Cooperative and Ultrastrong Light-Matter Coupling: Dicke Phenomena in Condensed Matter

Colloquium given by

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Abstract

Recent advances in optical studies of condensed matter systems have led to the emergence of a variety of phenomena that have conventionally been studied in the realm of quantum optics. These studies have not only deepened our understanding of light-matter interactions but also introduced aspects of many-body correlations inherent in optical processes in condensed matter systems. This talk will describe our recent studies of cooperative light-matter coupling, first studied by Dicke in 1954, in solids. In one type of experiment, electron-hole pairs were incoherently prepared, but a macroscopic polarization spontaneously emerged and cooperatively decayed, emitting a giant pulse of coherent light, i.e., a superfluorescent burst. In another type of experiment, we placed an ultrahigh-mobility 2D electron gas in a photonic-crystal cavity in a magnetic field and achieved ultrastrong light-matter coupling, which suppressed superradiance, leading to ultrahigh cooperativity and a vacuum Bloch-Siegert shift due to the breakdown of the rotating-wave approximation. Finally, we studied microcavity exciton polaritons in a film of aligned carbon nanotubes embedded in a Fabry-Perot cavity, exhibiting ultrastrong light-matter coupling with continuous controllability over the coupling strength through polarization rotation. These results show that cooperative effects in solid-state systems are not just small corrections that require exotic conditions to be observed; rather, they dominate the nonequilibrium dynamics and light emission processes of interacting electrons.

Short Biography

Junichiro Kono received his B.S. and M.S. degrees in applied physics from the University of Tokyo in 1990 and 1992, respectively, and completed his Ph.D. in physics from the State University of New York at Buffalo in 1995. He was a postdoctoral research associate in condensed matter physics at the University of California, Santa Barbara, in 1995-1997 and the W. W. Hansen Experimental Physics Laboratory Fellow in the Department of Physics at Stanford University in 1997-2000. He joined the Department of Electrical and Computer Engineering of Rice University in 2000 as an Assistant Professor and was promoted to Associate Professor in 2005 and to Professor in 2009. He is currently a Professor in the Departments of Electrical & Computer Engineering, Physics & Astronomy, and Materials Science & NanoEngineering at Rice University. Professor Kono was a recipient of the National Science Foundation CAREER Award in 2002 and has been a Fellow of the American Physical Society (APS) since 2009 and a Fellow of the Optical Society (OSA) since 2015.