Lamb-shift and vacuum forces in ultrastrong coupling cavity QED

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Over the last years there has been an increasing interest in the physics emerging from the ultrastrong light-matter interaction, where the coupling strength is comparable to the transition frequencies present in the system. Special attention has received the modification of ground-state properties under these extreme coupling conditions. Here we study the vacuum effects in a reduced cavity QED setup composed of a polar molecule interacting with the quantized field of a single-mode LC resonator. Following a rigorous microscopic description, we have been able to study the combined role of the induced charges on the metallic boundaries and the operative ultrastrong-coupling effects. Compared to large quantum chemistry simulations, our approach has also allowed us to derive analytical predictions for some regimes of interest. In particular, we have computed (non-diverging, cutoff-free) analytical estimates of the Lamb-shift corrections from all the higher electromagnetic modes and determined the modification of the interaction between a pair of molecules due to the electrostatic effects.

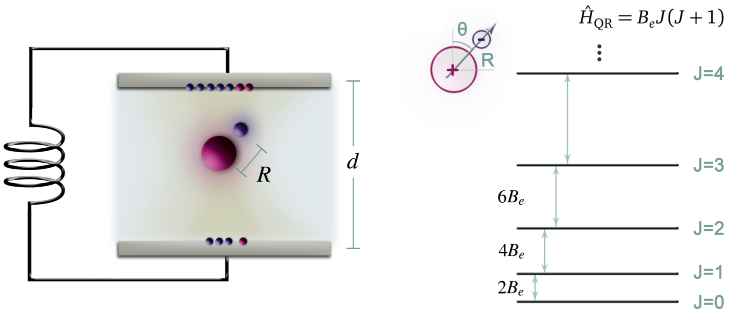

Fig. 1: (Left) Sketch of the system, a polar molecule within a lumped-element LC circuit. (Right) Characteristic spectrum of a rigid rotor, which serves as a model for the polar molecule in the relevant frequency regime.

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