Control of Magnetic Reconnection in Laser-Plasma Interaction

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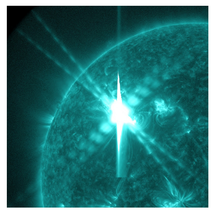
Summary

- We introduce a technique to control the onset of magnetic reconnection in laser-produced plasmas.
- This technique is the use of a short pulse laser.
- The density gradient matters

What is Magnetic Reconnection (MR)?

- Magnetic energy can build up in plasmas over a long time but then quickly be released into kinetic energy via MR.

Solar flare triggered by magnetic reconnection



The Laser-Driven Magnetic Reconnection Platform

- We collide two self-magnetizing laser-plasma plumes
- Then we add a short-pulse laser

The density scale length of the pre-existing plasma plumes effects the hot electron distribution generated by the SP

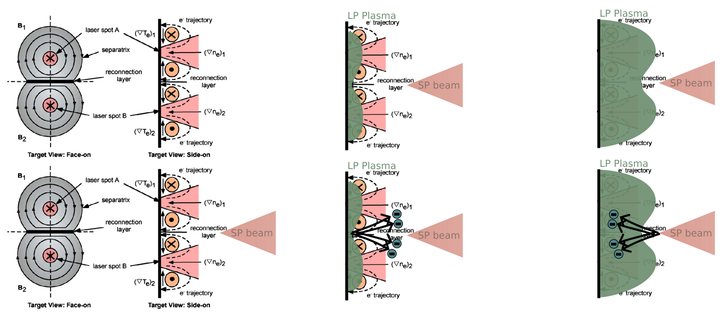
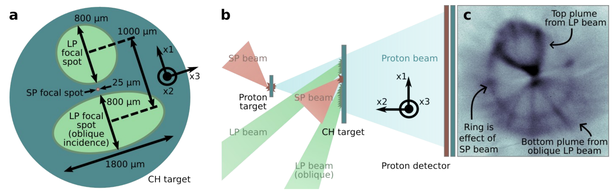


Figure adapted from Ref. 1

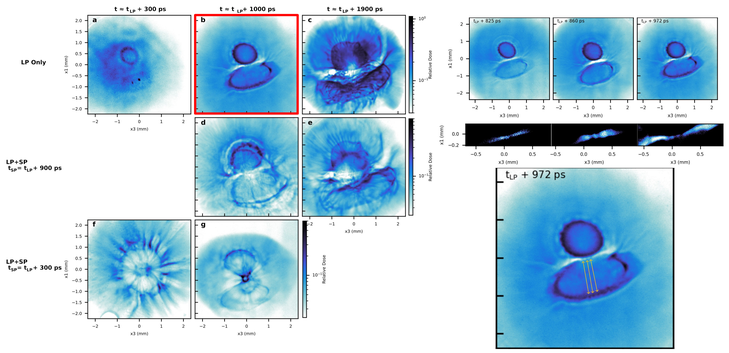
Experiment Setup at OMEGA-EP



- "LP" long-pulse, 2.5 nanoseconds, ~ 1 x 10^{14} W/cm^2
- "SP" short-pulse, 10 picoseconds, ~ 1 x 10^{19} W/cm^2

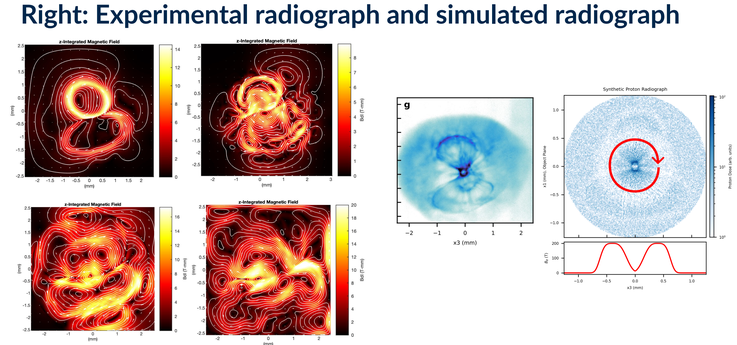
Experiment Results – Proton Radiographs

- Long-pulse only: Plasmoids develop in the current sheet at t~1000 ps, followed by lots of instabilities by t~1900 ps.
- Firing the short pulse (d, f) changed the dynamics of the long-pulse-driven plasma (e, g)



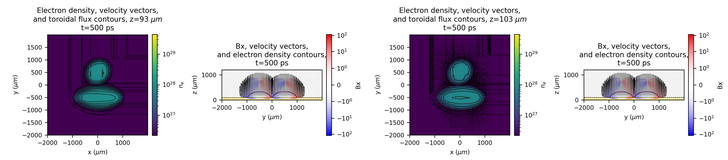
- SP at t=900 ps: CCW B-field, at 300 ps: CW B-field

Left: Experimental radiograph inversions of (b-e) above
Right: Experimental radiograph and simulated radiograph



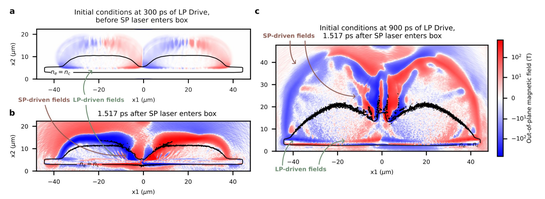
3D e-MHD Simulation of LP Expansion

- Further from the target the plasma has less magnetic flux and greater expansion velocity



3D PIC Simulation of SP with e-MHD Data for the Initial Conditions

- Simulation shows SP magnetic field generation clockwise far from the SP laser focus between the plumes, counter-clockwise near the focus, and laser filamentation for the longer scale-length case (c)



Acknowledgements

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2. P. T. Campbell, B. K. Russell, C. Dong, G. Fiksel, P. M. Nilson, A. G. R. Thomas, C. A. Walsh, K. M. Krushelncik, and L. Willingale, Physical Review Research **6**, L012016 (2024).