Relativistic Laser Perturbation to Laser-Driven Magnetic Reconnection

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Motivation: Magnetic Reconnection

Magnetic reconnection (MR) is essential to understanding solar flares and other astrophysical phenomena, [1] and has implications for inertial confinement fusion. We want to see how laser-driven MR is affected by a perturbation of relativistic particles at the MR interface.

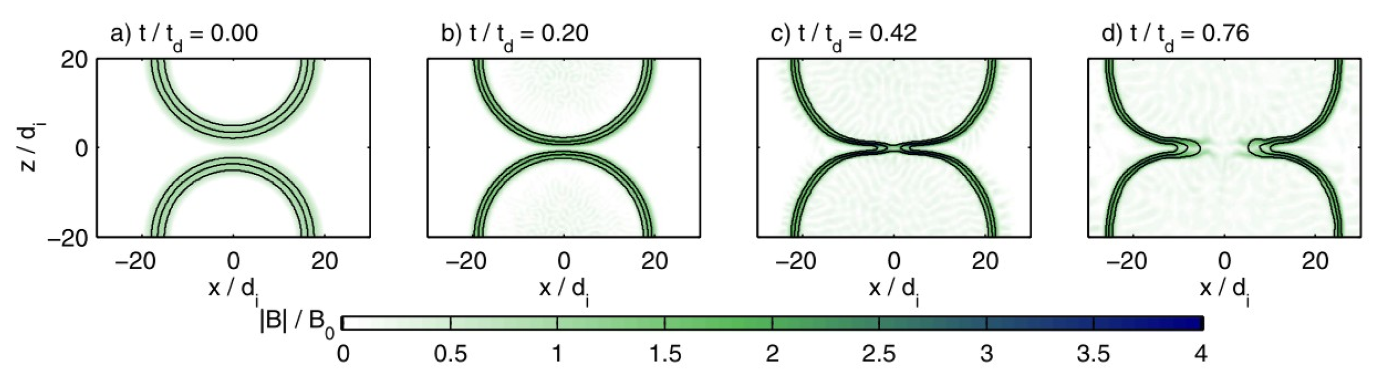
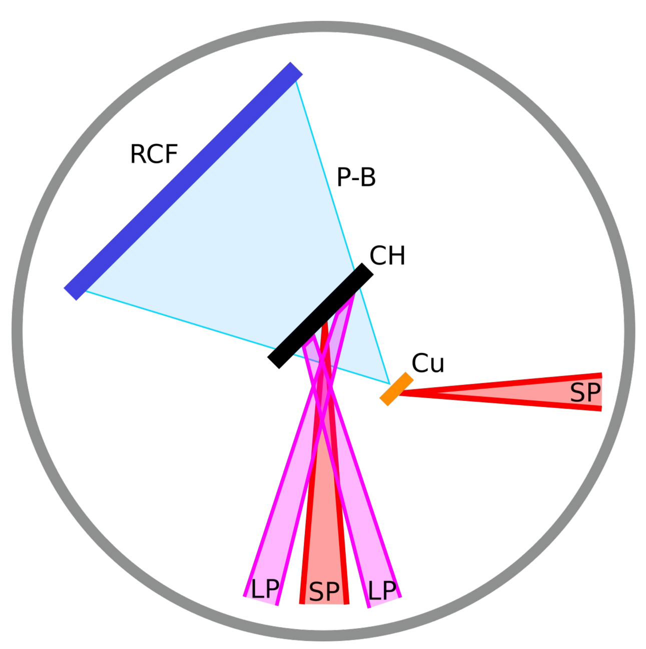


Figure 1: Magnetic field in simulation of colliding plasma bubbles [2].

OMEGA-EP Experimental Setup

Figure 2: Schematic of experimental setup. Abbreviations are: **LP**: Long-pulse UV laser; **SP**: Short-pulse IR laser; **CH**: Plastic target foil; **Cu**: Copper probing foil; **P-B**: TNSA Proton beam; **RCF**: Radio-chromic film



Laser Parameters: The LP lasers had a 2.5 ns duration at ~ 1 x 10^{14} W/cm^2, 800 μm diameter spots, two spots separated by 1000 μm. The SP on CH had intensity ~ 2 x 10^{19} W/cm^2 for 10 ps in an 80 μm spot. The proton-radiography SP was 320 J in ~ 1 ps at best focus.

Proton Radiography of Laser Plasmas

The LP laser induces a clockwise-directed magnetic field through the Biermann battery effect. Protons traveling through the target (read reference about proton radiography [3]) are deflected inward, creating a dark ring (high proton flux) surrounded by a lighter-colored ring (low proton flux), as in the no-SP shot shown in Fig. 3.

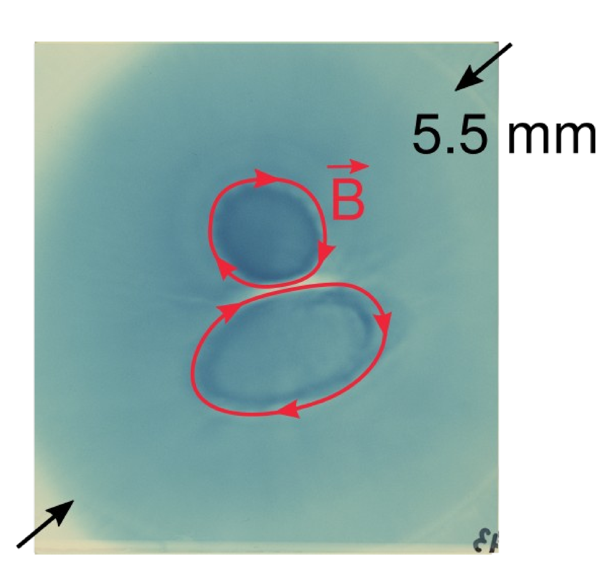


Figure 3: RCF with two LP's; inferred mag. field in red

Results – MR Inhibited by Rel. Laser

Figure 4 shows the mid-term effects of firing the SP laser at an early time. In Fig. 4(a) the unperturbed antiparallel magnetic fields push protons away from the reconnection region. In Fig. 4(b) the SP laser perturbation led to a dark ring on the RCF in between the two LP laser plumes, indicating a counter-clockwise magnetic field (Fig. 5).

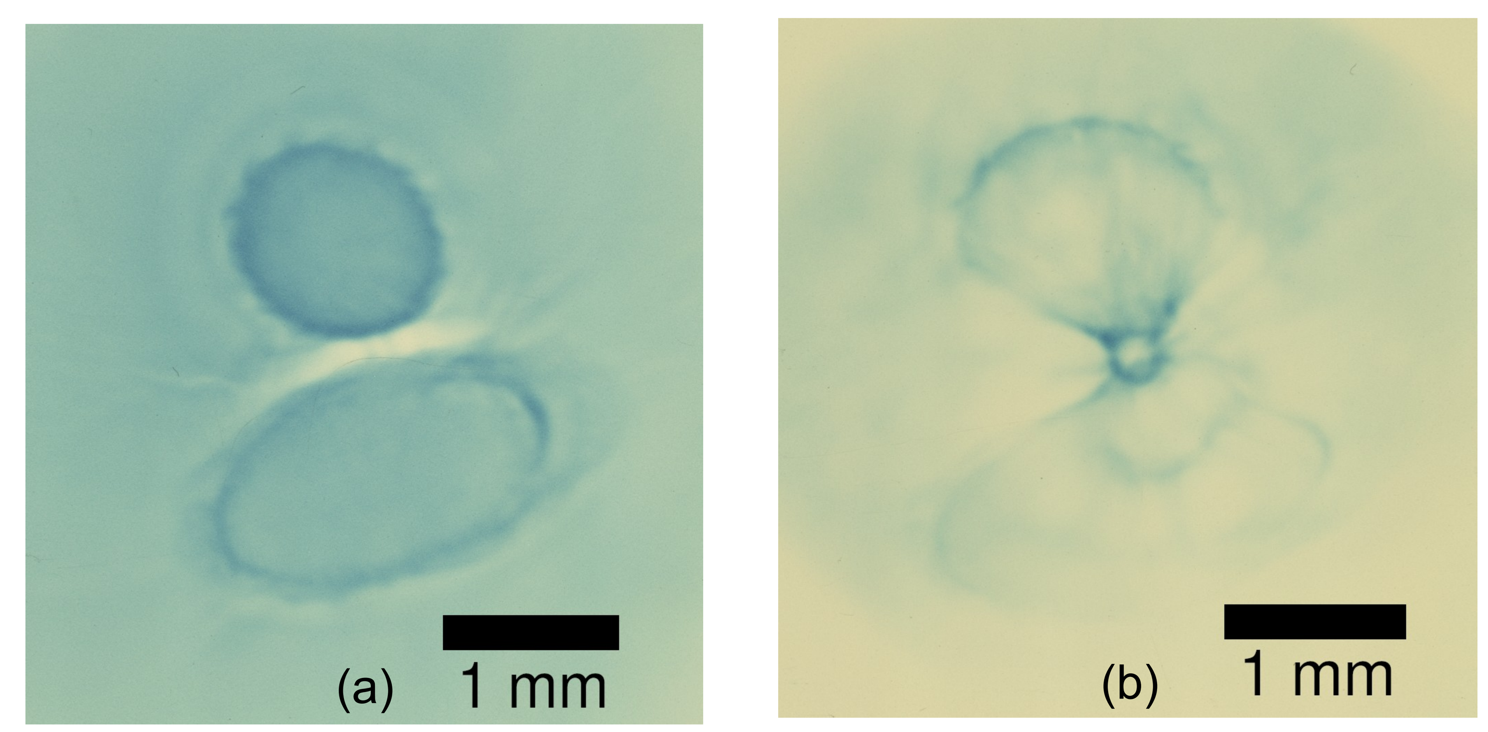


Figure 4: RCF of target at intermediate time (t_0 + 900 ps, where t_0 is the onset of the LP lasers) without (a) and with (b) the SP laser at early time (t_0 + 360 ps).

Results – MR Enhanced by Rel. Laser

If the SP laser struck the target when the LP-driven plumes were already interacting, then the effect was much less pronounced. The SP laser caused some blurring of the features in the reconnection region (Fig. 5b) compared to the unperturbed case (Fig. 5a), indicating less steep magnetic field gradients.

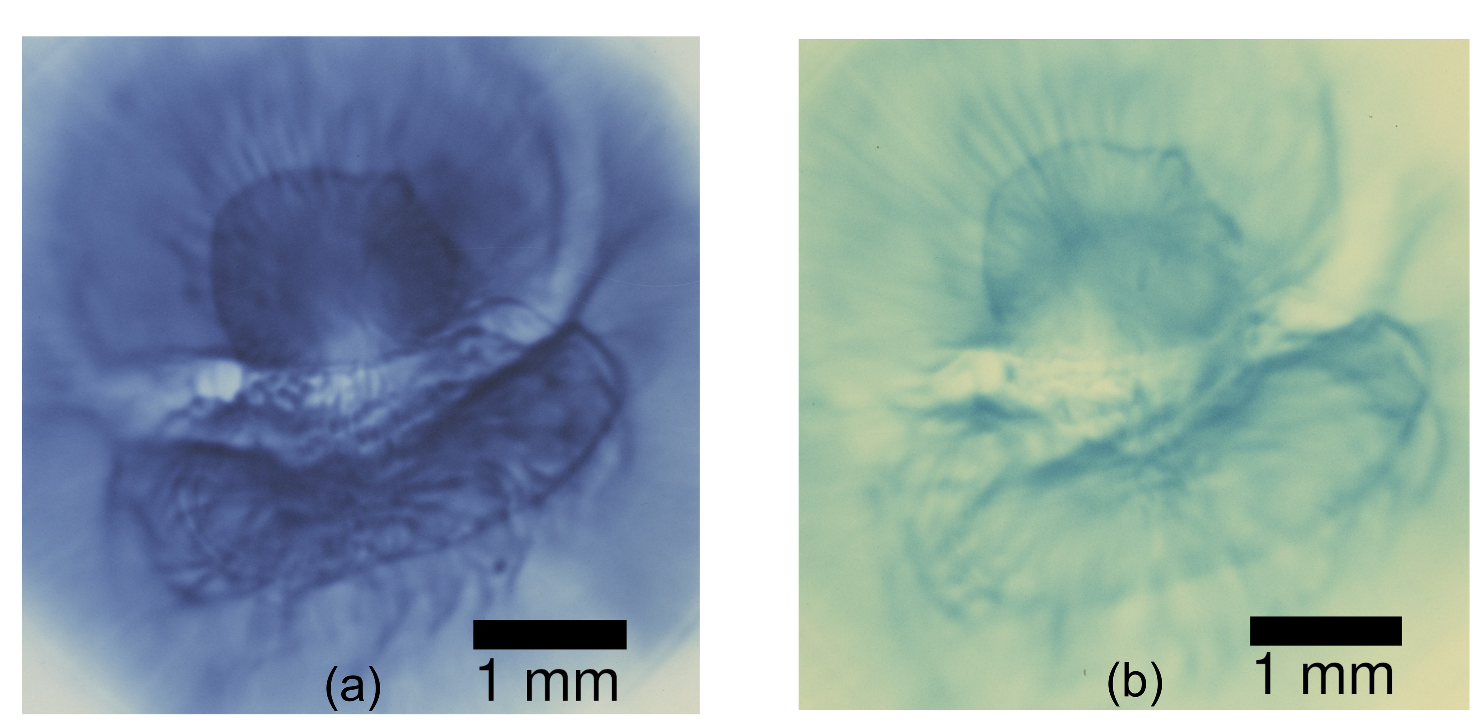


Figure 5: RCF of target at late time (t_0 + 1900 ps) without (a) and with (b) the SP laser at intermediate time (t_0 + 950 ps).

Interpretations – Mag. field generation

A counter-clocwise ring of magnetic field (Fig. 5) could be caused by the electron currents ponderomotively pushed by the SP laser [4]. The guitar-pick shape of the plumes may be due to the outflow of SP-dirven plasma (Fig. 6).

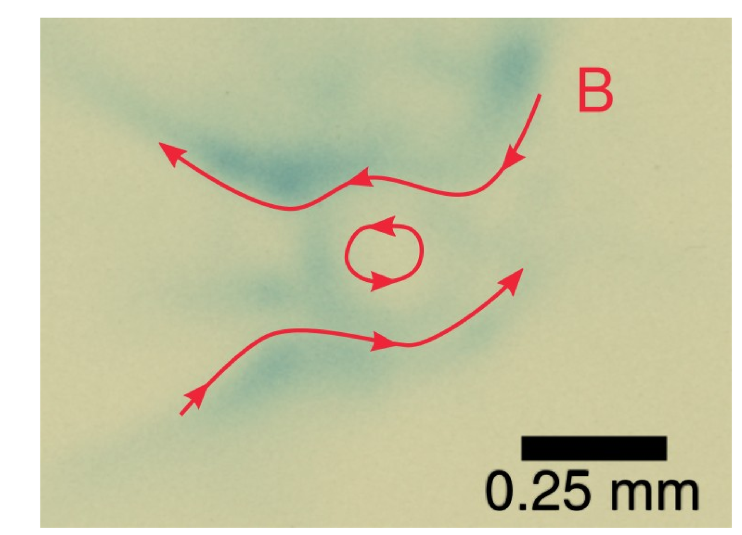


Figure 5: High-energy proton radiograph of the reconnection region in Fig. 4(b).

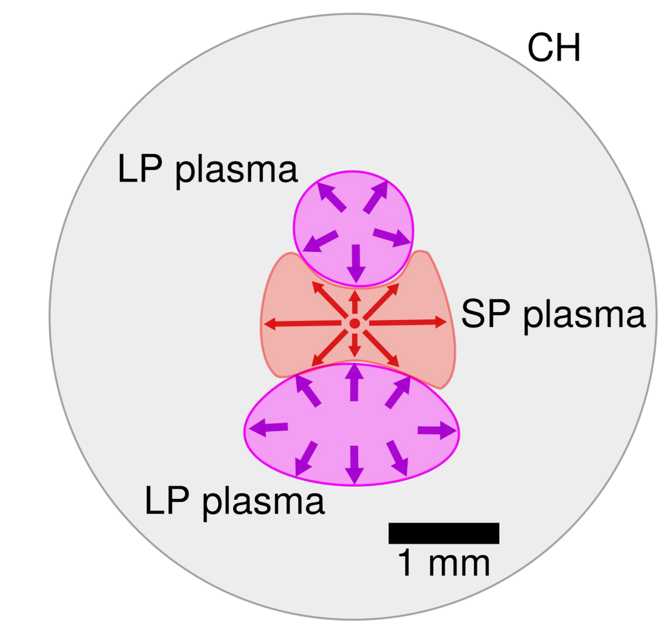


Figure 6: Diagram of the outflow (arrows) of the plasma which may contribute to the egg-timer shape of Fig. 3b.

Summary

We have introduced a new knob for understanding high-energy-density MR.
The effect of the 10 ps pulse ("short pulse") heavily depended on the timing relative to the two 2.5 ns pluses driving the plasma bubbles.

Acknowledgements

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