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From weak to ultra-strong matter-light coupling with organic materials[1]

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The idea of studying strong matter-light coupling using organic molecules has a long history, but has recently seen an explosion of experimental interest. Polaritons — hybrid matter-light particles, formed from the superposition of cavity photons and electronic excitations in the organic materials — have been seen in a variety of such materials, including anthracene, organic polymers, fluorenes, and various molecular aggregates. As compared to inorganic semiconductors, one intriguing novel aspect of these materials is the complex absorption and emission spectra they show, arising from the strong coupling between electronic and vibrational states. Experiments on these materials have shown polariton lasing and condensation when the material is optically pumped. Other experiments have explored how strong matter-light coupling can modify material properties, potentially even in the absence of pumping. These experiments pose several questions about the relation of polariton condensation and lasing, and about the role of vibrational modes in the physics of photon and polariton condensation. In particular, it requires understanding the interplay of two kinds of strong coupling: firstly, the coupling between cavity light and the electronic state of the molecules, and secondly the coupling between electronic state and vibrational modes of the molecules. A particular challenge arises because such systems involve many molecules, and so one is forced to address this as a many body problem. I will review how this system can be modeled, and how the behavior of the system varies from weak matter-light coupling (where one may think of a picture of incoherent absorption and emission) to strong coupling (where the new polaritonic modes arise), and ultra-strong coupling where even the vacuum state is modified by matter-light coupling.

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