VACUUM SHIFTS IN CAVITY QED: COUPLING RYDBERG EXCITONS TO MICROWAVE CAVITIES

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In recent years, vacuum-induced modifications of molecular properties have regained considerable attention in the context of cavity QED, where the coupling of matter to individual electromagnetic modes is strongly enhanced by a tight confinement of the field. It has been speculated that under such ultrastrong coupling conditions, the electromagnetic vacuum could change the rate of chemical reactions or modify work functions, phase transitions and (super-)conductivity, even without externally driving the cavity mode.

Here we study the ground state energy shift of a single dipole due to its coupling to the electromagnetic vacuum in a confined geometry and address the fundamental question of whether or not it is possible to achieve conditions under which the light-matter coupling can result in nonperturbative corrections to the dipole's ground state. Our findings show that while the effect of confinement *per se* is not enough to result in substantial vacuum-induced corrections, the presence of high-impedance modes, such as plasmons or engineered LC resonances, can drastically increase these effects [1].

Firstly, we consider two simplified, but otherwise rather generic cavity QED setups, which are representative for a large variety of ultrastrong coupling experiments—a lumped-element LC resonator and a plasmonic nanocavity. This allows us to derive analytic expressions for the total ground state energy of the dipole and to distinguish explicitly between purely electrostatic and genuine vacuum-induced contributions. Finally, we extend this formalism to describe Rydberg excitons in cuprous oxide coupled to microwave fields.

References

[1] R. Sáez-Blázquez, D. de Bernardis, J. Feist, and P. Rabl, *Phys. Rev. Lett.* **131**, 013602 (2023)

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