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(I) Many-body QED with atoms and photons

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An exciting frontier in quantum information science is the creation and manipulation of quantum systems that are built and controlled quanta by quanta. In this context, there is active research worldwide to achieve strong and coherent coupling between light and matter as the building block of complex quantum systems. Despite the range of physical behaviours accessible by these QED systems, the low-energy description is often masked by small fluctuations around the mean fields. In contrast, we describe our theory/experimental program towards novel forms of light-matter quantum systems, where highly correlated Rydberg material is strongly coupled to cavity fields. We call this new domain of strong coupling quantum optics, “many-body quantum electrodynamics.” I describe our laboratory efforts towards the exploration of new physics for light-matter interaction, where locally gauged quantum materials are entirely driven by quantum optical fluctuation. Genuinely surprising phenomena may arise from the universal features of non-perturbative physics of many-body QED.

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