**Exploring frontiers of light-matter interaction: from superradiant phase transitions to strongly interacting photons**

Remarkable experimental progress in controlling light-matter interaction has enabled engineering microscopic interactions among individual atoms, solid-state emitters, and photons and building complex quantum systems from them. It not only paves the road for building a physical architecture for quantum computing, but it also opens new frontiers of quantum optics exploring newly engineered, exotic interactions of lights to quantum matters. In this talk, I will first show that, by using the lasers to adjust energy scales of qubit and harmonic oscillator, even a single qubit coupled to a harmonic oscillator can be used to explore superradiant phase transitions despite being far from achieving the thermodynamic limit. The underlying principle of phase transitions occurring in a few atomic systems and its prospect for experimental observations using trapped-ions will be discussed. Second, I will present a counter-intuitive finding that there is a threshold in the light-matter interaction strength, beyond which the effective interaction among photons induced by the matter starts to vanish, which has led us to uncover various exciting phenomena such as the breakdown of photon-blockade, the photon-delocalization transition, and the emergence of metastability. I will explain the role of counter-rotating terms and also introduce recent experiments in superconducting circuits where these newly predicted phenomena could be observed.