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Lawson criterion for ignition exceeded in an inertial fusion experiment

Omar A. Hurricane, Lawrence Livermore National Laboratory

For more than half a century, researchers around the world have been engaged in attempts to achieve fusion ignition as a proof of principle of various fusion concepts. As recently reported [1-3], a burning plasma state, where the alpha-heating in the plasma is the primary source of heating, was achieved in laboratory experiments. Following the Lawson criterion, an ignited plasma is one where the fusion heating power is high enough to overcome all the physical processes that cool the fusion plasma, creating a positive thermodynamic feedback loop with rapidly increasing temperature. In inertially confined fusion, ignition is a state where the fusion plasma can begin ``burn propagation" into surrounding cold fuel, enabling the possibility of high energy gain. While ``scientific breakeven" (i.e. unity target gain) has not yet been achieved, this talk reports the first controlled fusion experiment on the National Ignition Facility to produce capsule gain greater than unity (here 5.8) and reach ignition [4] by many different formulations of the Lawson criterion. In the talk, we will discuss some key basic physics inertial confinement fusion (ICF) principles behind the burning plasma and ignition results as well as discuss future challenges.

[1] Zylstra, Hurricane, Callahan, et al, “Burning plasma achieved in inertial fusion,” Nature (2022). https://doi.org/10.1038/s41586-021-04281-w
[2] Kritcher, Young, Robey, et al., “Design of inertial fusion implosions reaching the burning plasma regime,” Nature Physics (2022). https://doi.org/10.1038/s41567-021-01485-9
[3] Ross, Ralph, Zylstra, et al., “Experiments conducted in the burning plasma regime with inertial fusion implosions. Preprint at https://arxiv.org/abs/2111.04640 (2021).
[4] Hurricane, Kritcher, Zylstra, Callahan, et al., “Lawson criterion for ignition exceeded in an inertial fusion experiment,” Submitted to Phys. Rev. Lett. (2022).

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