Hexagonal Plaquette Spin-spin Interactions and Quantum Magnetism in a Two-dimensional Ion Crystal

Tue, 2016-06-07 15:52 - Christine Muschik [1] **Date:** 2015-04-07

Author(s):
Rejish Nath, Marcello Dalmonte, Alexander W Glaetzle, Peter Zoller, Ferdinand Schmidt-Kaler, Rene Gerritsma

Reference:
New J. Phys. 17 (2015) 065018

URL:
http://arxiv.org/pdf/1504.01474v1.pdf [2]

We propose a trapped ion scheme en route to realize spin Hamiltonians on a Kagome lattice which, at low energies, are described by emergent Z2 gauge fields, and support a topological quantum spin liquid ground state. The enabling element in our scheme is the hexagonal plaquette spin-spin interactions in a 2D ion crystal. For this, the phonon-mode spectrum of the crystal is engineered by standing-wave optical potentials or by using Rydberg excited ions, thus generating localized phonon-modes around a hexagon of ions selected out of the entire two-dimensional crystal. These tailored modes can mediate spin-spin interactions between ion-qubits on a hexagonal plaquette when subject to state-dependent optical dipole forces. We discuss how these interactions can be employed to emulate a generalized Balents-Fisher-Girvin model in minimal instances of one and two plaquettes. This model is an archetypical Hamiltonian in which gauge fields are the emergent degrees of freedom on top of the classical ground state manifold. Under realistic situations, we show the emergence of a discrete Gauss's law as well as the dynamics of a deconfined charge excitation on a gauge-invariant background using the two-plaquettes trapped ions spin-system. The proposed scheme in principle allows further scaling in a future trapped ion quantum simulator, and we conclude that our work will pave the way towards the simulation of emergent gauge theories and quantum spin liquids in trapped ion systems.

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