Comment on "In-depth Plasma-Wave Heating of Dense Plasma Irradiated by Short Laser Pulses"

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 $E_{\rm cut} = 50$ keV; time integrating the specific resistive energy deposition ηj_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 $E < 30$ keV; the discrepancy [Fig. 1(a), red and black curves] is due to the 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 one-dimensional (1D) particle-in-cell (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 $> 5v_{\rm th}$, the local thermal velocity [2], one obtains a larger current than Ref. [1], illustrated by the running integral of the current over the grey band in Fig. 1(b); the resulting time-integrated heating is consistent with the PIC temperature deep in the target [Fig. 1(a), orange curve], while the profile based on Sherlock's definition of j_f is not [Fig. 1(a), red curve] [3]. We define the temperature via the FWHM of the local electron distribution function; note that our "measurement" of temperature agrees with Ref. [1]. Figure 1(b) shows the first velocity moment of the electron distribution function at 8 μm and time 90 fs and its running integral to illustrate this difference. Its minimum at $5v_{\rm th}$ allows for a well-defined distinction between "background" and "fast" electrons. (2) The amplitude of wakefields drops rapidly with the distance from the target interface (see Fig. 2) because of a combination of the velocity dispersion of laser-driven relativistic electron bunches and the 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., $\lambda_p \approx 0.03\ \mu$m at solid density. Most of the current in a single bunch of laser accelerated fast electrons lags behind the speed of light by λ_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.

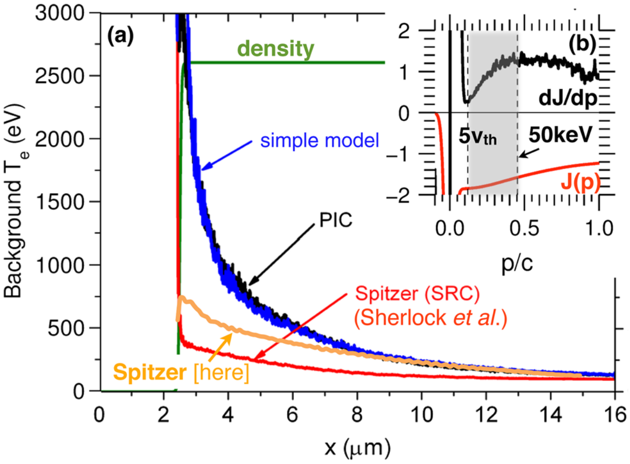

FIG. 1. (a) Temperature profiles from Fig. 1, Ref. [1], and a dynamical Spitzer return current (SRC) heating (orange curve); density ramps up to $9 \times 10^{29}\ {\rm m}^{-3}$ at $x = 2.5\ \mu$m. (b) Spectrum of the current and its integral at 8 μm and 90 fs; dashed lines at $5v_{\rm th}$ and 50 keV.

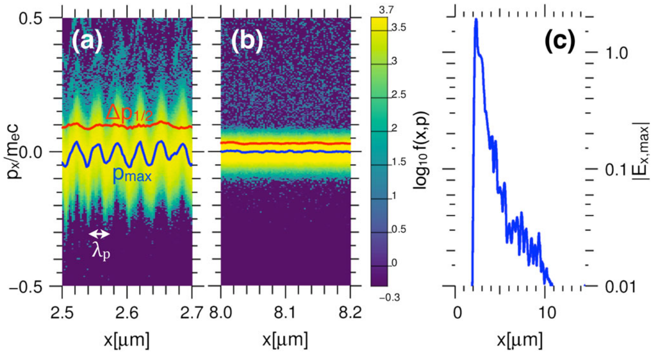

FIG. 2. Longitudinal electron phase space at 90 fs (a) near the solid interface and (b) inside the bulk plasma. (c) Peak wakefield amplitude in units of $m_e\omega_L/c$ vs the position at 90 fs.

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

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