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Possibility for observing Hawking-like effects via the interaction of multi-PW class laser pulses with plasmas

Masahiro Yano[1], Alexei Zhidkov[1], James Koga[2], Tomonao Hosokai[1,3], and Ryosuke Kodama[1,4]

[1] *Graduate School of Engineering, Osaka Universit,* [2] *Kansai Photon Science Institute, National Institutes for Quantum and Radiological Science and Technology,* [3] *Innovative Light Sources Division, RIKEN SPring-8 Center,* [4] *Institute of Laser Engineering, Osaka University*

e-mail (speaker): *myano@ef.eie.eng.osaka-u.ac.jp*

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Petawatt class femtosecond lasers and x-ray free electron lasers (XFEL) open up a new page in research fields related to space and vacuum physics. One of fundamental principles can be explored by these new instruments is the equivalence principle, saying that gravitation and acceleration should be treated equivalently. If it is true this must lead to the appearance of the Unruh effect analogous to Hawking's black hole radiation. It says that a detector moving with a constant acceleration *w* sees a boson's thermal bath with its temperature *Tw* = *w*/2 *kB c*. Practical detection of the Unruh effect requires extremely strong acceleration and fast probing sources. Here we demonstrate that x-rays scattering from highly accelerated electrons can be used for such detection. We present two, feasible for the Unruh effect, designs for highly accelerated systems produced in underdense plasma irradiated by high intensity lasers pulses. The first is Thomson scattering of a XFEL pulse from plasma wave excited by an intense laser pulse. Properly chosen observation angles enable us to distinguish the Unruh effect from the normal Doppler shift with a reasonable photon number. The second is a system consisting of electron bunches accelerated by a laser wake-field, as sources and as detectors, which move in a constantly accelerating reference frame (Rindler space) and are probed by x-ray free electron laser pulses. The numbers of photons is shown to be enough to observe reproducible results.

Regular electron bunches undergoing extremely high acceleration emulating the behavior of electrons near black holes are shown to occur in underdense plasma irradiated by multi-PW laser pulses with intensity over 10^{22} W/cm^2. Interaction of multi-PW laser pulses with underdense plasma, in the regime of strong relativistic wave-breaking, is investigated via fully relativistic 3D particle-in-cell simulations including ion motion and radiation reaction. The effect of a transverse cylindrical plasma wave in laser pulse wakes on the formation of regular electron bunches under extremely high acceleration, *w*, suitable for detection of Hawking-Unruh temperature $T_H = \hbar w / 2\pi k_B c$ is shown and analyzed.

In addition, propagation of short and ultra-intense laser pulses in a semi-infinite space of overdense hydrogen plasma is analyzed via fully-relativistic, real geometry particle-in-cell (PIC) simulations, including the radiation friction. The relativistic transparency and hole-boring regimes are found to be sensitive to the transverse plasma field, backward light reflection, and laser pulse filamentation.

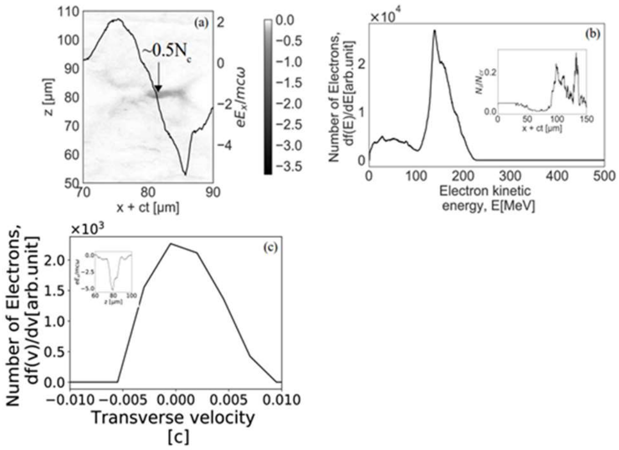

Figure (a)Electron density, longitudinal electric field in the *p*-plane, (b) energy spectrum of the bunch, and ion density, (c)transverse velocity of the bunch and transverse distribution of longitudinal electric field at x = 85 μm for plasma density N_{e0} = 5.0x10^{19} cm^{-3}, intensity $I=10^{24}$ W/cm^2, and mass-to-charge ratio $M/Zm_p=1$; t=625 fs. The average energy of electrons is about 150 MeV with the energy spread of ~20%.

References

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