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Modification of Material Properties and Molecular Structure driven by QED phenomena

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Exciton transport plays a crucial rule in natural phenomena such as photosynthesis and in artificial devices such as organic solar cells, but is inefficient in many organic materials. We will discuss how the formation of collective polaritonic modes can dramatically enhance exciton conductance when the molecules are strongly coupled to an electromagnetic mode [1], which can be exploited to "harvest" and direct excitations to specific positions by tuning the spatial distribution of the EM mode [2]. We then show that in systems with a discrete EM mode spectrum, strong-coupling-enhanced exciton transport can proceed through "dark" modes that acquire a delocalized character in the strong-coupling regime [3].
In the second part, we discuss the influence of strong coupling on internal molecular structure and chemical reactions. While most models of strong coupling are based on simple two-level models, pioneering experiments have shown modifications of chemical reaction rates under strong coupling [4]. In order to address this mismatch, we have developed a first-principles model that takes into account both electronic and nuclear degrees of freedom [5]. We will first discuss the applicability of the Born-Oppenheimer approximation, which is challenged by the introduction of the new intermediate timescale of energy exchange between the molecule and the field. Based on these findings, we then show how photochemical reactions such as photoisomerization can be almost completely suppressed under strong coupling [6]. Finally, we show that this suppression works more efficiently when many molecules are coupled to a single light mode due to a "collective protection" effect in the delocalized polaritonic state.

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