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Review article

Spin decoherence of magnetic atoms on surfaces

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ABSTRACT

We review the problem of spin decoherence of magnetic atoms deposited on a surface. Recent breakthroughs in scanning tunnelling microscopy (STM) make it possible to probe the spin dynamics of individual atoms, either isolated or integrated in nanoengineered spin structures. Transport pump and probe techniques with spin polarized tips permit measuring the spin relaxation time T_1, while novel demonstration of electrically driven STM single spin resonance has provided a direct measurement of the spin coherence time T_2 of an individual magnetic adatom. Here we address the problem of spin decoherence from the theoretical point of view. First we provide a short general overview of decoherence in open quantum systems and we discuss with some detail ambiguities that arise in the case of degenerate spectra, relevant for magnetic atoms. Second, we address the physical mechanisms that allows probing the spin coherence of magnetic atoms on surfaces. Third, we discuss the main spin decoherence mechanisms at work on a surface, most notably, Kondo interaction, but also spin–phonon coupling and dephasing by Johnson noise. Finally, we briefly discuss the implications in the broader context of quantum technologies.

Contents

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1. Introduction

Major technological revolutions have occurred when the humankind has been able to harness natural resources, such as fire, electricity or nuclear energy. We are now in the verge of the so called second quantum revolution, that aims to harness two of the weirdest natural resources, coherence and entanglement. This is a tall order that calls for a great dose of ingenuity, because keeping quantum states in coherent superpositions that could be used towards our advantage requires to defeat a rather powerful enemy, the infamous decoherence. Here, we review the phenomenon of spin decoherence in the context of magnetic atoms deposited on surfaces.

1.1. The relevance of decoherence

The interaction of quantum spins with their environment introduces relaxation and decoherence in the otherwise fully coherent evolution of ideal closed quantum systems [1]. Spin relaxation and decoherence play a central role in many branches of physics. In the case of nuclear spins, the time scales associated to energy relaxation and decoherence, T_1 and T_2 respectively, provide a very meaningful information of the environment that forms the basis of magnetic resonance imag-