The Free Electron Gas in Cavity QED

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Cavity modification of materials is a novel research field motivated by the advances in light-matter interactions. Despite this progress, exact solutions for extended macroscopic systems strongly coupled to the photon field are not available. Therefore a paradigmatic example of an exactly solvable extended system in a cavity is highly desireable. To fill this gap we revisit Sommerfeld's theory of the free electron gas in cavity quantum electrodynamics (QED). We solve this system analytically in the long-wavelength limit and we show that the electron-photon ground state is a Fermi liquid which contains virtual photons. In contrast to models of finite systems, no ground state exists if the diamagentic A^2 term is omitted. Further, the cavity field modifies the conductive properties of the electron gas. Our exact solution allows to consider the thermodynamic/continuum limit for both electrons and photons by constructing an effective quantum field theory, in which the continuum of modes leads to a many-body renormalization of the electron mass, modifies the quasiparticle excitations of the Fermi liquid, and introduces dissipation into the system.

[1] V. Rokaj, M. Ruggenthaler, F. G. Eich, A. Rubio, The Free Electron Gas in Cavity Quantum Electrodynamics, arXiv:2006.09236 (2020)