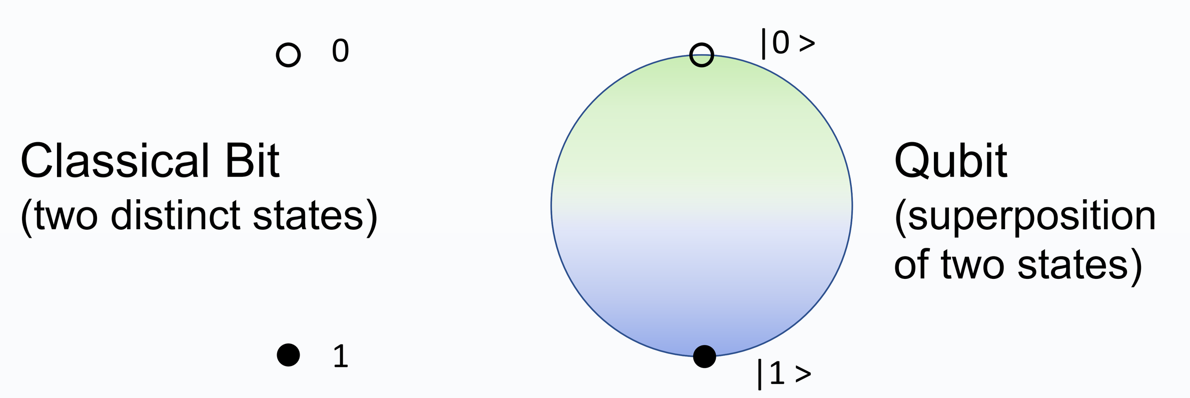
Synthesis of High-Symmetry Lanthanide Complexes for Quantum Information Processing

Gia Rivers, Miguel Gakiya-Teruya, Michael Shatruk

Department of Chemistry and Biochemistry, Florida State University

Abstract

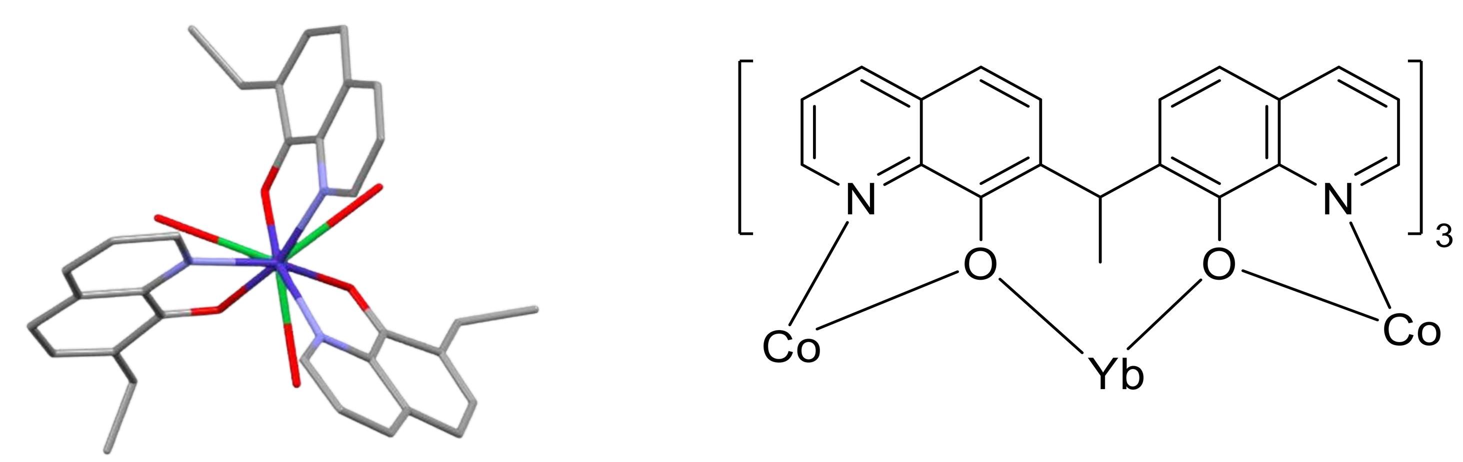
A ***qubit*** is an important component for quantum information processing. Unlike a classical bit, which can exist only in two states, 0 or 1, a qubit can exhibit a superposition of these states to allow a remarkable increase in computational power. Among many possible implementations of qubits currently under investigation, molecular spin qubits have drawn interest due to their synthetic tunability and scalability. In this contribution, we report the investigation of high-symmetry metal-organic frameworks that can host spin-qubit centers with long coherence times.



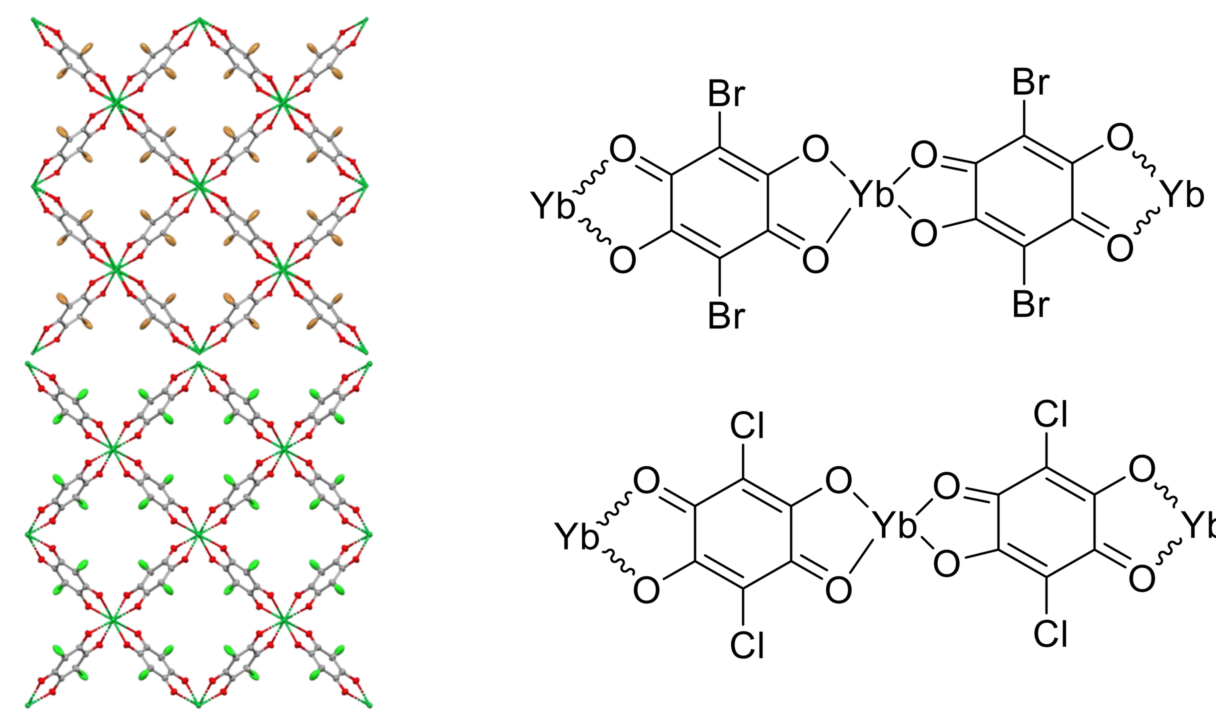
Background and Motivation

Quantum information processing takes advantage of current knowledge of quantum principles of matter to advance computing technology. Placing a qubit in a coherent superposition state can dramatically speed up computational processes. It is important that a qubit is able to communicate with other qubits in order to perform operations. One important parameter that should be studied and optimized is qubit's ***coherence time***, which is the lifetime of the superposition state. Our current research focuses on ***ytterbium*** (Yb) and ***gadolinium*** (Gd) spins embedded in ***metal organic frameworks*** (MOFs). We study the influence of the rigidity and vibrational properties of MOFs on the coherence time. The other objective is to study high-symmetry complexes for optical readout of spin qubits and for the implementation of spin ***qudits***. This research project is carried out in close collaboration with the ***electron paramagnetic resonance*** (EPR) group at the National High Magnetic Field Laboratory.

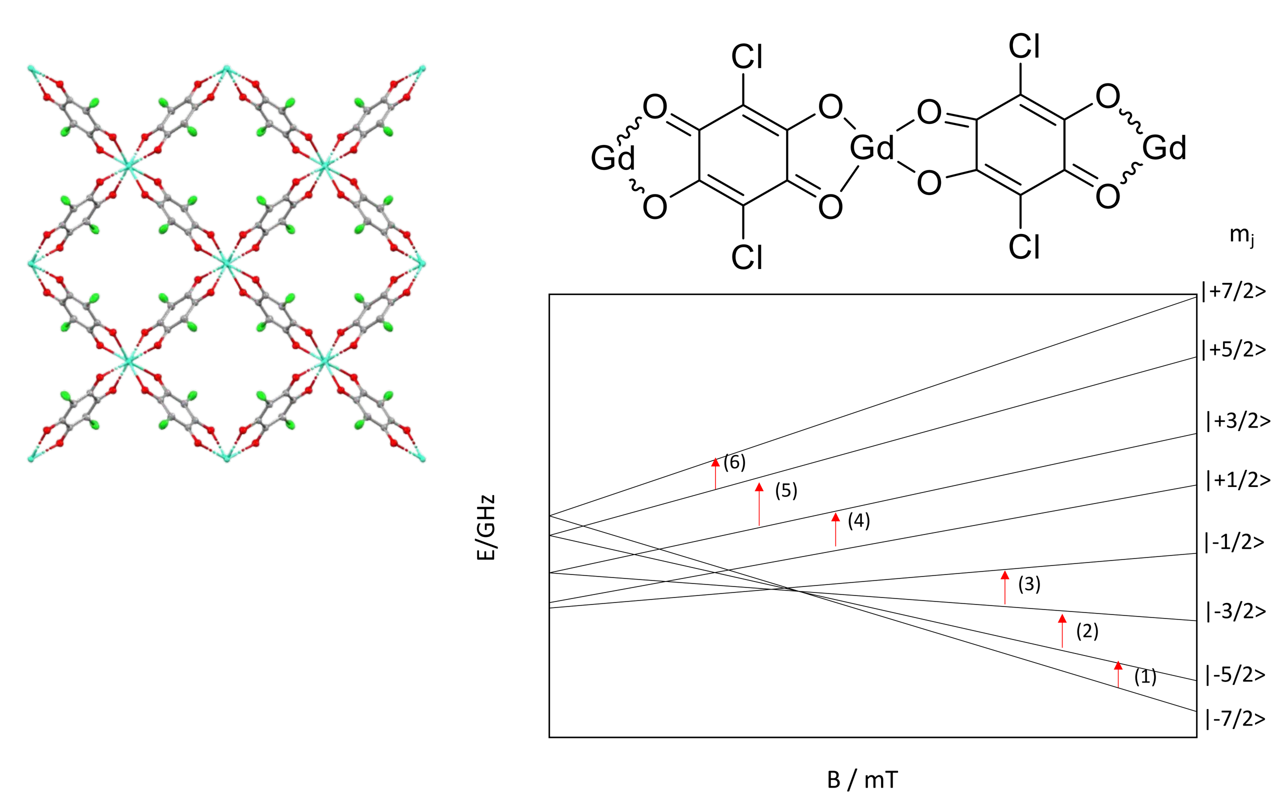
Synthesis of Trigonal Yb Complexes



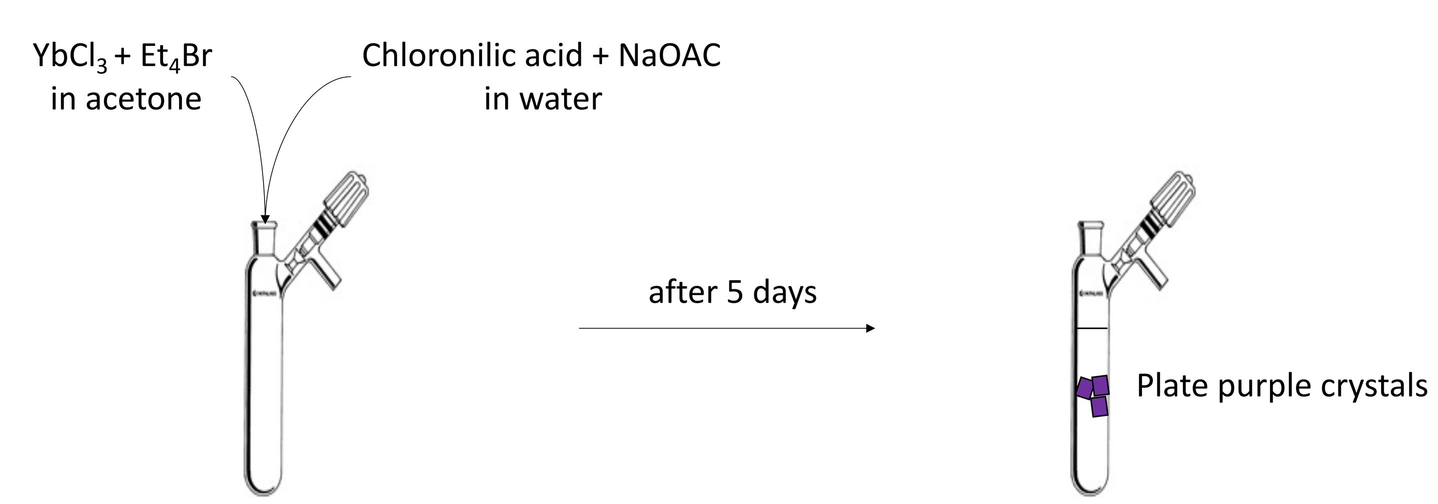
Synthesis of Tetragonal Yb MOFs



Synthesis of High-Symmetry Gd Qudits



Crystallization by Solvent Diffusion



Research Objectives

1. Study high-symmetry luminescent complexes for optical readout of spin qubits
2. Synthesize a Yb metal-organic framework and explore the influence of its rigidity and vibrational properties on the qubit coherence time
3. Explore Gd complexes with high-symmetry structures for the implementation of spin "qudits"

Methods

Crystal growth:
slow diffusion of antisolvent into an aqueous solution of corresponding metal complexes

Crystal structure analysis:
single-crystal X-ray diffraction to ensure that the intended crystal structure was formed

Magnetic property measurements:
SQUID magnetometry and EPR spectroscopy at the National High Magnetic Field Laboratory

Preliminary Results

The desired crystals of the three complexes shown on the left have been obtained and the crystal structures have been confirmed by X-ray diffraction.

Acknowledgements

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References

Atzori, M.; Sessoli, R. The second quantum revolution: role and challenges of molecular chemistry. *Journal of the American Chemical Society* **2019**, *141*, 11339.

Wasielewski, M. R.; Forbes, M. D. E.; Frank, N. L.; et al. Exploiting chemistry and molecular systems for quantum information science. *Nature Review Chemistry* **2020**, *4*, 490.