The Planck law cancelled?

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Abstract: Currently, the cancel culture in the USA driven by identity politics threatens not only the traditions of the USA as a country, but also the future of Science. Some scientists have placed their perception of Science above those of traditional values, the perceptions of which have consequences. Over the past decades, the consequence of US scientists cancelling the Planck law of quantum mechanics (QM) at the nanoscale in favor of classical physics has led to countless numbers of meaningless papers in the literature returning science to the dark ages at the exorbitant expense of the US taxpayer. Contrary to classical physics that allows atoms at the nanoscale to fluctuate in temperature, the Planck law denies atoms the heat capacity for temperature fluctuations. What this means is all known theories of Near-Field Radiation Heat Transfer (NFRHT) based on temperature fluctuations in nanoscale gap surfaces are invalid. In effect, the Planck law requires NFRHT theories that do not depend on temperature. One such theory is simple QED based on the Planck law that describes NFRHT by temperature independent EM travelling waves that carry heat flow, the EM waves by the photoelectric effect producing a plasma that increases heat flow. A similar photoelectric argument to replace quantum fluctuations in the attractive Casimir force by electrostatics was made over a decade ago. Recent NFRHT theory applied to single-digit nanoscale gaps is discussed.

Keywords: NFRHT, Planck law, simple QED, EM waves, photoelectric effect, Casimir force

I. INTRODUCTION

NFRHT began over a decade ago with the finding the Stefan-Boltzmann law could not explain the heat flux between hot and cold bodies separated by a nanoscale gap d as illustrated in Fig. 1.

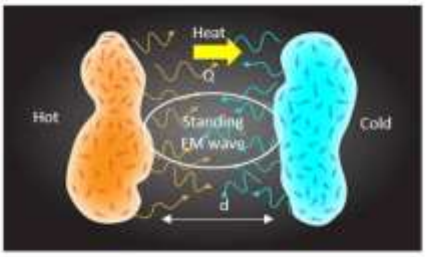

Figure 1. Near-field Heat Transfer

In NFRHT, the mechanisms by which heat Q flows from hot to cold bodies was extensively sought, all of which assumed surface temperatures of hot and cold bodies, the difficulty of measuring surface temperature in nanoscale gaps avoided by assuming bulk values. Non-thermal EM waves standing across the gap do not require surface temperatures, but presumably were excluded because since Fourier, temperature differences alone were thought necessary for heat Q flow. In Fig. 1, an EM wave is shown transferring heat Q across the gap d absent a temperature difference.

Today, all known NFRHT mechanisms transfer heat Q by gap surface temperature. What this means is temperature dependent phonons and evanescent waves known to exist in surfaces of bodies separated by large distances are assumed to exist in nanoscale gaps.

Contrarily, the Planck law [1] of QM denies atoms in the surfaces of nanoscale gaps the heat capacity to change in temperature which may be understood by considering the average Planck energy E of the atom mediated by the Bose distribution,

$$E = \frac{\frac{hc}{\lambda}}{\left[\exp\left(\frac{hc}{\lambda kT}\right) - 1\right]} \tag{1}$$

and at 300 K is plotted in relation to classical physics in Fig. 2.

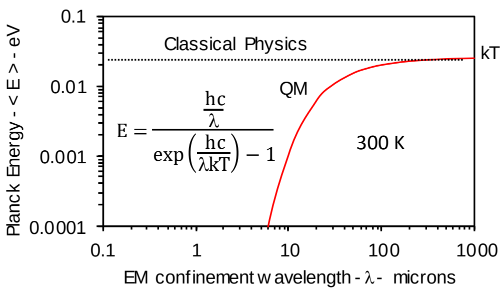

Figure. 2: Planck law of QM at 300 K
In the inset, E is Planck energy, h Planck's constant, c light speed, k Boltzmann's constant, T temperature, and λ the EM wavelength.

The Planck law at 300 K shows classical physics allows the atom to have constant thermal kT heat capacity over all EM wavelengths λ. QM differs as the kT heat capacity decreases for $\lambda < 200\ \mu m$, and vanishes at the nanoscale for $\lambda < 0.1\ \mu m = 100$ nm. Lacking heat capacity, atoms in nanoscale gap surfaces are absent temperature.

Today, NFRHT faces a dilemma in that all known theories based on phonons and evanescent waves, or variants thereof which require the atoms in the surface of nanoscale gaps to have temperature are invalid. In effect, the Planck law requires any NFRHT theory to be independent of temperature.

II. PURPOSE

The purpose of this paper is to propose temperature independent simple QED heat transfer [2] as the NFRHT theory at the nanoscale. To illustrate how Science has cancelled the Planck law, the literature for NFRHT theory in single-digit nanoscale gaps is discussed and compared to simple QED.

III. THEORY

Simple QED is the consequence of the Planck law denying atoms in nanostructures the heat capacity to increase in temperature upon the absorption of heat. QED stands for quantum electrodynamics, a complex theory based on *virtual* photons advanced by Feynman [3] and others. Simple QED is far simpler only requiring the heat capacity of the atoms in nanostructures to vanish allowing conservation to proceed by the creation of *real* photons comprising EM waves that stand across the nanostructure.

Similar to atomic quantum states described by electrons in discrete orbitals, simple QED quantum states are dependent on the dimension of the nanostructure over which the EM waves stand. The Planck energy E of a simple QED photon standing across a distance d is given by the time τ for light to travel across and back, $\tau = 2d/(c/n)$, where n is the index of refraction of the nanostructure material. Hence, the Planck energy E of the simple QED photons is, $E \sim h/\tau$ having wavelength $\lambda = 2nd$,

$$E = \frac{hc}{2nd} \qquad (2)$$

To illustrate simple QED, consider heat flux Q having wavelength λ_o heating a nanoparticle (NP) of diameter d. For $\lambda_o \gg d$, the NP is immersed in the heat flux Q as illustrated in Fig. 3.

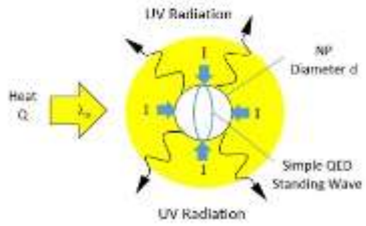

Figure 3. Heating of a NP

Importantly, heat flux Q absorbed by the NP must be placed under brief EM confinement to create the simple QED photons, the process of which depends on the Planck law denying NP atoms the heat capacity to allow the temperature changes required for Fourier heat conduction. Hence, the heat flux Q cannot penetrate the NP surface, and therefore conservation of Q at the NP surface can only proceed by creating non-thermal EM waves to carry the heat Q across and back the NP diameter d in time $\tau = 2nd/c$ that defines the energy E of the simple QED photon.

The EM confinement at the NP surface is caused by the brief inward spherical Poynting vector S = Q carrying momentum I (shown as blue arrows in Fig. 3). Here, U is the energy from the heat flux Q acting over an increment of time Δt, $U = QA \cdot \Delta t$, where A is the NP surface area, units of S and Q ~ Wm^{-2} and U ~ J giving momentum $I = U/c \sim Nt \cdot s$. Over time Δt, N simple QED photons having momentum $I_P = h/2nd$ are created, where $N < I/I_P$. Once $NI_P > I$, the simple QED photons are emitted to surroundings.

In the interest of whether simple QED photons absent a discrete heat Q may be created from the thermal surroundings alone, consider a NP in the ambient environment at temperature T. The Planck law gives the heat flux Q_T as radiant thermal power energy density,

$$Q_T = \left(\frac{2c}{\lambda^4}\right) \frac{\frac{hc}{\lambda}}{\left[\exp\left(\frac{hc}{\lambda kT}\right) - 1\right]} \qquad (3)$$

The Q_T momenta $I_T = U_T/c$ driven by the NP at absolute zero, provide the confinement of the simple QED photons, the number N_T of which at temperature T is $N_T = Q_T V/E$, where V is NP volume, and $E = hc/\lambda$. At 300 K, $Q_T = 2.71 \times 10^5$ $J/s \cdot m^3$. For Covid-19 vaccines [2] having d ~ 80 nm lipid NPs, $V = 2.68 \times 10^{-22}\ m^3$. Taking n = 1.6, $\lambda = 2nd \sim 254$ nm or UVC with $E = 7.80 \times 10^{-19}$ J = 4.88 eV. Hence, the NPs emit $N_T \sim 100$ UVC photons/s to stimulate the immune system (Fig. 3). Depending on size, simple QED radiation from the IR to EUV may be emitted from NPs in ambient surroundings, albeit at low intensity.

The EM confinement of simple QED photons in the NP by the inward spherical momenta is not applicable to NFRHT in gaps between hot and cold bodies as illustrated in Fig. 4.

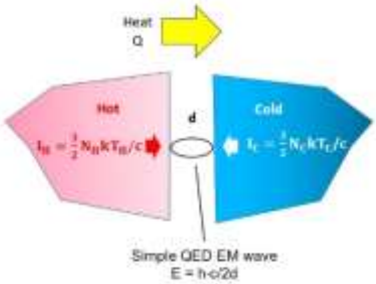

Figure 4. NFRHT.

Heat Q is transferred from hot to cold bodies across a nanoscale gap with vanishing thermal kT energy of atoms in hot and cold gap surfaces as required by the Planck law. To compensate for the surface atoms effectively at absolute zero, the number of adjacent atoms in hot N_H and cold N_C bodies having finite thermal kT energy $U_H = \frac{3}{2} N_H kT_H$ and $U_C = \frac{3}{2} N_C kT_C$ form the Poynting vectors of momentum $I_H = U_H/c$ and $I_C = U_C/c$ directed toward the respective gap surfaces, the momenta providing the EM confinement to form the simple QED photons.

Heat Q flows if the momentum $I_H > I_C$. In the gap, the Planck law precludes conservation of Q by a change in temperature, and instead proceeds by the creating a number N of EM waves, the heat Q/N ~ W/wave delivered to the gap d in time $\Delta t = 2d/c$ is,

$$\frac{Q}{N} = \frac{E}{\Delta t} = \frac{h}{4}\left(\frac{c}{d}\right)^2 \qquad (4)$$

The NFRHT time $\Delta t = d/2c$ is the same as the NP time $\tau = d/2nc$ having refractive index n = 1.

Q/N is based on evacuated gaps assumed in NFRHT theories. However, the simple QED wave energy E for small gaps at UV and EUV levels ionize the atoms in the gap surfaces to produce a plasma that upper bounds Q/N. In Casimir experiments, both plates usually gold plated were charged positive [4] by the simple QED induced photoelectric effect. But one plate was always grounded to avoid stray effects, and therefore the Casimir force is one of electrostatic attraction - not quantum fluctuations.

Similar to Casimir, NFRHT nanoscale gap surfaces of gold are charged positive but lacking a ground the electrons create a negative charged plasma with increased thermal conductivity [5] by one order of magnitude over uncharged conductivities. For gold having an ionization potential of E = 9.22 eV, the electron plasma forms in NFRHT gaps d < 70 nm.

IV. APPLICATIONS

NFRHT between bodies separated by nanoscale vacuum gap distances d > 20 nm have been extensively studied and thought [6-8] to exceed the blackbody limit by the tunneling of evanescent waves. But for d at single-digit gaps, the heat flow Q was found [9] in disagreement with NFRHT theories as shown in Fig. 5.

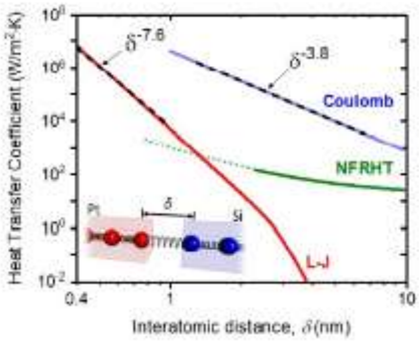

Figure 5. NFRHT and other theories.

Generally, the heat transfer coefficient H was found much higher than predicted by NFRHT theories of fluctuating temperatures. Fig. 5 shows L-J and Coulomb theories based on contact of opposing gap surfaces giving ~ 6 orders of magnitude higher H prompting [9] to suggest resolution by acoustic phonon tunneling.

Indeed, H = 1.11x10^6 W/m^2K were reported [10] comparable to contact estimates shown in Fig. 5. However, the high H values were promptly rebutted in [11] on the basis of surface contamination. Today, the validity of NFRHT theories explaining single-digit nanoscale gaps remains in question.

Contrary to the suggestion [9] that acoustic phonon tunneling can account for the disparity is refuted as surface phonons only exist at ambient temperatures in the IR at 10-15 microns. Along gap surfaces, the intensity normal to the surface [7] at 100 nm is intensified, but still in the IR cannot propagate across the nanoscale gap. Surface phonon polaritons can be excited in the UV, but are more difficult to excite thermally.

Regardless, the Planck law denies gap surface atoms the heat capacity necessary for the temperature to create acoustic phonons to support NFRHT theories at single-digit nanoscale gaps. Indeed, simple QED based on the Planck law refutes Rytov's theory of temperature fluctuations at the nanoscale by requiring heat to be conserved by temperature independent EM waves, e.g., the Pt and Si atoms (Fig. 5) are at the same temperature. What this means is Rytov's theory is a classical notion not applicable to the nanoscale. By continuing this falsity, Science has in effect cancelled the Planck law.

More importantly, the focus of NFRHT over the past decades to show the heat Q transferred across in nanoscale gaps exceeds the blackbody limit was ill-conceived. Placing a nanoscale gap d in the middle a rod of length L having area A can never increase the heat flow $Q = \kappa A(T_1-T_2)/L$, where κ is thermal conductivity and $T_1 > T_2$ are temperatures at the rod ends. Numerous NFRHT analysis showing high heat transfer H coefficients suggesting the gap increases heat flow Q are simply not correct as Q only depends on temperatures of the rod ends. Indeed, the heat transfer coefficient H = Q/A upper bounds NFRHT by the gap filled with a material having the same thermal conductivity κ of the rod,

$$H = \frac{\kappa}{d} \sim \frac{W}{m^2K} \qquad (5)$$

which always exceeds the Planck blackbody limit. Therefore, NFRHT analyses over decades to support the argument that H exceeds the blackbody limit were never necessary.

In [9] Fig 2(e) gives the NFRHT theory computed Q ~ 35 nW/K at d = 1 nm. For tip area $A = 2.88x10^{-14}$ m^2, $H = Q/A = 1.2x10^6$ W/m^2K. But Eqn. 5 for gold having κ = 320 W/mK increased to 3200 W/mK for ionization [5] gives $Q/A = 3200x10^9$ $W/m^2K >> 1.2x10^6$ W/m^2K measured. Therefore, the heat flow $Q/A = 1.2x10^6$ W/m^2K in [9] is not ionized.

The Planck blackbody radiation [10] is estimated as $H = 2.1$ W/m^2K. Since the measured $H = 1.11x10^6$ W/m^2K, the measured H is $5x10^5$ X greater than blackbody radiation. However, for gaps from a few Å to 5 nm [11] suggests the large deviations from NFRHT theory in [10] are caused by surface contamination effects. Further, [11] states H as large as 3 nW/K are reported in the literature which is overstated and instead should be H = 0.5 nW/K, but this is incorrect. Paper [9] gives 35 nW/K and [11] Fig. 3 (b-e) shows cleaning reduces H, but the mean minimum is closer to 2 nW/K not 0.5 nW/K.

In contrast to NFRHT theory, simple QED conserves power across the gap by creating EM waves at zero temperature difference consistent with the Planck law. For d = 1 nm, Eqn. 4 gives Q/N = 14.9 W/wave. But simple QED based on EM waves requires heat flow Q > 14.9 W, as otherwise heat does not flow across the gap. From [9] giving Q = 35 nW/K evaluated for $\Delta T = \sim 170$ K gives $Q \sim 6x10^{-6}$ W < 14.9 W, and therefore simple QED requires heat flow Q = 0 across the 1 nm gap, as well as other single-digit nanoscale gaps.

Unlike simple QED, NFRHT theory based on fluctuating temperatures lacks a criterion for heat flow Q = 0 suggested from experiments on single-digit nanoscale gaps.

V. CONCLUSIONS

NFRHT theory is based on the falsity that temperatures fluctuate in evacuated nanoscale gaps contrary to the Planck law that denies gap surface atoms the heat capacity necessary for temperature fluctuations.

All known NFRHT theories assume temperature fluctuations in gaps and implicitly require temperature differences between gap surfaces are therefore invalid by the Planck law.

Only temperature independent NFRHT theories are valid at the nanoscale, one of which is simple QED based on the Planck law itself.

Evanescent waves and phonons on the surface of macroscopic bodies do not exist in the surfaces of nanoscale gaps.

The Planck law aside, NFRHT touted as the method to show the Planck blackbody heat transfer is an unnecessary effort as simple thought experiments on rods shows a nanoscale gap does not increase the heat flow along its length.

Experiments to verify NFRHT based on temperature fluctuations are perhaps near impossible as the Planck law denies temperatures in nanoscale gaps. Measurements reported in the literature of temperature differences across nanoscale gaps which do not exist are shown to be fraught with error.

The Casimir effect by charging of plates by the simple QED induced photoelectric effect and not by quantum fluctuations is related to NFRHT by ionizing the gap surfaces, but is not significant for NFRHT in 1 nm gaps.

The Science acceptance of NFRHT theory based on Rytov fluctuational electrodynamics from classical physics does not bode well for the future of nanotechnology as cancelling the Planck law is a step back into the dark ages.

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