Fermion Property Change by Unruh Radiation at Laser Intensities for Vacuum Pair Production

Heinrich Hora

University of New South Wales, Sydney/Australia

h.hora@unsw.edu.au

Unruh radiation at a black body temperature above $2mc^2$ appears at the same electric fields where laser fields produce the Sauter-Schwinger electron pair production in vacuum. Attention is given from evaluation of the strong coupling of electrons to black body radiation for temperatures above mc^2, where a deviation of the Fermion state of electrons is changed as derived from the Richardson-Suhrmann equation when treated as integral equation for electron emission [1]. It was suggested that the Fermi-Dirac statistics for electrons concluded by Pauli [2] will not longer be valid at higher temperatures [3] and that intermediary statistics should apply. For considering the conditions of the electrons within this high temperature Planck radiation, the generated Unruh radiation may offer an access to explore these properties [4][5]. It was concluded that the electrons are in the state of quivering in the radiation as known for lower temperatures but a part of 15/p = 4.77% of the electrons are involved in pair production and annihilation. At the now available nearly solid hydrogen density and several hundred eV temperature plasmas of NIF, electron the non-Fermion state with strong coupling to hohlraum radiation may be of interest under the aspect of the Unruh effect [6] but also will lead to more accurate theoretical models at these conditions.

[1] S. Eliezer et al. *Fundamentals of Equations of State,* Section 1.5. Singapore: World Scentific 2002
[2] W. Pauli, Novo Cimento **6**, 204 (1957)
[3] H. Hora & H. Müller, Zeitschr. für Physik **164**, 359 (1961)
[4] H. Hora Nuovo Cimento Letter **22**, 55 (1978)
[5] H. Hora, R. Castillo, T. Stait-Gardner, Dieter H.H. Hoffmann George H. Miley and Paraskevas Lalousis. Laser acceleration up to black holes values and B-meson decay. *Journal and Proceedings of the Royal Society of New South Wales* **144**, 25-31 (2011) [see Proceedings IZEST Conference KEK/Japan, Nov. 2011]
[6] T.Stait-Gardner & R. Castillo, Laser and Particle Beams **24**, 579 (2006)v

Electrons in black body Planck radiation at

Temperature kT > mc^2 (1957)

Sauter-Schwinger pair production

Unruh Effect

Electron emission from solids

O.W.Richardson Phil. Mag. 23 (1912) 594

$$j = M_r T^r \exp(-h\nu_o/kT)$$

Thermionic emission:

$r = 2 \quad M_2 = 4\pi m_e k^2 e/h^3$ **Sommerfeld & Bethe**

Photoelectric emission:

$r = 3 \quad M_3 = 2ek^3/(c^2h^3)$

$$
j = \begin{cases}
(4\pi m_0 k^2 e/h^3) T^2 \exp[-h\nu_0/kT] \\
\quad \text{for } (2m_0 kT)^{3/2} \ll \min[n_e h^3; (4\pi m_0{}^2 c^2)^{3/2}], \\
n_e e(k/2\pi m_0)^{1/2} T^{1/2} \exp[-h\nu_0/kT] \\
\quad \text{for } (2m_0 kT)^{3/2} \gg n_e h^3 > \dfrac{(2\pi)^{1/2}}{2m^2 c^2}(2m_0 kT)^{5/2}, \\
\dfrac{2e}{c^2}\dfrac{k^3}{h^3} T^3 \exp[-h\nu_0/kT] \\
\quad \text{for } \dfrac{(2\pi)^{1/2}}{2m_e{}^2 c^2}(2m_0 kT)^{5/2} > \min[n_e h^3; 4\pi^2 (m_0{}^2 c^2)^{3/2}
\end{cases}
$$

General summary of emission current (1957)

$$\int_0^\infty D(\nu)Q(\nu)\,\nu^2 e^{-\frac{h\nu}{kT}}\,d\nu = B^{(r)}\,T^r e^{-\frac{h\nu_0}{kT}} \qquad (0 \leq T < \infty)$$

Suhrmann equation for **photoelectric Richardson Eq. (1929)**

Solution as **integral equation for photoelectric quantum efficiency** with r=3 for Stefan-Boltzmann law (Hora 1957)

$$Q(\nu) = 0 \qquad \text{for } \nu < \nu_o$$

$$= (\nu - \nu_o)^2/2\nu^2 \qquad \text{for } \nu > \nu_o$$

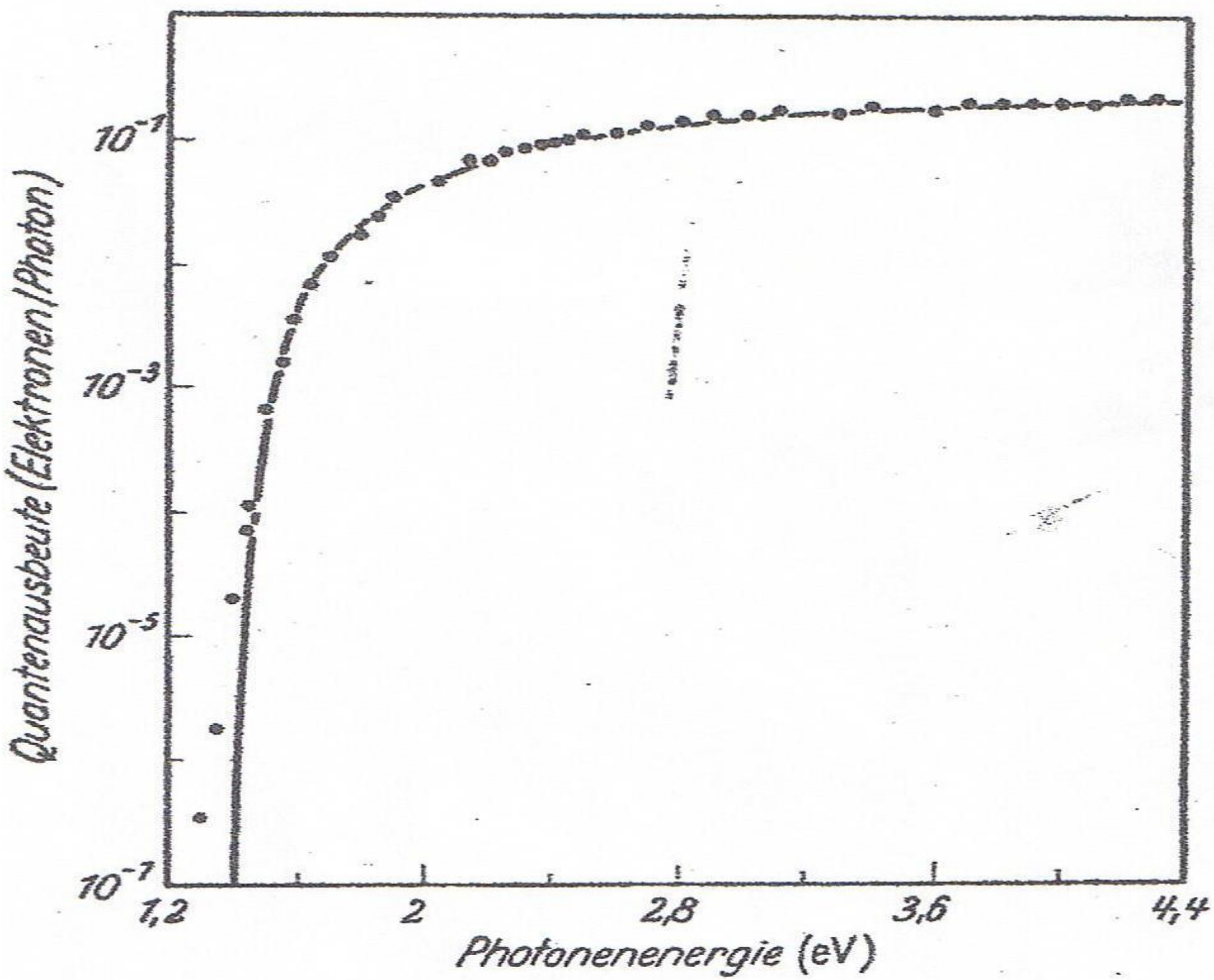
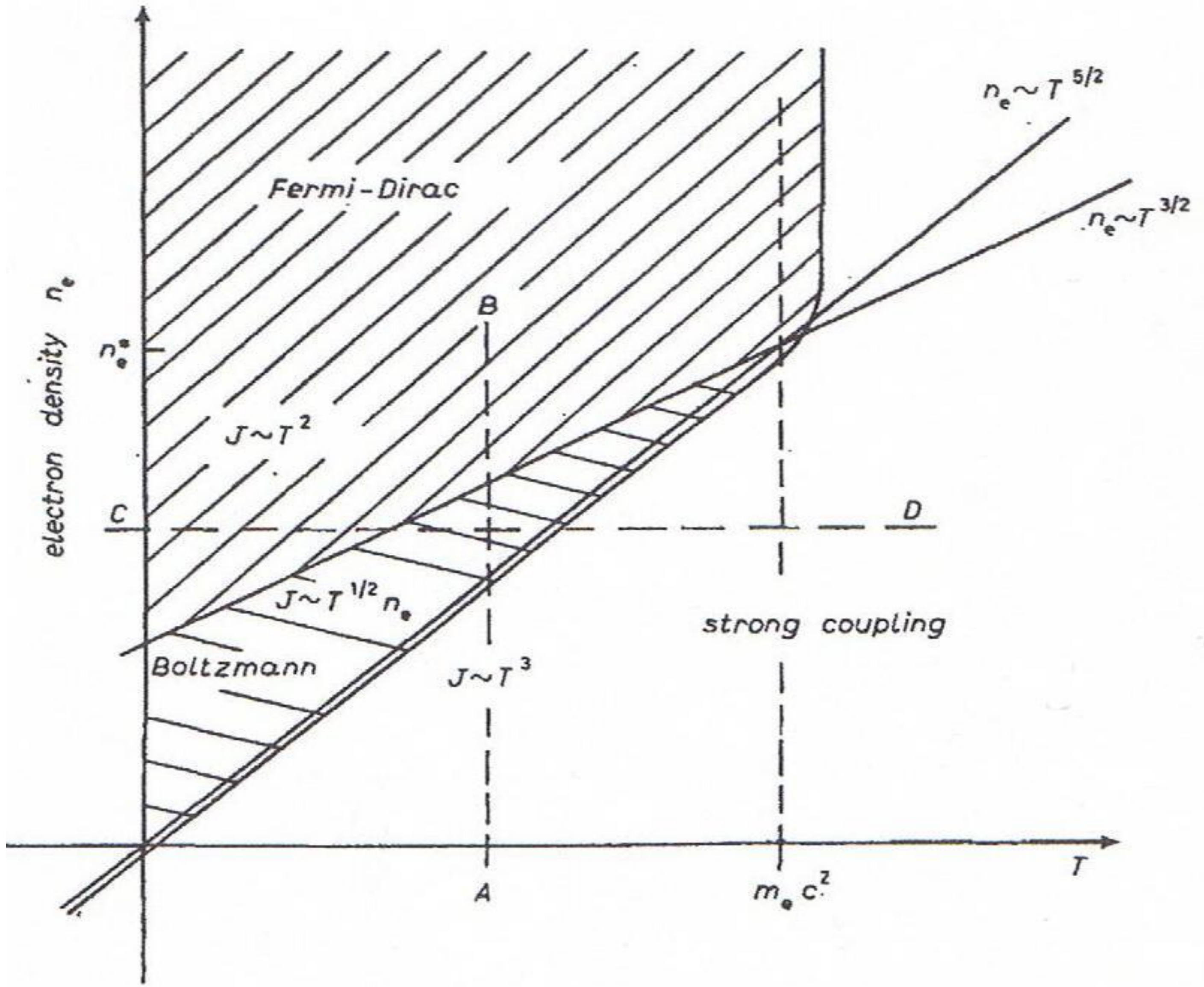


Fig. 1. Spektrale Verteilung für die Quantenausbeute einer [Cs] $Na_xK_{3-x}Sb$-Photokathode. Meßpunkte nach SPICER[13], Kurve nach Gl. (6) mit (7) und dem Parameter $h\nu_0 = 1{,}4$ eV

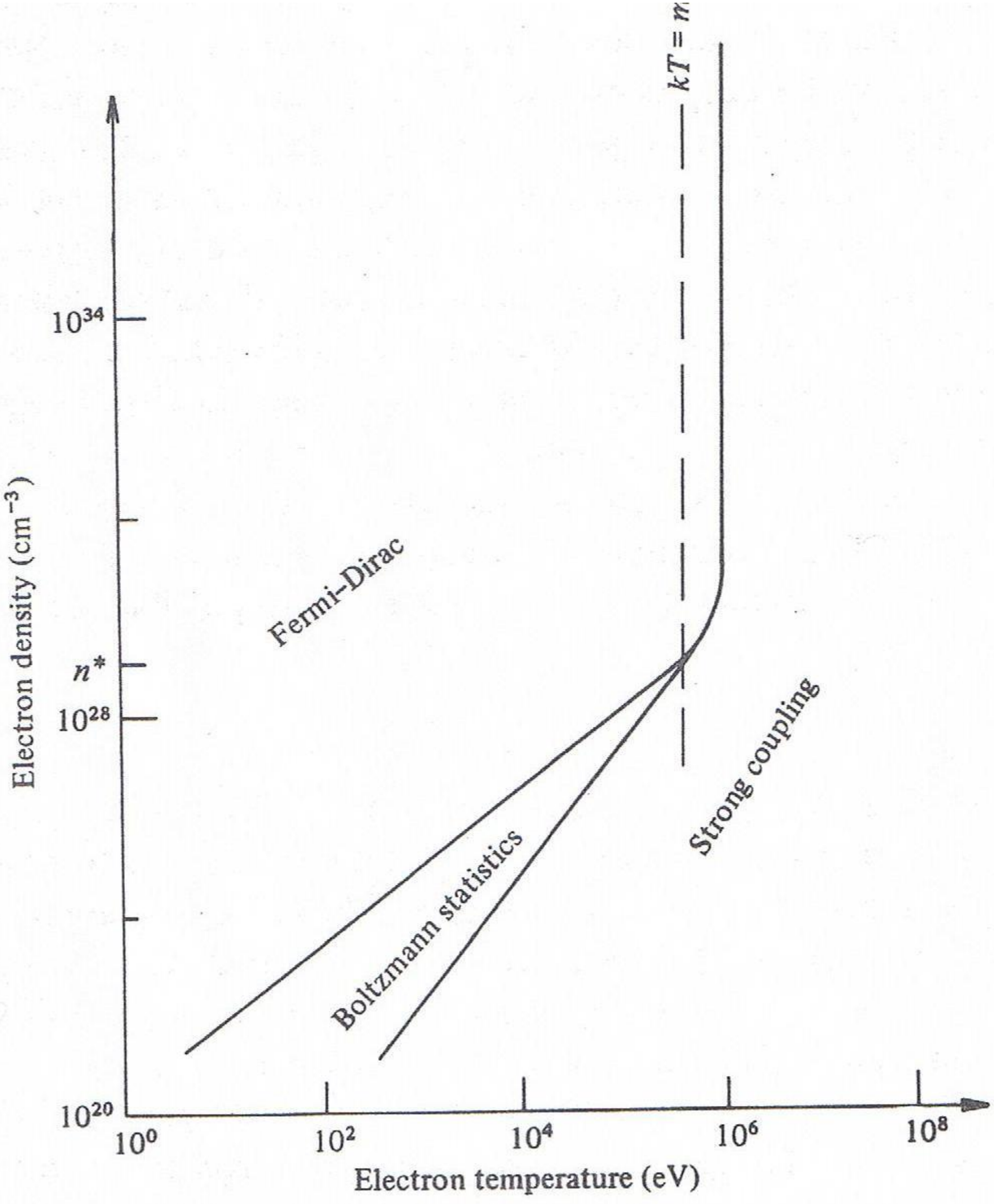
Thermionic electron emission from metals: degnerate electron gas **without coupling** to black body radiation (r=2).

Electron coupling to Planck radiation only at T > million degree Kelvin

But what at temperature above mc^2



ELECTRON COUPLING TO BLACK BODY RADIATION



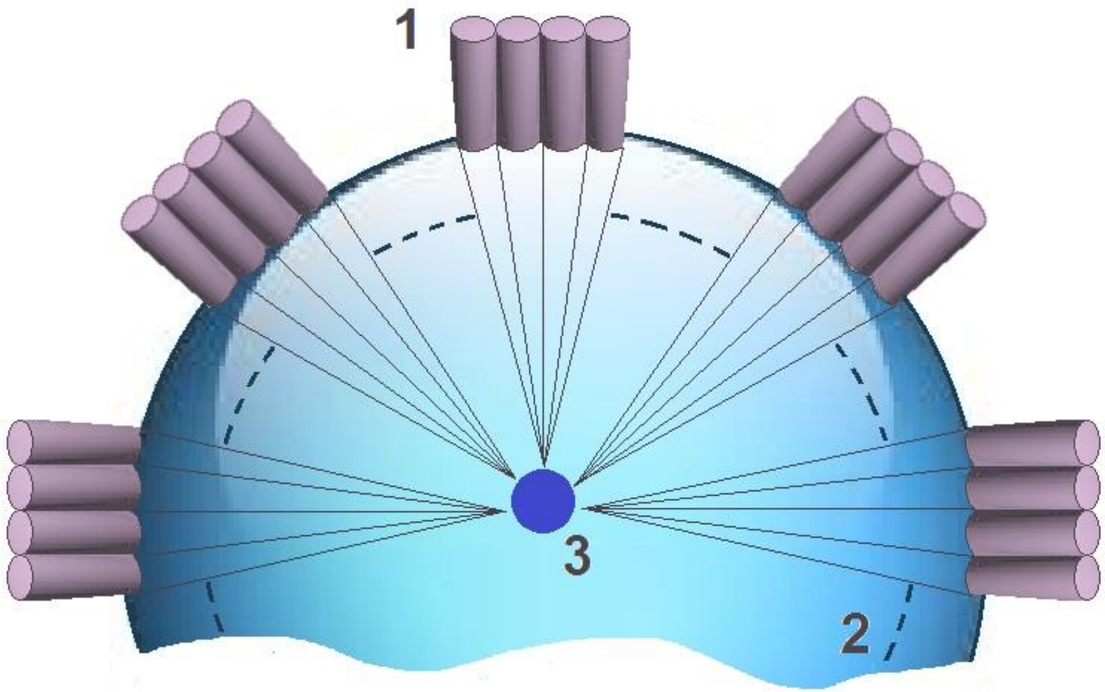
kT = n
10³⁴
n*
10²⁸
10²⁰
Electron density (cm⁻³)
Fermi-Dirac
Boltzmann statistics
Strong coupling
10⁰
10²
10⁴
10⁶
10⁸
Electron temperature (eV)

Electrons in laser fields above 10^{29} W/cm^2 with pair production in "in vacuum" are due to **Unruh radiation** in black body Planck radiation of temperature above mc^2 and **do not follow Fermi statistics due to strong coupling** to the radiation.

ICAN spherical fibre laser (polymers)

Fibre ends 1 on sphere of radius R with radial fibre axes for producing ps spherically converging laser pulse interacting with sphere 3 of HB11 fuel for initiating a fusion flame

ZETAWATT pulses single mode for > 10^29W/cm^2 with radius of about 15 meters: Laser & Prt.Bms 32 (2014) 63



NIF experiment with indirect drive: hohlraum temperature above 300eV will have strong coupling for electron gas at densities below 10^{21} per ccm: **not longer degenerate**, but under strong coupling.

STRONG COUPLNG STATE CAN BE STUDIED AS IN CASE WITH

UNRUH RADIATION

End

Thank You