Molecular magnets, a fascinating plateform for quantum experiments

F. Balestro
C. Godfrin, R. Ballou, E. Bonet, M. Ruben, S. Klyatskaya, W. Wernsdorfer
Institut Néel, CNRS-UGA, 25 rue des Martyrs, 38021 Grenoble
franck.balestro@neel.cnrs.fr

The realization of a universal quantum computer is one of the major scientific objectives of the 21st century, as its promises are revolutionary: inviolable cryptography, higher computing power, simulation processes inaccessible to conventional technologies ... Its principle is based on qubit, a two-level quantum system, a quantum analogue of the classical bit. Today, the challenge is to increase the number of qubits in interaction to achieve more complex and more efficient quantum information protocols. In this context, molecular magnets of nanometric size are of major interest. The information is carried by the direction of magnetization which is multiple, unlike conventional magnets which have only two. They thus make it possible to have d-states quantum devices or qudits. These multi-level devices could the processes involved in the manipulation of quantum spin more efficient. The use of these would also simplify some computational tasks, and thus the circuits required to realize a quantum computer. In this context, it is possible to fully control a multilevel system based on a single molecular magnet. Proving that it is possible to read-out and manipulate the four-level spin of the terbium nucleus of a molecule was a first step to show the long decoherence time of a single nuclear spin which is by nature strongly isolated from its environment[1].

Among those properties, superposition of states and phase interference are two fundamental mechanisms from which quantum computing can benefit. We explored these properties by applying 3 interference protocols involving the phases of the four nuclear spin states[2]. A first measurement makes it possible to know the coherence time of the coherent superposition of a quantum system. Applied to a coherent superposition of three nuclear spin states, this protocol can be generalized to any given qudit. The second protocol makes it possible to directly measure the final phase of a quantum state on which different quantum gates where applied. It is an essential tool for the development of quantum algorithms. Finally, in a physical system that evolves adiabatically and cyclically, one can highlight, a phase that depends on the entire evolution during a cycle.

REFERENCES

1. Operating Quantum States in Single Magnetic Molecules : Implementation of Grover's algorithm. C. Godfrin, A. Ferhat, R. Ballou, S. Klyatskaya, M. Ruben, W. Wernsdorfer and F. Balestro. *Phys. Rev. Lett.* 119, 187702 (2017).
2. Generalized Ramsey Interferometry Explored with a single nuclear spin Qudit **.** C. Godfrin, R.Ballou, E. Bonet, M. Ruben, S. Klyatskaya, W. Wernsdorfer and F. Balestro. *Npj Quantum Information* **4**, 53 (2018)

FIGURES

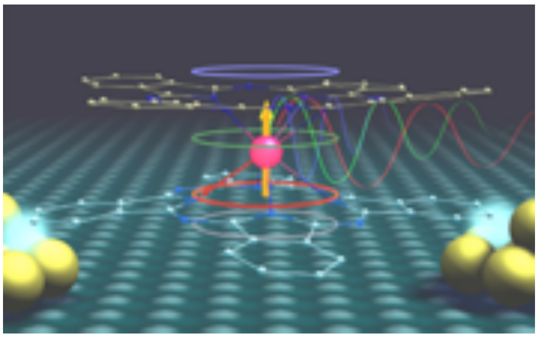

Figure 1: Artist view of a a single magnet molecular transistor. The heart of the circuit is the terbium-based molecular magnet (pink): two planar organic molecules protecting the Terbium ion. The magnet is connected to two metal electrodes (gold atoms) deposited on a substrate. The reading of the four spin states of the nucleus (represented in the magnification in the form of colored rings) is performed by an means of electric current. The exploration of the quantum properties of this is obtained by the application of microwave electric field pulse (blue, green and red)