Photon dose lowering by fast electron energy loss induced by return current as a short-pulse high-intensity laser interacts on a metal solid target

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During the interaction of a short-pulse high-intensity laser with the preplasma produced by the pulse's pedestal in front of a high-Z metal solid target, high-energy electrons are produced, which in turn create an X-ray source by interacting with the atoms of the converter target. The current brought by the hot electron current is almost completely neutralized by a return current driven by the background electrons of the conductive target, and the force exerted on the hot electrons by the electric field induced by the Ohmic heating produced by the background electrons reduces the energy of the hot electrons and thus lowers the X-ray emission and photon dose. This effect is analyzed here by means of a simple 1-D temperature model which contains the most significant terms of the relativistic Fokker-Planck equations with electron multiple scattering, and the energy equations of ions, hot and cold electrons are solved numerically. The energy loss of the hot electrons by Ohmic heating varies with different parameters as the plasma scale length, the target thickness, and the laser characteristics. For instance for a ps laser pulse with 10 microns spot size on a tantalum target, the energy loss fraction by Ohmic heating is about 10 to 40%. Laser and plasma parameters may be optimized to reduce this effect, for instance at small plasma scale length or at small laser spot size. Conversely, the resistive heating is enhanced with a foam target or at long plasma scale length and high laser spot size and intensity, at which the incident hot electron bunch have a small mean emission angle given by the ponderomotive force. The X-ray emission and dose produced by a laser interacting in a gas jet may thus be inhibited under these circumstances. The resistive heating may also be maximized in order to reduce the X-ray emission to lower the radiation level for instance in a safety radiological goal.