Observation of magnon dynamics in a quantum dot ladder

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Abstract

Analog quantum simulators promise to shed light on current problems in natural sciences before digital, fault tolerant quantum computers reach quantum practicality. In recent years, semiconductor gate-defined quantum dot arrays have emerged as a promising platform for both digital and analog efforts. In the past, these systems have been used to simulate a plethora of physical phenomena [1-5], thanks to the in-situ tunability of tunnel couplings and onsite interactions, as well as the direct mapping of their Hamiltonian to an extended Fermi-Hubbard or Heisenberg model, depending on the parameter regime.

In this work, we use an array of quantum dots in a Ge/SiGe quantum well to simulate the dynamics of single spin excitations or magnons, based on our previous efforts characterizing charge and two-spin states in similar devices [5,6]. For this purpose, we control exchange interactions between neighbouring sites throughout the array, individually tunable over several orders of magnitude. Using transitions with a controlled degree of adiabaticity and exchange-based gates, we demonstrate initialization and readout of several spin states. This ultimately allows us to initialize single magnons in desired locations in the array and pinpoint their position as they propagate over time. We observe their evolution for different exchange coupling configurations and topologies, and compare the results to simulations based on the Heisenberg model.

Furthermore, we exploit the rich physics of holes in germanium to explore the impact of disorder to the magnon dynamics. Owing to their strong intrinsic spin-orbit interaction, spins in germanium exhibit site-dependent g-tensors, which act as a source of single-site disorder. We observe how moderately high ratios of disorder to interactions disrupt the ideal dynamics of single magnons and ultimately lead to localization. The obtained results are promising in the context of simulating many-body localization and other disorder-based solid-state phenomena.

References

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Figures

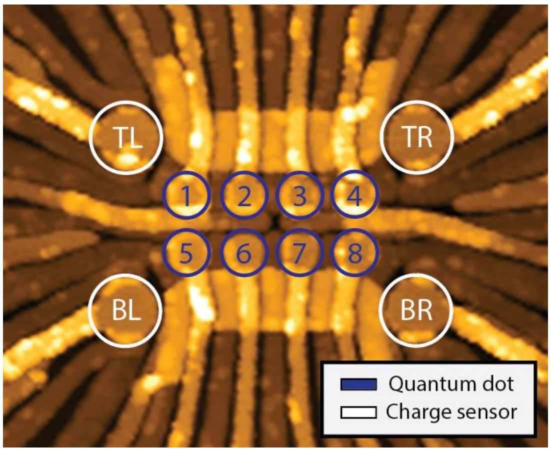

Figure 1: AFM image of a 2x4 germanium quantum dot ladder with four sensing dots, nominally identical to the one used for this experiment.