New Fundamental *Light Particle* and Breakdown of Stefan-Boltzmann’s Law

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January 12, 2013

Abstract

Recently, we predicted the existence of fundamental particles in Nature, neutral *Light Particles* with spin 1 and rest mass \( m = 1.8 \times 10^{-4} m_e \), in addition to electrons, neutrons and protons. We call these particles Light Bosons because they create electromagnetic field which represents Planck’s gas of massless photons together with a gas of *Light Particles* in the condensate. Such reasoning leads to a breakdown of Stefan–Boltzmann’s law at low temperature. On the other hand, the existence of new fundamental neutral *Light Particles* leads to correction of such physical concepts as Bose-Einstein condensation of photons, polaritons and exciton polaritons.
1 Introduction

First, the quantization scheme for the local electromagnetic field in vacuum was presented by Planck in his black body radiation studies [1]. In this context, the classical Maxwell equations lead to appearance of the so-called ultraviolet catastrophe; to remove this problem, Planck proposed the model of the electromagnetic field as an ideal Bose gas of massless photons with spin one. However, Dirac [2] showed the Planck photon-gas could be obtained through a quantization scheme for the local electromagnetic field, presenting a theoretical description of the quantization of the local electromagnetic field in vacuum by use of a model Bose-gas of local plane electromagnetic waves propagating by speed $c$ in vacuum.

In a different way, in regard to Plank and Dirac’s models, we consider the structure of the electromagnetic field [3] as a non-ideal gas consisting of $N$ neutral Light Bose Particles with spin 1 and finite mass $m$, confined in a box of volume $V$. The form of potential interaction between Light Particles is defined by introduction of the principle of wave-particle duality of de Broglie [4] and principle of gauge invariance. In this respect, a non-ideal Bose-gas consisting of Light Particles with spin 1 and non-zero rest mass is described by Planck’s gas of massless photons together with a gas consisting of Light Particles in the condensate. In this context, we defined the Light Particle by the model of hard sphere particles [5]. Such definition of Light Particles leads to cutting off the spectrum of the electromagnetic wave by the boundary wave number $k_0 = \frac{mc}{\bar{h}}$ or boundary frequency $\omega_{\gamma} = 10^{18}$ Hz of gamma radiation at the value of the rest mass of the Light Particle $m = 1.8 \times 10^{-4}m_e$. On the other hand, the existence of the boundary wave number $k_0 = \frac{mc}{\bar{h}}$ for the electromagnetic field in vacuum is connected with the characteristic length of the interaction between two neighboring Light Bosons in the coordinate space with the minimal distance $d = \frac{1}{k_0} = \frac{\bar{h}}{mc} = 2 \times 10^{-9}m$. This reasoning determines the density of Light Bosons $N = \frac{3}{4\pi d^3} = 0.3 \times 10^{26}m^{-3}$.

It is well known that Stefan-Boltzmann’s law [6] for thermal radiation, presented by Planck’s formula [1], determines the average energy density $\frac{U}{V}$ as

$$\frac{U}{V} = \frac{2}{V} \sum_{0 \leq k < \infty} \bar{h} ki_{k}^2 i_{k} = \sigma T^4,$$

where $\bar{h}$ is the Planck constant; $\sigma$ is the StefanBoltzmann constant; $i_{k}^2 i_{k}$ is the average number of photons with the wave vector $\vec{k}$ at the temperature $T$:

$$i_{k}^2 i_{k} = \frac{1}{e^{\frac{\bar{h} ki}{kT}} - 1}$$

Obviously, at $T = 0$, the average energy density vanishes in Eq.(1), i.e. $\frac{U}{V} = 0$, ...
which follows from Stefan-Boltzmann’s law.

However, as we show, the existence of the predicted Light Particles breaks Stefan-Boltzmann’s law for black body radiation at low temperature.

2 Breakdown of Stefan-Boltzmann’s law

Now, we consider the results of letter [3], where the average energy density of black radiation \( \frac{U}{V} \) is represented as:

\[
\frac{U}{V} = \frac{mc^2 N_{0,T}}{V} + \frac{2}{V} \sum_{0<k<k_0} \hbar \omega_{\hat{k}^2} \sqrt{i_{\hat{k}^2}},
\]

(3)

where \( \frac{mc^2 N_{0,T}}{V} \) is a new term, in regard to Plank’s formula (1), which determines the energy density of Light Particles in the condensate; \( \frac{N_{0,T}}{V} \) is the density of Light Particles in the condensate.

In this respect, the equation for the density of Light Particles in the condensate \( \frac{N_{0,T}}{V} \) represents as:

\[
\frac{N_{0,T}}{V} = \frac{N}{V} - \frac{1}{V} \sum_{0<k<k_0} \frac{L_k^2}{1-L_k^2} = \frac{1}{V} \sum_{0<k<k_0} \frac{1}{1-L_k^2} \sqrt{i_{\hat{k}^2}}
\]

(4)

with the real symmetrical function \( L_k \) from the wave vector \( \hat{k} \):

\[
L_k^2 = \frac{\hbar^2 k^2}{2m} + \frac{mc^2}{2} - \hbar \omega_{\hat{k}}
\]

(5)

Our calculation shows that at absolute zero the value of \( \sqrt{i_{\hat{k}^2}} \) = 0, and therefore the average energy density of black radiation \( \frac{U}{V} \) reduces to

\[
\frac{U}{V} = \frac{mc^2 N_{0,T=0}}{V} = \frac{mc^2 N}{V} - \frac{m^4 e^5 B(2,3)}{4\pi^2 \hbar^3} \approx \frac{mc^2 N}{V},
\]

(6)

where \( B(2,3) = \int_0^1 x(1-x)^2 dx = 0.1 \) is the beta function.

Thus, the average energy density of black radiation \( \frac{U}{V} \) is a constant at absolute zero. In fact, there is a breakdown of Stefan-Boltzmann’s law for thermal radiation.

In conclusion, it should be also noted that Light Bosons in vacuum create photons, while Light Bosons in a homogeneous medium generate the so-called polaritons. This fact implies that photons and polaritons are quasiparticles, therefore, BoseEinstein condensation of photons [7], polaritons [8] and exciton polaritons [9] has no physical sense.
Acknowledgements

We are particularly grateful to Professor Marshall Stoneham F R S (London Centre for Nanotechnology, and Department of Physics and Astronomy University College London, UK) as well as Elena Aleksandrovna Nikulnikova (Joint Institute for Nuclear Research, Dubna, Russia) for help with the English.
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