Abstract

The Quantum Theory of Fundamental 1/f Noise (Q1/fN) is a new aspect of quantum mechanics, introduced along with the corresponding phase noise in 1975 as an infrared divergence phenomenon. It is present in many forms. The QED form describes the fundamental 1/f noise in the materials, devices and systems of electrophysics, electronics, microelectronics, nanotechnology, sensors and phase noise in HF or UHF devices and systems, or high stability frequency standards. The quantum gravidynamic (QGD) form replaces photons by gravitons and describes it in macroscopic and mesoscopic streams of matter, with terrestrial and cosmic implications. The quantum lattice-dynamic (QLD) form describes it in electric currents in ferroelectric materials like BaSr(TiO$_3$)$_2$ or bulk GaN, with piezo-phonons replacing the photons as infraquanta. The Fermi-sphere quantum 1/f noise, present, e.g. in contact noise at a metallic surface, has electron-hole pairs at the Fermi surface as infraquanta. In general, the quantum 1/f noise is always present when a current of any nature has infrared-divergent (IRD) coupling to a system of massless, environment-forming, infraquanta. The Q1/fN contains in all forms the conventional and coherent Quantum 1/f Effects (Q1/fE).

The conventional Q1/fE is a property of the physical cross sections $\sigma$ and process rates $\Gamma$ of quantum mechanics (QM), a new aspect of QM. In QED, e.g., the well-known infrared catastrophe caused by the IRD gives the number of emitted infra-photons as $v=(2\alpha/3\pi)(\Delta v/c)^2$, and gives the spectral density of fractional fluctuations in this “physical cross section or process rate” of the process considered as $S_{\delta\alpha/\sigma}=2v/N_f$. The last step assumes that the phases of the bremsstrahlung energy loss components were randomized by decoherence. Here $\alpha=e^2/\hbar c=1/137$ is the fine structure constant, $\Delta v/c$ the vector velocity change (in units of the speed of light) of the electrons in the (e.g., scattering or tunneling) process considered, and $N_f$ the number of carriers defining the current whose fluctuations are considered.

The coherent Q1/fE is a property of any current, caused by the coherent state of the (photonic, gravitonic, etc.) field of a physical particle. This is not an energy eigenstate, therefore a nonstationary state, and for QED the ensuing current fluctuations have a universal spectrum $S_{\delta j\j}=[2\alpha/\pi N_f].$

The resulting Q1/fN is obtained with the coherence parameter $s=2r_o N'$ that is the number of carriers along the current, contained in a slice of thickness $r_o=e^2/mc^2$, perpendicular to the current direction. Here $N'$ is the number of carriers per unit length and $m$ the mass of the electron. The QED-Q1/fN is thus $S_{\delta j\j}=[1/N_f(1+s)][(4\alpha/3\pi)(\Delta v/c)^2 + 2s\alpha/\pi].$

The QGD-Q1/fN is $S_{\delta j\j}=[1/N_f(1+s')][(8G/5c^5 \hbar )\mu^2 v^4 \sin^2 \theta + 2s'GM^2/c^2].$

where $\theta$ is the scattering angle of the particles in the center-of-mass reference system, with relative velocity $v$ of the particles, and their reduced mass is $\mu$. Here $s'=2NGM/c^2 = N r_s$ is a coherence parameter introduced by us like the parameter $s$ for electromagnetic Q1/fE and $s'$ for the piezoelectric Q1/fE. $N'$ is the number of particles per unit length and $r_s = 2GM/c^2$ is their Schwarzschild radius.

The derivation of $s''$ will be done for the first time in this paper. The $s''$ parameter is applicable only when an equivalent QGD resistance can be defined, analog to the QED case.

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