

Invalidity of Thermal Fluctuations at the Nanoscale

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Thermal fluctuations although valid for macroscopic structures based on the fluctuation dissipation theorem (FDT) of electrodynamics including the formation of evanescent waves are shown invalid at the nanoscale as the Planck law of quantum mechanics (QM) precludes the atoms in nanostructures from fluctuating in temperature. Radiation at the nanoscale is proposed modified to conserve heat by creating EM radiation instead of temperature

INTRODUCTION

The FDT states any process that dissipates energy by conversion into heat there is a fluctuation that converts the corresponding temperature fluctuations into thermal radiation. But the FDT is problematic for athermal systems [1] which do not depend on temperature. At the macroscale, this is achieved by making the heat capacity of a material vanish, say by operation at a temperature of absolute zero. Unlike the macroscale, absolute zero temperatures are avoided [2] at the nanoscale by the size effect of QM as the Planck law requires heat capacity of the atoms to vanish under high EM confinement, say in the flow of liquids through physical nanoscopic channels. But atoms in nanostructures absent physical EM confinement having high surface-to-volume ratios are confined as any heat absorbed is almost totally deposited in the surface, the surface heat itself providing the momentarily EM confinement. Heat transfer at the nanoscale is therefore athermal thereby invalidating the FDT as temperature fluctuations do not occur. Even Casimir's attractive force based on the FDT between bodies separated by a nanoscale gap as the direct macroscopic manifestation [3] of QM is invalidated as the atoms in the gap surfaces under EM confinement are precluded from thermal fluctuations. Moreover, since evanescent waves do not exist without thermal fluctuations, the theory of Transformative Optics [4] which relies on evanescent waves restoring diffraction-limited images cannot be valid. Modifications in current radiation analysis at the nanoscale are suggested to be consistent with QM.

QM AND THE PLANCK LAW

The validity of thermal fluctuations at the nanoscale relies on the Planck law of QM illustrated at 300 K in Figure 1. By classical physics, the kT heat content of the atom is independent of the EM confinement wavelength λ , where k is the Boltzmann constant and T absolute temperature. QM differs as the heat content or capacity of the atom decreases under EM confinement $\lambda < 100$ nm. But at the nanoscale for $\lambda < 100$ nm, the heat content may be said to vanish. The EM confinement may be physical as for liquids flowing in nanochannels or the natural consequence of solid nanostructures having high S/V ratios where any absorbed

heat is almost entirely confined to their surfaces, the surface energy itself providing momentary EM confinement of atoms over nanoscale wavelengths.

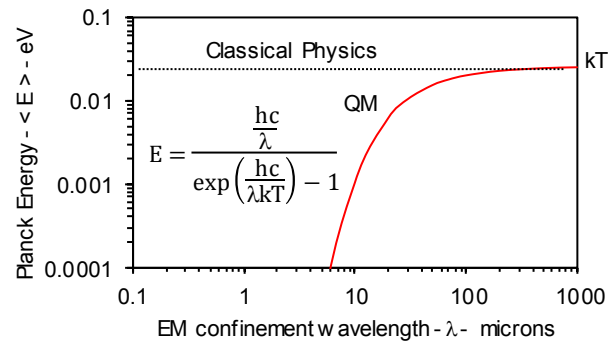


Figure 1 Planck law of the Atom at 300 K

In the inset, E is Planck energy, h Planck's constant, c light speed, k Boltzmann's constant, T temperature, and λ EM confinement wavelength

SIMPLE QED

Nanostructures lacking heat capacity cannot conserve heat by an increase in temperature. Conservation proceeds by the creation of standing EM radiation within the nanostructure by the process of simple QED. QED stands for quantum electrodynamics, but differs from the complex relativistic QED by Feynman and others. Briefly stated:

Simple QED conserves heat Q supplied to a nanostructure
absent heat capacity by creating standing EM radiation having half-wavelength
 $\lambda/2 = d$, where d is the minimum distance across the nanostructure

The standing EM radiation is created within by the physical or natural heat induced surface confinement of the nanostructure. Physical confinement is permanent, but not momentary surface heat. In the latter, once the surface heat is depleted in forming the standing EM radiation, the confinement vanishes and the EM radiation may escape to the surroundings. The Planck energy E is, $E = hf$, where the frequency f of the EM radiation is, $f = (c/n)/\lambda = c/2nd$, with the velocity of light c corrected for the slower speed by the refractive index n of the liquid or solid nanostructure.

INVALIDITY OF THE FDT AND EVANESCENT WAVES

Electromagnetic waves derived from the FDT combined with Maxwell's equations has emerged as the preferred analysis method in radiation heat transfer. But QM by photons is more understandable than QM by waves. Perhaps, the QM validity of the FDT in electromagnetic analysis brought into question by the extraordinary claims [5] of enhanced heat

transfer between bodies separated by nanoscale gaps could have been avoided [6] if photons would have been adopted as the basis for radiation heat transfer.

In this regard, the Planck law was used [5] to define the dominant NIR wavelengths of thermal radiation given by Wien's law, i.e., 3.6 and 14.5 μm for body temperatures of 800 and 200 K, respectively. But the validity of the FDT depends [6] on the wavelengths of EM waves standing across the gap – not the dominant NIR wavelength at body temperature. By simple QED, atoms on surfaces of < 100 nm nanoscale gaps are under EM confinement $\lambda < 200$ nm, the standing EM radiation having Planck energy $E > 6.2$ eV in the UV. From Figure 1, the surface atoms lack the heat capacity to undergo thermal fluctuations, thereby invalidating the FDT including the existence of evanescent waves. Heat transfer is not enhanced because simple QED conserves the NIR heat by creating UV photons that tunnel across the gap. The Stefan-Boltzmann law upper bounds the heat transfer.

CONCLUSIONS

Modifications are suggested to thermal radiation analysis consistent with QM. A first temperature solution is obtained with the current electromagnetic analysis procedure, but the FDT is only invoked for macroscopic regions of the structure while excluding the FDT from all nanoscopic entities, e.g., nanoparticles and surfaces exposed to nanoscale gaps. A second solution is then obtained for the EM radiation produced by simple QED at each nanoscopic entity using the heat found in the first solution. The process is repeated until temperatures converge.

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