Invalidity of Thermal Fluctuations at the Nanoscale

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Thermal fluctuations although valid for macroscopic structures based on the fluctuation dissipation theorem of electrodynamics including the formation of evanescent waves are shown invalid at the nanoscale as the Planck law of quantum mechanics 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, athermal conditions occur naturally [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. QM stands for quantum mechanics. Absent physical walls of EM confinement, atoms in nanostructures under high surface-to-volume ratios are also confined as any heat absorbed is almost totally deposited in the surface, the surface heat itself providing the momentarily EM confinement necessary for the heat capacity of atoms to vanish.

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 is not valid. Modifications in current EM radiation heat transfer 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 rapidly decreases under EM confinement $\lambda < 100$ microns and 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.

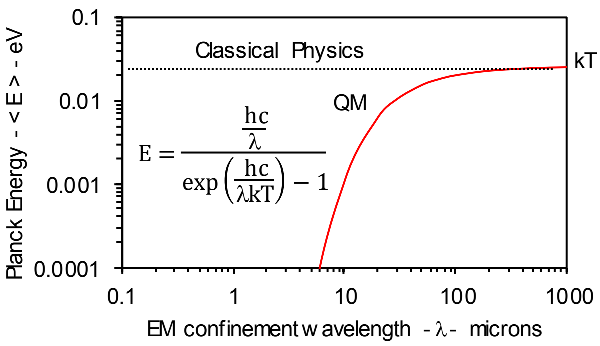

Figure 1 Planck law of the Atom at 300 K

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

By QM, 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 the nanostructure by the physical or natural heat induced surface confinement. 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 [3] as the preferred analysis method in radiation heat transfer. But QM by Planck's photons is more understandable than by Maxwell's waves. Indeed, the QM validity of the FDT in EM analysis would not have brought into question [5] where it not for the extraordinary claims [6] of enhanced heat transfer between bodies separated by nanoscale gaps, the latter using the Planck law to define the dominant NIR wavelengths of thermal radiation of macroscopic bodies given by Wien's law, i.e., 3.6 and 14.5 microns for body temperatures of 800 and 200 K, respectively. But the validity of the FDT depends [5] on the wavelengths of EM waves standing across the gap – not in the meaningless NIR at the temperatures of the macroscopic bodies. By simple QED, atoms on surfaces of nanoscale gaps between macroscopic bodies lack heat capacity. From Figure 1, the standing EM radiation under confinement $\lambda < 200$ nm is in the UV having Planck energy $E > 6.2$ eV and not in the NIR as assumed [6] where the atom has heat capacity. Hence, surface atoms under UV lack the heat capacity to undergo thermal fluctuations, thereby invalidating the FDT including the existence of evanescent waves. Contrarily, heat transfer is not enhanced [3, 6] in nanoscale gaps because simple QED conserves the NIR heat by creating UV photons that tunnel [5] across the gap. The Stefan-Boltzmann law therefore upper bounds the heat transfer.

CONCLUSIONS

Modifications are suggested to current EM radiation heat transfer consistent with QM. A first temperature solution including the FDT is obtained for macroscopic regions of the structure, but the FDT is excluded at all nanoscopic entities, e.g., nanoparticles and surfaces exposed to nanoscale gaps. The first solution gives the local heat flow into each nanoscopic entity that is specified as an EM radiation input to a second solution, the EM radiation given by simple QED. The process is repeated until temperatures converge.

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