Quantum simulation of geometrically frustrated systems based on trapped ions.

Henning Kalis, Manuel Mielenz, Miriam Bujak, Ulrich Warring and Tobias Schaetz

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Quantum-disordered phases may offer a variety of exotic behaviour, e.g., manifestation of quantum spin-liquid phases. Understanding the physics governing these systems in detail could as well help to gain an insight into related topics like resonating valence bond theory attempting to depict high-temperature superconductivity [1].
Unfortunately, such quantum systems are not fully accessible by classical simulations. One approach to overcome this difficulty could be to implement these quantum systems directly and in a well controllable quantum simulator, as proposed by R. Feynman [2].
Geometrical frustration has turned out to be a mechanism for inducing quantum disordered phases. The first system of interest, which will be focused to be implemented in an ion-trap, would be the transversal antiferromagnetic Ising-Model on a triangular lattice, exhibiting a macroscopic number of energetic equivalent (classical) groundstates. Switching on a non-commuting magnetic field, will break the degeneracy of the groundstates, introducing quantum fluctuations, which will cause the system to perform a 2nd order quantum-phase transition into a quantum ordered (polarized) phase [3, 4]. This phenomenon is known as "order by disorder" [5].
However high-fidelity quantum control of such systems is obligatory and has been demonstrated in linear Paul-Traps (e.g. the quantum simulation of the 1D transverse-field Ising-Model [6, 7]). Though high operational fidelity exceeding 99% is currently still restricted to a very limited number of constituents. A promising bottom-up approach for scaling the trapped ion system in size and dimension is based on radio-frequency surface-electrode traps [8], spanning arrays of individual rf-traps. These surface-electrode traps may thus extend the control to 2D arrays of individual traps (lattices) enabling, in principle, the simulation of 2D Hamiltonians. We introduce our surface trap geometry and report on the current status of the experiment.

References

[1] P.W. Anderson, Materials Research Bulletin, 8(2):153 160, (1973).

[2] R.P. Feynman, Int. J. Theor. Phys., VoL 21, Nos. 6/7, (1982).

[3] S. V. Isakov and R. Moessner. Phys. Rev. B, 68:104409, (2003).

[4] M.Powalksi et al., Phys. Rev. B 87, 054404, (2013).

[5] R. Moessner and S. L. Sondhi. Phys. Rev.B, 63:224401, (2001).

[6] R. Islam et. al, arXiv:1210.0142, (2012).

[7] A. Friedenauer et al., Nature Physics 4, 757 - 761 (2008).

[8] R.Schmied, Phys. Rev. Lett. 102, 233002 (2009).