Exploring Qubit Dynamics via Electron Paramagnetic Resonance Spectroscopy

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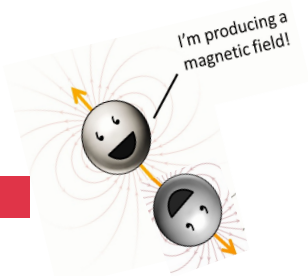
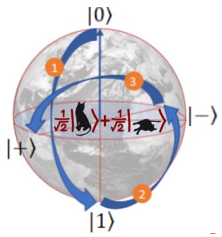
Introduction to Qubits

Imagine a coin that's both HEADS and TAILS at the same time! Welcome to the quantum world!



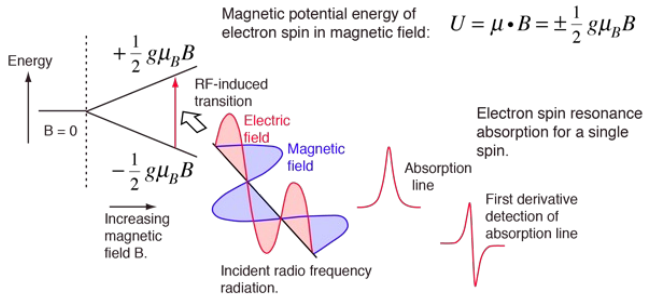
Electron Spin Qubit

Bloch Sphere



Such superposition enables electron spin qubits to exist in multiple states simultaneously, providing a powerful platform for storing and processing information beyond classical limits.

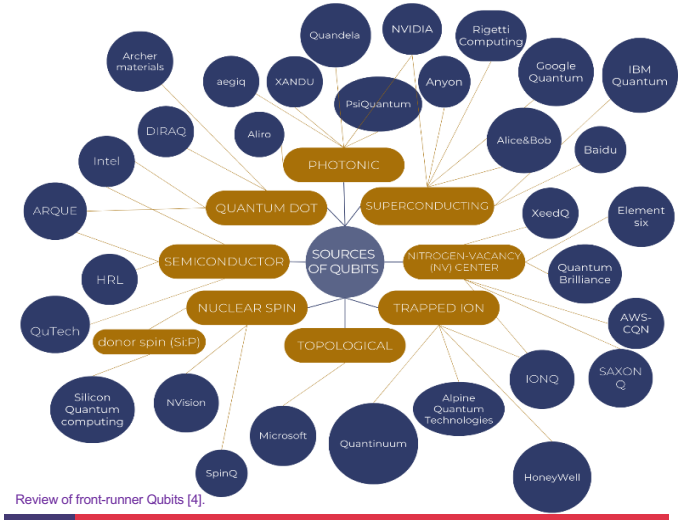
What is EPR?



Principle: EPR spectroscopy detects species with unpaired electrons by measuring their absorption of microwave radiation in a magnetic field.

Qubit Platforms in Quantum Technologies

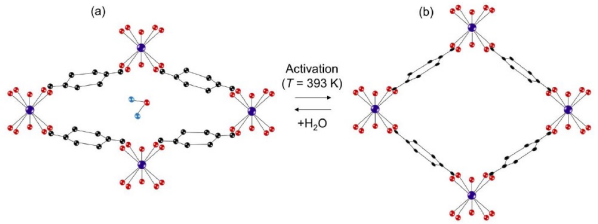
Our literature review



Review of front-runner Qubits [4].

What Do We Study?

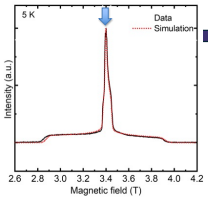
Metal Organic Frameworks



MOFs: Metal Organic Frameworks, a Nobel Prize (2025) recognized class of materials, are scalable, tunable, EPR accessible, and promising for qubit and qudit platforms.
Scheme: MIL-53(Al/Cr) [3].

What Do We Measure?

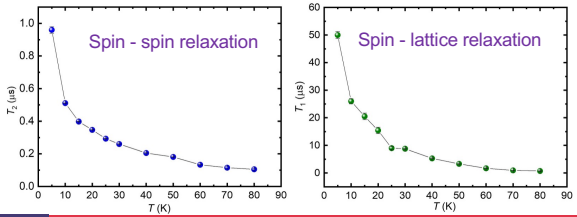
Echo detected field sweep



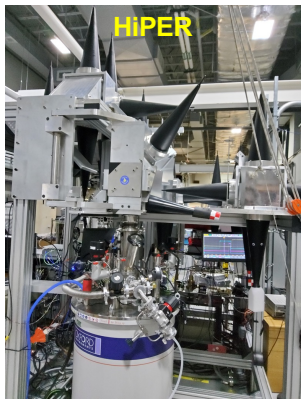
Close Pore Phase (Water adsorption)

g	D (GHz)	E (GHz)	E/D	D_{strain} (GHz)	E_{strain} (GHz)
1.978(2)	7.20(1)	2.40(4)	0.33	0.9(2)	0.3(1)

HiPER studies on a high-spin Cr(III)-based MIL-53 metal - organic framework complex revealed temperature-dependent relaxation that follows a mixed Raman and direct process. Furthermore, guest-induced pore transformation could potentially enhance the qubit lifetime.



Experimental Technique – At the MagLab



HiPER capabilities

- **High microwave power** (~1 kW) [1,2].
- W-band (**94 GHz**) quasi-optical EPR.
- Supports both **CW** and **pulsed** EPR.
- Short pulses **with broad excitation** bandwidths [2].
- Temperature = 2 - 300 K.
- Samples - powder, liquid, crystals.

What do we study?

- Qubit lifetime (Spin-spin and Spin-lattice)
- Spin Hamiltonian parameters
- Relaxation mechanism

Bridging EPR towards quantum technology [4].

Conclusions and Outlook

- Superposition, one of the most fascinating properties of quantum mechanics, serves as a linchpin of our quantum research and forms a foundation for the qubit materials we study.
- The simple idea that an electron can exist in multiple states at once forms the foundation of a quantum bit — the essence of what makes quantum research so unique.
- HiPER studies on a high-spin Cr(III)-based MIL-53 metal–organic framework complex revealed temperature-dependent relaxation.
- In this project, we conducted a literature review on various qubit platforms in quantum technologies, focusing on how EPR-based experimental techniques are used to investigate and extend qubit lifetimes, particularly in academia-driven metal–organic framework (MOF) systems.

References

[1] Paul A. S. Cruickshank et al., *Review of Scientific Instruments*, 2009, 80, 103102;
[2] D. Marcinkowski et al., *Dalton Transactions*, 2022, 51, 12041;
[3] **K. Thangavel** et al, RSC Adv., 2024, 14, 4244-4251.
[4] **B. Alvarado, N. Frank, K. Thangavel**, Manuscript under preparation – EPR towards industrial translation.

Acknowledgement

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