ULTRASTRONG LIGHT-MATTER AND MATTER-MATTER COUPLING: DICKE PHENOMENA

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Recent experiments have demonstrated that light and matter can mix together to an extreme degree, and previously uncharted regimes of light-matter interactions are currently being explored in a variety of settings, where new phenomena emerge through the breakdown of the rotating wave approximation [1]. This talk will summarize a series of experiments we have performed in such regimes. We will first describe our observation of ultrastrong light-matter coupling in a two-dimensional electron gas in a high-*Q* terahertz cavity in a quantizing magnetic field, demonstrating a record-high cooperativity [2]. The electron cyclotron resonance peak exhibited splitting into the lower and upper polariton branches with a magnitude that is proportional to the square-root of the electron density, a hallmark of cooperative vacuum Rabi splitting, known as Dicke cooperativity. Additionally, we have obtained clear and definitive evidence for the vacuum Bloch-Siegert shift [3], a signature of the breakdown of the rotating-wave approximation. The second part of this talk will present microcavity exciton polaritons in a thin film of aligned carbon nanotubes [4] embedded in a Fabry-Pérot cavity. This system exhibited cooperative ultrastrong light-matter coupling with unusual continuous controllability over the coupling strength through polarization rotation [5]. Finally, we have generalized the concept of Dicke cooperativity to demonstrate that it also occurs in a magnetic solid in the form of matter-matter interaction [6]. Specifically, the exchange interaction of N paramagnetic erbium(III) (Er^{3+}) spins with an iron(III) (Fe^{3+}) magnon field in erbium orthoferrite ($ErFeO_3$) exhibited a vacuum Rabi splitting whose magnitude is proportional to $N^{1/2}$. Our results provide a route for understanding, controlling, and predicting novel phases of condensed matter using concepts and tools available in quantum optics, opening up exciting possibilities to combine the traditional disciplines of many-body condensed matter physics and cavity-based quantum optics.

References

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