Quantum Optics of Chiral Many-Body Spin Systems - a Rydberg Implementation

Peter Zoller*†[1,2]

[1]Institut für Quantenoptik und Quanteninformation der Österreichischen Akademie der Wissenschaften – Otto Hittmair-Platz 1 / Technikerstr. 21A, A-6020 Innsbruck, Austria, Austria
[2]Institut für Theoretische Physik - Universität Innsbruck – Technikerstr. 21A, A-6020 Innsbruck, Austria

Abstract

We are interested in open quantum many-body systems, and in particular in the formation of strongly correlated quantum phases, which arise as a dynamical equilibrium between driving and dissipation. Our goal is to find interesting scenarios for such driven-dissipative quantum many-body dynamics, and their physical realization in setups with cold atoms.

As our model system we consider a 'chiral' quantum spin network, and an 'all atom' realization with Rydberg atoms interacting via dipolar interactions. The essential ingredients are a spins, which can 'decay' to spin chains with chiral (unidirectional) coupling, analogous to the discussion of synthetic gauge fields in dipolar spin systems. These spins can be wired up in a quantum network, as a spin analogue of chiral photonic networks discussed recently as atoms coupled to photonic nano-structures. Remarkably, the steady state evolves to a pure 'dark' state of the many-body dynamics, with the system spins pairing up as quantum dimers. This is the prediction of a master equation treatment, with the waveguides eliminated as a quantum reservoir as standard in quantum optics However, our system allows us to go significantly beyond the Born-Markov approximation, by including (part of) the spin chain as 'system dynamics' employing modern quantum many-body techniques such as time-dependent DMRG. This allows us to 'see' the reservoir dynamics, in particular to describe the entanglement of the system-reservoir, and discuss non-Markovian dynamics related to retardation effects and nonlinearities in propagation of spin excitations.

We conclude by pointing to various applications of such driven-dissipative chiral spin networks, e.g. in a quantum information context. Our setup can also be understood as defining a new quantum optical scenario ('quantum spintronics'), with spin excitations playing the role of 'hard core' photons.

*Speaker
†Corresponding author: Peter.Zoller@uibk.ac.at