The Most Unsolved Problem in Plasma Physics: Demonstrating a Burning Plasma in the Laboratory*

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The recent results from the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory raise the hopes for producing a thermonuclear burning plasma in the laboratory for the first time. A plasma is defined as "burning" when the self-heating from the fusion reactions is the main energy input to the plasma. A burning plasma represents the stage before thermonuclear ignition. Assessing the degree to which fusion alpha particles contribute to the fusion yield is essential to assess when the plasma is burning. The recent results from indirect-drive implosions on NIF [1,2] show that the total alpha energy is comparable to the input energy to the central hot spot of a compressed core. The level of alpha heating [3] of NIF indirect-drive implosions is inferred from the measurements of areal density and neutron yield, and compared to the results achieved by other approaches to nuclear fusion. An approach [4] is also developed to extrapolate fusion yields, including alpha heating from current direct-drive experiments on OMEGA at tens of kilojoules of incident laser energy to megajoule drivers such as the NIF assuming the same illumination configuration. The extrapolation assumes that the implosion hydrodynamic performance is unchanged at higher energies. It is estimated that the current best-performing OMEGA implosion [5] extrapolated to a 1.9 MJ laser driver would produce over 100 kJ of fusion energy [4] and similar levels of alpha heating [3] than current indirect-drive NIF implosions. While not included in this analysis, the predicted performance can be significantly degraded if laser-plasma instabilities become more detrimental at the larger energy scales.

[1] O. Hurricane *et al.*, Nature 503, 346 (2014).

[2] T. Doppner et al, Phys. Rev. Lett. 115, 055001 (2015).

[3] R. Betti *et al.*, Phys. Rev. Lett. 114, 255003 (2015).

[4] A. Bose *et al.*, submitted to Phys. Rev. Lett.

[5] S. Regan *et al.*, submitted to Phys. Rev. Lett.

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