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Goldstone and Higgs modes of photons inside an cavity and their detections[1] YU YIXIANG, Department of Physics and Astronomy, Mississippi State University, Mississippi State, 39762, YU CHEN, Department of Physics, Peking University, Beijing 100871, China, JINWU YE, Department of Physics and Astronomy, Mississippi State University, Mississippi State, 39762, WUMING LIU, Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China — It was well known that a broken global continuous symmetry leads to two associated collective modes: a massless Goldstone mode and a massive Anderson-Higgs amplitude mode. The two modes have been detected in various condensed matter systems and recently also in cold atom systems. The Higgs mode in particle physics was finally detected in two recent LHC experiments. In this work, we show that the two modes can also be detected in optical systems inside a cavity with only a few (artificial) atoms. We demonstrate this connection by studying the $U(1)$ Dicke (Tavis-Cummings) model where N qubits (atoms) coupled to a single photon mode. We perform both $1/J = 2/N$ expansion and exact diagonization (ED) study on the model. We determine the Goldstone and Higgs modes and theirs corresponding spectral weights from the system's energy spectrum and also from various photon and atom correlation functions. We find nearly perfect agreements between the results achieved from the $1/J$ calculations with those from the ED studies in all these physical quantities even when N gets down even to $N = 2$. The experimental detections of both modes are also discussed.

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