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

A.J. Kemp[1] and Y. Sentoku[2]
[1] *Lawrence Livermore National Laboratory, Livermore, CA 94551,*
[2] *University of Nevada, Reno NV 89577*

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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 $E_{\rm cut} = 50\,$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 $E < 30\,$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 $> 5\, v_{th}$, 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 8μm and time 90 fs and its running integral to illustrate this difference. Its minimum at $5 v_{\rm th}$ 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. $\lambda_p \approx 0.03\mu$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.

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].

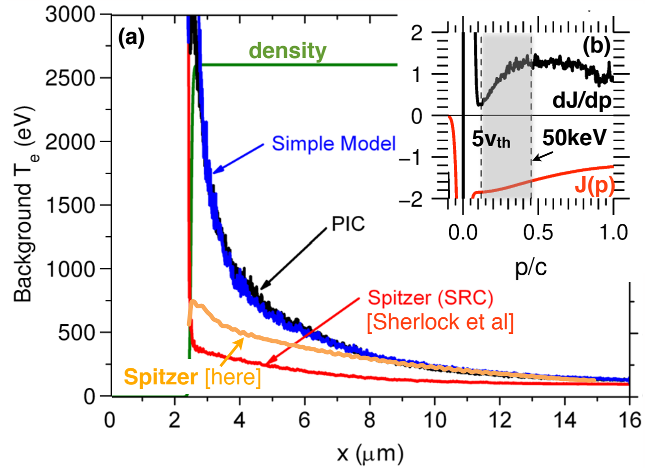

FIG. 1. (a) Temperature profiles from Fig.1, Ref. [1], and dynamical Spitzer return current (SRC) heating (orange curve); density ramps up to 9×10^{29}m^{-3} at $x = 2.5\mu$m. (b) Spectrum of current and its integral at 8μm and 90 fs; dashed lines at $5\, v_{th}$ and 50 keV.

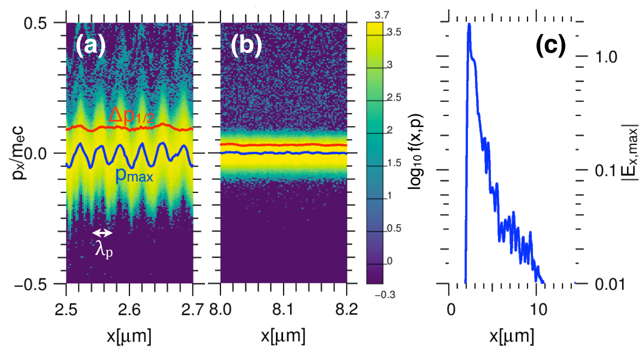

FIG. 2. Longitudinal electron phase space at 90fs, (a) near the solid interface and (b) inside the bulk plasma. (c) Peak wakefield amplitude in units of $m_e\omega_L/c$ vs. position at 90 fs.

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[1] M. Sherlock *et al.*, Phys. Rev. Lett. **113**, 255001 (2014).

[2] In extra simulations we find that reduced particle statistics can lead to 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).

[3] B. Cohen, A. Kemp, and L. Divol, J. Comp. Phys. **229**, 4591 (2010).

[4] E. Esarey *et al.*, IEEE Transact. Plasma Science **24**, 252 (1996).