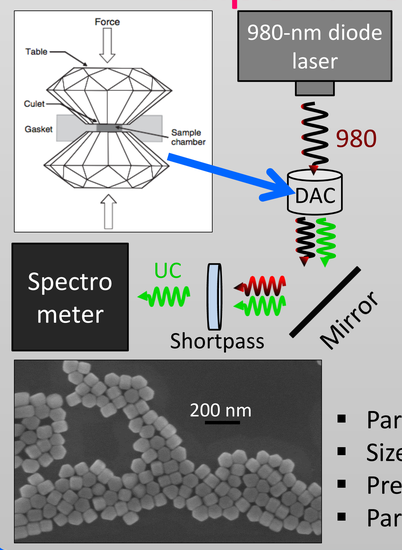
UC Peak Positions

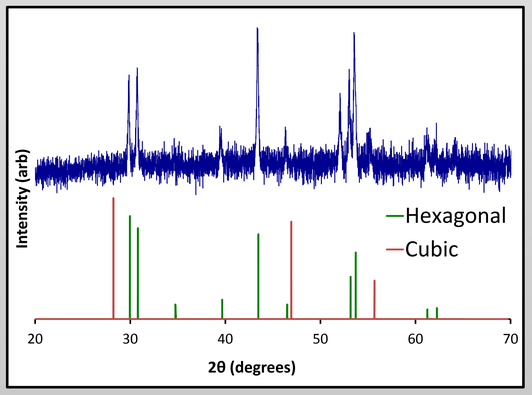


Changing Emission with Pressure



Experimental Procedure





- Particles of size **25, 40, and 90 nm** were synthesized
- Size and phase were verified via SEM and XRD
- Pressure was applied using a **diamond-anvil cell**
- Particles were illuminated with **980-nm light**

Outlook

UC emission peaks were observed to **decrease in intensity** and to exhibit **significant spectral shifts** with applied pressure. We believe these observations result **from changes in interionic distances** and **perturbations to the local crystal field** environments of the dopant ions.

Future Work

- Study **cubic-phase** $NaYF_4$:Er^{3+},Yb^{3+} nanoparticles
- Study hexagonal particles of **different morphologies**
- Conduct **synchrotron XRD** measurements
- Use **crystal field theory** to deduce **ion locations**

Acknowledgments

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References

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