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Comment on “In-depth Plasma-Wave Heating of Dense Plasma Irradiated by Short Laser Pulses”
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Sherlock et al. [1] have reported on the heating of solid density targets by collisional damping of wakefields that are driven by relativistic electron bunches generated in relativistic laser matter interaction. Analyzing collisional particle-in-cell simulations they calculate the fast electron current \( j_f \) inside the plasma by adding contributions from electrons with energies greater than \( E_{\text{cut}} = 50 \text{ keV} \); time-integrating the specific resistive energy deposition \( \eta j_f^2 \) they arrive at a temperature profile and compare the result to the one ‘measured’ in their simulation, defined as the energy of particles with \( E < 30 \text{ keV} \); the discrepancy (Fig.1a, red/black) is due to collisional damping of wakefields (CDW). We disagree with their metric of fast current, which leads to false conclusions about CDW heating being a volumetric, rather than surface effect.

Repeating their 1D PIC simulation with identical parameters (400 cells per micron, \( 10^4 \) particles per cell) [1], we arrive at the following conclusions: (1) When \( j_f \) is computed based on adding contributions from electrons with velocities \( > 5 v_{\text{th}} \), the local thermal velocity [3], one obtains a larger current than [1], illustrated by the running integral of the current over the grey band in Fig.1b; the resulting time-integrated heating is consistent with the PIC-temperature deep in the target (Fig.1a, orange), while the profile based on Sherlock’s definition of \( j_f \) is not (Fig.1a, red)[2]. We define temperature via the fwhm of local electron distribution function; note that our ‘measurement’ of temperature agrees with Ref. [1]. Fig.1b shows the first velocity-moment of the electron distribution function at 8\( \mu \text{m} \) and time 90 fs and its running integral to illustrate this difference. Its minimum at 5\( \tau_{\text{th}} \) allows for a well-defined distinction between “background” and “fast” electrons. (2) The amplitude of wakefields drops rapidly with distance from the target interface, see Fig.2, because of a combination of velocity dispersion of laser-driven relativistic electron bunches, and wave-particle interaction [4]; this drop is visible in Fig.4 of Ref.[1], but was not mentioned there. In order to drive a wakefield resonantly, the bunch width needs to be shorter than the plasma wavelength, e.g. \( \lambda_p \approx 0.03 \mu\text{m} \) at solid density. Most of the current in a single bunch of laser accelerated fast electrons lags behind the speed of light by \( \lambda_p \) within less than a few microns, under the present conditions; stretching of the electron bunches over distance leads to the observed drop in wakefield amplitude.

This means that background plasma physics effects need to be included over a few microns behind the solid density interface to explain heating on the surface, but not deep inside the target as suggested by the title of Ref.[1].

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[2] In extra simulations we find that reduced particle statistics can lead to enhanced $T_{\text{PIC}}$, while its effect on $T_{\text{Spitzer}}$ is small – the latter is mostly determined by the definition of $j_f$, see Fig.1(b).
