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Ultra-Intense X-Ray Radiation of Relativistic Laser Plasma Inducing Radiation-Dominated Matter Kinetics

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The energy of petawatt optical laser pulses of pico- and femto-second duration and relativistic intensities exceeding 1021 W/cm2 is efficiently converted to X-ray radiation, which is emitted by hot electron component in collision-less processes and heats the solid density plasma periphery. In turn, the intense X-ray radiation effectively ionizes the matter inside out, providing a large population of exotic states called hollow ions, i.e. ions with empty inner and populated outer electron shells. Hollow-ion emission from radiation-dominated hot, dense plasmas provides a new opportunity for diagnosing high-intensity x-ray radiation fields. However, constructing adequate non-LTE atomic models remains a challenge, since configuration interaction plays a significant role in the structure of the emission, and multiply excited states with many holes in both valence and inner shells can lead to enormous structural and computational complexity. Currently, the process of hollow ion production by X-rays is of particular importance due to the advent of multiple high-power X-ray lasers such as: transient–collisional, based on plasma pumping by visible lasers and the free-electron lasers.
Direct high-resolution spectroscopic measurements demonstrate that X-ray radiation from plasma periphery exhibits unusual non-linear growth ˜E4–5 of its power. The non-linear power growth occurs far earlier than the known regime when the radiation reaction dominates particle motion (RDR). Nevertheless, the radiation is shown to dominate the kinetics of the plasma periphery, changing in this regime the physical picture of the laser plasma interaction. Although in the experiments reported here we demonstrated by observation of KK hollow ions that X-ray intensities in the keV range exceeds 1018 W/cm2, there is no theoretical limit of the radiation power.
Therefore, such powerful X-ray sources can produce and probe exotic material states with high densities and multiple inner-shell electron excitations even for higher Z elements. Relativistic laser-produced plasmas may thus provide unique ultra-bright polychromatic X-ray source for future studies of matter in extreme conditions and radiography applications.

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