Spin flip induced by microwave pulses in a molecular spin transistor

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Introduction

The ability to control the quantum state of a single spin is a key step towards the development and realization of spin-based quantum computation.

Here, we demonstrate the possibility to induce the reversal of an individual electronic spin embedded in a molecular spin transistor by means of microwave (MW) pulses.

Molecular Magnet as Electronic and Nuclear spin quantum system

Electronic spin

$J = 6$

$\mu = 9\,\mu_B$

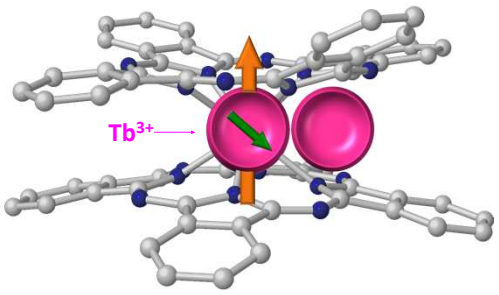
$m_J = \pm 5\ (ES)$

$\Delta E = 600\ K$

$m_J = \pm 6\ (GS)$

→ Ising spin

$|\uparrow\rangle$ & $|\downarrow\rangle$



Terbium double-decker ($TbPc_2$)

Nuclear spin

$I = 3/2$

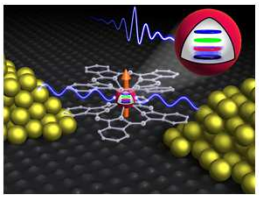
$\mu_I \sim 1/1000\ \mu_B$

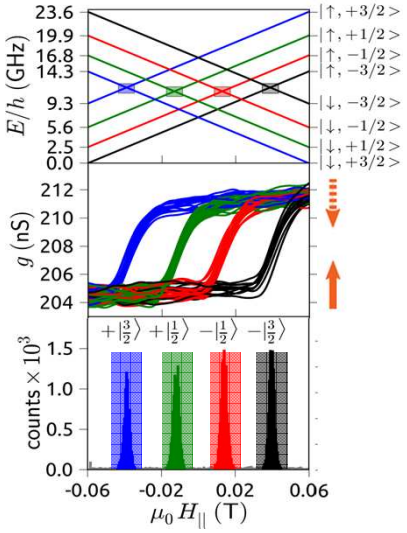
$m_I = \pm 3/2 \pm 1/2$

$\mathrm{H_{hf}} = \mathbf{A}\,\mathrm{I}\cdot J + P I_z^2$

$|-\frac{3}{2}\rangle$ — 3.7 GHz — $|-\frac{1}{2}\rangle$ — 3.1 GHz — $|+\frac{1}{2}\rangle$ — 2.5 GHz — $|+\frac{3}{2}\rangle$

Spin transistor





Single-molecule transistor for electrical single nuclear spin detection and manipulation.

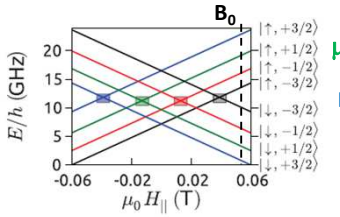
R. Vincent, S. Klyatskaya, M. Ruben, W. Wernsdorfer, F. Balestro *Nature* **488**, 357 (2012)

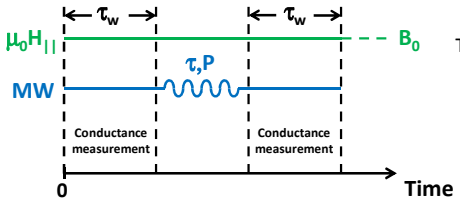
S. Thiele, F. Balestro, R. Ballou, S. Klyatskaya, M. Ruben, W. Wernsdorfer, *Science* **344**, 1135 (2014)

C. Godfrin, S. Thiele, A. Ferhat, S. Klyatskaya, M. Ruben, W. Wernsdorfer, F. Balestro, *ACS Nano* **11**, 3984 (2017)

Electronic spin manipulation through MW pulses

a) Protocol of measurement

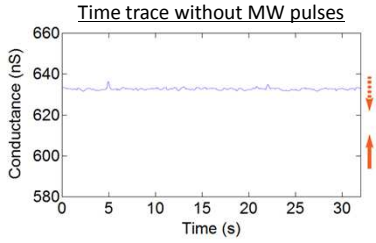




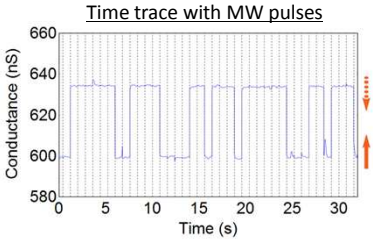
Typical values:

- $B_0 = 60\ mT$
- $\tau_w = 0.4\ s$
- $\tau = 2\ ms$
- $P = 3 - 10\ dBm$

Time trace without MW pulses



Time trace with MW pulses

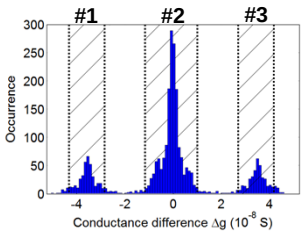


MW pulses are applied every $2\tau_w$ at the time instants indicated by the vertical dotted lines.

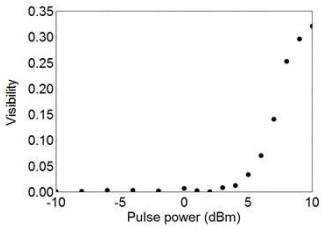
b) Visibility of the electronic spin reversal process

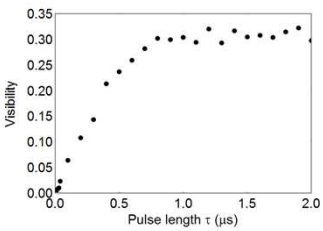
For each MW pulse, the difference between the conductance measured after and before the pulse is computed.

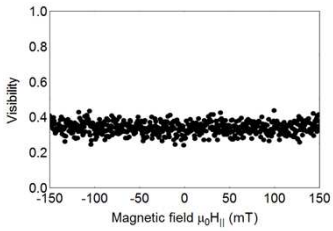
- $\Delta g < 0$: $|\downarrow\rangle \rightarrow |\uparrow\rangle$ transition
- $\Delta g = 0$: no e⁻ spin reversal
- $\Delta g > 0$: $|\uparrow\rangle \rightarrow |\downarrow\rangle$ transition



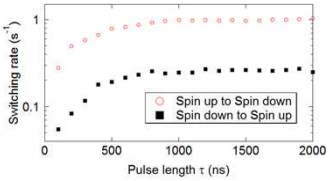
$$Visibility = \frac{Area(\#1) + Area(\#3)}{Area(\#1) + Area(\#2) + Area(\#3)}$$

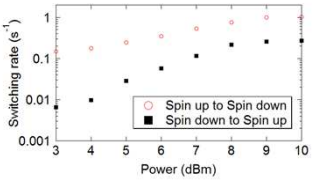






c) Switching rates





The reversal of the Tb^{3+} electronic spin is mainly caused by the local temperature increase induced by the MW pulses.

Acknowledgements

FUTURO IN RICERCA

MoQuaS Molecular Quantum Spintronics FP7-ICT-2013-10

MOISpin COST

Agence Nationale de la Recherche ANR