Open quantum system phase transition: the case of a driven condensate in a cavity

Barıṣ Öztop\textsuperscript{1,2}, Mykola Bordyuh\textsuperscript{2}, Özgür E Müstecaplıoğlu\textsuperscript{3} and Hakan E. Türeci\textsuperscript{2,1}

\textsuperscript{1} Institute for Quantum Electronics, ETH Zürich, 8093 Zürich, Switzerland
\textsuperscript{2} Department of Electrical Engineering, Princeton University, Princeton, New Jersey 08544, USA
\textsuperscript{3} Department of Physics, Koç University, İstanbıl, 34450, Turkey

Recent experiments have demonstrated an open system realization of the single-mode Dicke quantum phase transition in the motional degrees of freedom of an optically driven Bose-Einstein condensate in a cavity [1,2]. We investigate the effects of openness on the phase transition and propose three photodetection schemes to probe the collective light-matter excitations of the system. While the non-equilibrium nature of the system derives from the leakiness of the cavity, photons leaking out also provide an invaluable channel to continuously monitor the intra-cavity dynamics. We show that the superradiant phase transition occurring in the photonic channel is equivalent to a superfluid-supersolid phase transition from the point of view of the atomic condensate. This phase transition can be captured by examining the long-range correlations between atoms mediated by cavity photons. The presence of such long-range correlations are reflected in the excitation spectrum which displays a roton-like minimum.

1. References