Quantum-nano photonics for quantum simulations

Dimitris G. Angelakis

School of Electronic and Computer Engineering, Technical University of Crete, Chania, Crete, Greece, 73100
Centre for Quantum Technologies, National University of Singapore, 3 Science Drive 2, Singapore 117543
http://www.dimitrisangelakis.org

The progress in manipulating light-matter interactions at the micro- and nano-scale as in the case of cold atoms interfaced with nano-photonic structures, and in circuit QED, make it now possible to robustly observe strong coupling and nonlinear optical interactions at the quantum level. The latter has recently motivated the birth of a new field where strongly correlated states of light generated in such optical set ups are proposed for simulating quantum phase transitions, topological effects, as well as gauge and relativistic field theories [1,2,3]. The accessibility of local observables, and the ability to probe out-of-equilibrium many-body phenomena in these systems, combined with efficient optical measurements, offer complementary advantages over other quantum simulators approaches based in purely atomic or ionic set ups. I will briefly review the main theory results in this area along with our recent efforts for simulations of models exhibiting strongly correlated phases and topological protected modes in out of equilibrium driven slow light and circuit QED set ups [4,5]. I will conclude by presenting a recent experimental simulation of the unphysical Majorana equation and charge conjugation dynamics using photons in an integrated photonic chip [6].

References

[1] Tomadin & Fazio, Many-body phenomena in QED-cavity arrays. J. Opt. Soc. Am. B. 27 A130-A136 (2010); Houck, Tureci, & Koch, J. On-chip quantum simulation with superconducting circuits. Nat. Phys. 8 292-299 (2012).
[2] Angelakis, et al," "Photon blockade induced Mott transitions and XY spin models in coupled cavity arrays", Phys. Rev. A 76, 031805(R) (2007); Cho, Angelakis, Fractional Quantum Hall state in coupled cavities". Phys. Rev. Lett 101, 246809 (2008).
[3] Angelakis, et al, A photonic Luttinger liquid and spin-charge separation in hollow core fibers" Phys. Rev. Lett. 106, 153601 (2011); Angelakis, et al." Mimicking interacting relativistic theories with stationary light"" Phys. Rev. Lett. 110, 100502 (2013).
[4] Gruzic, Clark, Angelakis, Jacksh, "Non-equilibrium many-body effects in driven nonlinear resonator arrays" New Jour,. of Phys. 14, 103025 (2012).
[5] P. Das, C. Noh, Angelakis "Realizing the driven non-linear Schrodinger equation with slow light", EPL 103 34001, (2013); Angelakis, Das, Noh. "Probing the topological properties of the Jackiw-Rebbi model with light". arXiv:1306.2179, Nature Scientific Reports, 4, 6110 (2014).
[6] Keil, Noh, Rai, Stutzer, Nolte, Angelakis, A. Szameit "Experimental simulation of charge conservation violation and Majorana dynamics", http://arxiv.org/abs/1404.5444