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K-α emission form medium and high-Z materials irradiated by femtosecond laser pulses

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Fast electrons are created at the target surface during the interaction of high intensity ultra short laser pulses with solids. Fast electrons penetrate deep into the target where they generate K-α and Bremsstrahlung radiation. Generated high brightness K-α pulses offer the prospect of creating a cheap and compact X-ray source, posing a promising alternative to synchrotron radiation, e.g. in medical application and in material science.. With an increase in laser intensity, efficient X-ray emission in the multi-keV range with pulse duration shorter than few picoseconds is expected. This short incoherent but monochromatic X-ray emission synchronized with laser pulses may be used for time-resolved measurements.

Acceleration of fast electrons, their transport and K-α photon generation and emission from the target surface in both forward and backward directions are studied here numerically. The results are compared to recent experiments studying K-α emission from the front and rear surface of copper foil targets of various thicknesses and for various parameters of the laser plasma interaction. One-dimensional PIC simulations coupled with 3D time-resolved Monte Carlo simulations show that account of ionization processes and of density profile formed by laser ASE emission is essential for reliable explanation of experimental data.

While sub-relativistic intensities are optimum for laser energy transformation into K-α emission for medium-Z targets, relativistic laser intensities have to be used for hard X-ray generation in high-Z materials. The cross-section for K-α shell ionization of high-Z elements by electrons increases or remains approximately constant within a factor of two at relativistic electron energies up to electron energies in the 100-MeV range. Moreover, the splitting ratio of K-α photon emission to Auger electron emission is favorable for high-Z materials, and thus efficient K-α emission is possible. In our simulations and analytical estimates, laser energy conversion to hard K-α emission greater that 10^{-4} has been found for laser intensities above 10^{19} W/cm^2. Possible ways to the conversion efficiency enhancement via laser and target optimization are depicted.

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