Operating Quantum States in Single Magnetic Molecules: Implementation of Quantum Gates and Algorithm

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The application of quantum physics to the information theory turns out to be full of promises. The first step is to realize the basic block that encodes the quantum information, the qubit. Among all existing qubits, spin based devices are very attractive since they reveal electrical read-out and coherent manipulation. Beyond this, the more isolated a system is, the longer its quantum behavior remains, making of the nuclear spin a serious candidate for exhibiting long coherence time and consequently high numbers of quantum operation.

In this context I will present experimental results based on a $TbPc_2$ single molecular magnet spin transistor. This setup enabled us to read-out electrically both the electronic and the nuclear spin states and to coherently manipulate the nuclear spin[1,2]. I will present the study of the dynamic of a single 3/2 nuclear spin under the influence of a microwave pulse. After the energies difference measurement between these states I will show the coherent manipulation of the three nuclear spin transitions up to 10MHz, using only a microwave electric field, exhibiting coherence time higher than 1ms.

More than demonstrating the qubit dynamic, these measures demonstrate that a nuclear spin embedded in a molecular magnet transistor is a four quantum states system that can be fully controlled. Theoretical proposal demonstrated that quantum information processing could be implemented using a 3/2 spin such as quantum gates [3] and algorithm [4]. I will present the implementation of the Grover algorithm [5] to then show the implementation of the iSWAP gate and the measurement of its phase.

[1] Thiele S. et al. Science 344, 1135 (2014)
[2] Godfrin C. et al. ACS Nano 11, 3984 (2017)
[3] Kiktenko E. O. et al. Phys. Rev. A 91, 042312 (2015)
[4] Leuenberger M. et al. Phys. Rev. Lett. 89, 207601 (2003)
[5] Godfrin C. et al. Phys. Rev. Lett. 119, 187702 (2017)