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Stuttgarter Physikalisches Kolloquium

Max-Planck-Institut für Festkörperforschung
Max-Planck-Institut für Intelligente Systeme
Fachbereich Physik, Universität Stuttgart

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Login data will be announced by e-mail and on the colloquium webpage.

Dienstag, 6. Juli 2021 | **16.15 Uhr** | **Online-Vortrag**

Stuttgarter Max-Planck-Institute, Heisenbergstraße 1, 70569 Stuttgart-Büsnau

Dicke Cooperativity in Solids

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Abstract

Recent advances in optical studies of condensed matter have led to the emergence of a variety of phenomena that have conventionally been studied in quantum optics. These studies have not only deepened our understanding of light-matter interactions but also introduced aspects of many-body effects inherent in condensed matter. This talk will describe our recent studies of Dicke cooperativity, i.e., many-body enhancement of light-matter interaction, a concept in quantum optics [1]. This enhancement has led to the realization of the ultrastrong coupling (USC) regime, where new phenomena emerge through the breakdown of the rotating wave approximation (RWA) [2]. We will first describe our observation of USC in a 2D electron gas in a high-Q THz cavity in a magnetic field [3]. The electron cyclotron resonance peak exhibited a polariton splitting with a magnitude that is proportional to the square-root of the electron density, a hallmark of Dicke cooperativity. Additionally, we obtained definitive evidence for the vacuum Bloch-Siegert shift [4], a signature of the breakdown of the RWA. The second part of this talk will present microcavity exciton polaritons in a thin film of aligned carbon nanotubes [5] embedded in a Fabry-Pérot cavity. This system exhibited cooperative USC with unusual continuous controllability over the coupling strength through polarization rotation [6]. Finally, we have shown that Dicke cooperativity also occurs in a magnetic solid in the form of matter-matter interaction [7]. Specifically, the exchange interaction of N paramagnetic Er^{3+} spins with an Fe^{3+} magnon field in $ErFeO_3$ exhibited a Rabi splitting whose magnitude is proportional to $N^{1/2}$. These results provide a route for understanding, controlling, and predicting novel phases of condensed matter using concepts and tools available in quantum optics.

1. For a review, see K. Cong, Q. Zhang, Y. Wang, G. T. Noe II, A. Belyanin, and J. Kono, *J. Opt. Soc. Am. B* **33**, C80 (2016).
2. For a review, see P. Forn-Díaz, L. Lamata, E. Rico, J. Kono, and E. Solano, *Rev. Mod. Phys.* **91**, 025005 (2019).
3. Q. Zhang *et al.*, *Nat. Phys.* **12**, 1005 (2016).
4. X. Li *et al.*, *Nat. Photon.* **12**, 324 (2018).
5. X. He *et al.*, *Nat. Nanotechnol.* **11**, 633 (2016).
6. W. Gao *et al.*, *Nat. Photon.* **12**, 362 (2018).
7. X. Li *et al.*, *Science* **361**, 794 (2018).