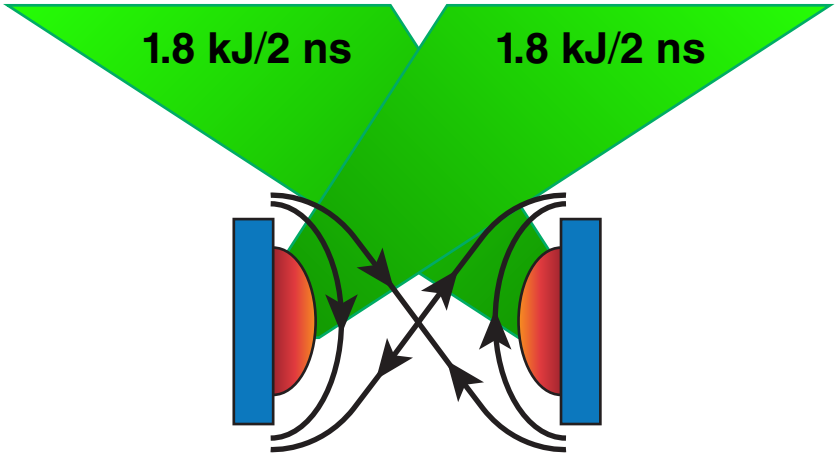
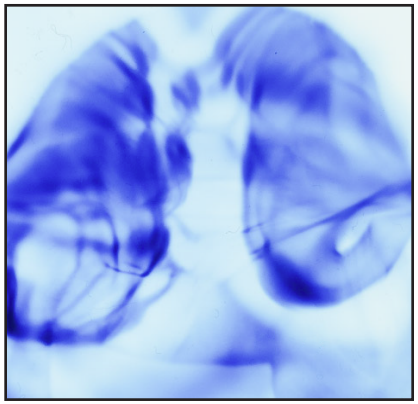
Strongly Driven Magnetic Reconnection in Magnetized High-Energy-Density Plasmas

Experimental setup



Proton radiography of compressed and reconnected B field



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Summary

Reconnection of an external magnetic field was observed in a high-energy-density (HED), laser-produced plasma

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- Formation of colliding magnetized "ribbons," magnetic-flux compression and pile-up, and reconnection were demonstrated*
- Reconnection is fast, with a rate comparable to the Alfvén rate
- Sharp gradients of magnetic field and plasma density may indicate the formation of shock structures
- Particle-in-cell simulations closely match the experimental results

*G. Fiksel *et al.*, Phys. Rev. Lett. 113, 105003 (2014).

Collaborators

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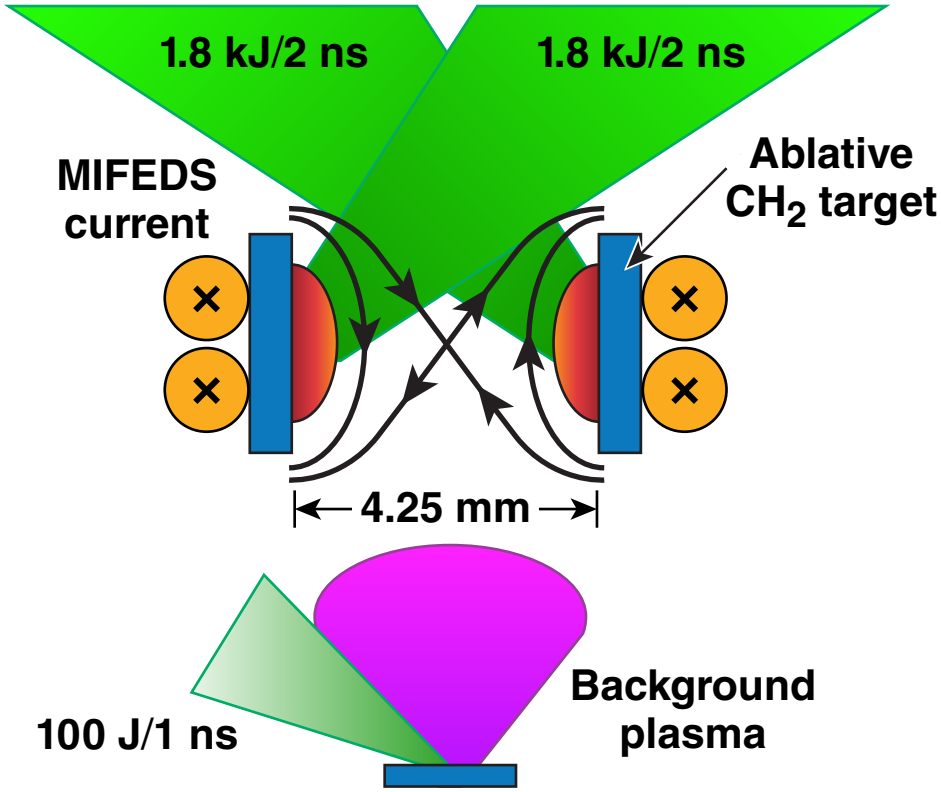
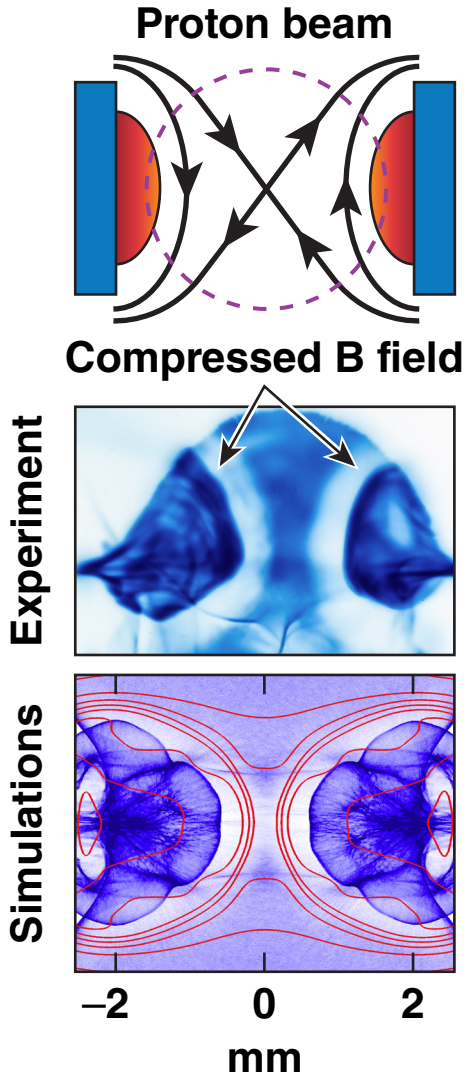
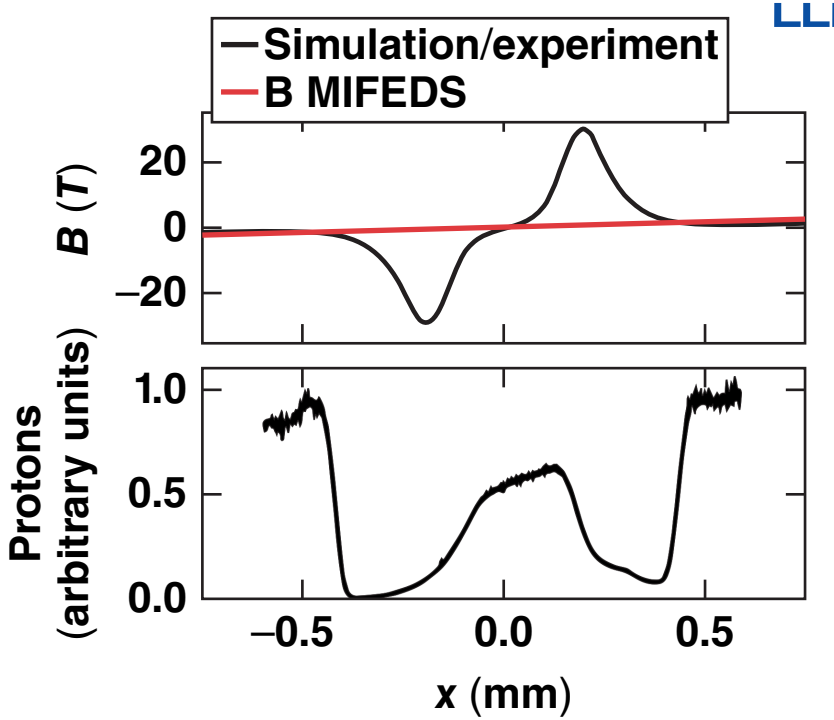
Reconnection of an external B field was studied by colliding two HED plasmas on the OMEGA EP Laser System



- The external field (8 T at the target) is created by a pulsed-current generator, magneto-inertial fusion electrical discharge system (MIFEDS)
- The region between the targets is prefilled by a tenuous background plasma
- The counter-propagating plasma plumes compress the background plasma and B field, which then reconnects
- The magnetic field and plasma density were profiled by fast-proton deflectometry and 4ω angular filter refractometry

Magnetic "ribbons" with strong compressed B fields are formed





- The magnetic field is profiled with fast, laser-produced 10-MeV to 20-MeV protons
- Strong magnetic field pile-up with B_{max} ~ 30 *T* is observed
- The deflected proton pattern exhibits sharp (~50- to 100-μm) caustic boundaries

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Counter-propagating plasma plumes compress and reconnect the magnetic field

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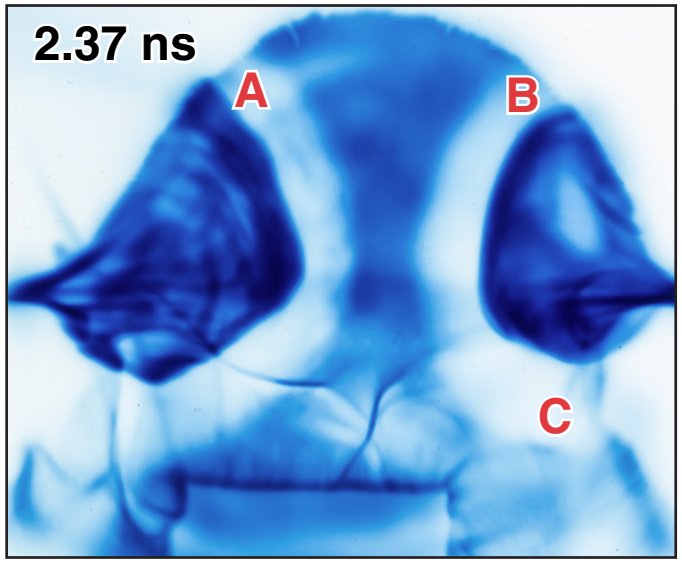
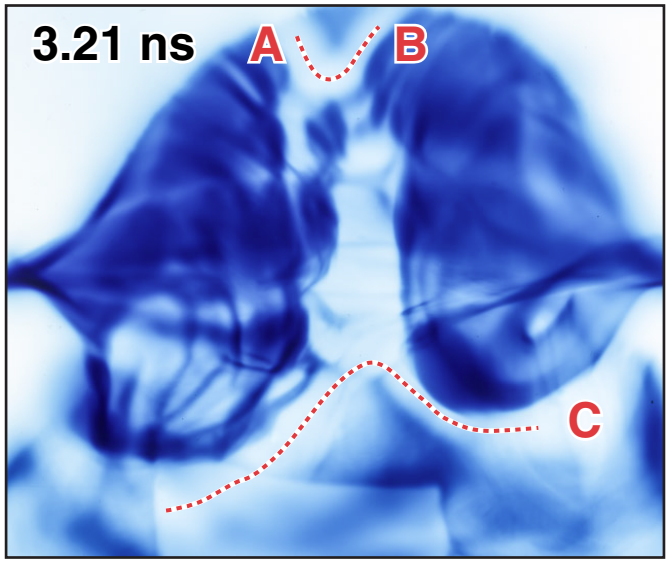
Before reconnection
- A and B are disconnected
- B and C are connected

After reconnection
- A and B are connected
- B and C are disconnected
- Outflows are formed





Changes in the magnetic-field topology indicate reconnection.

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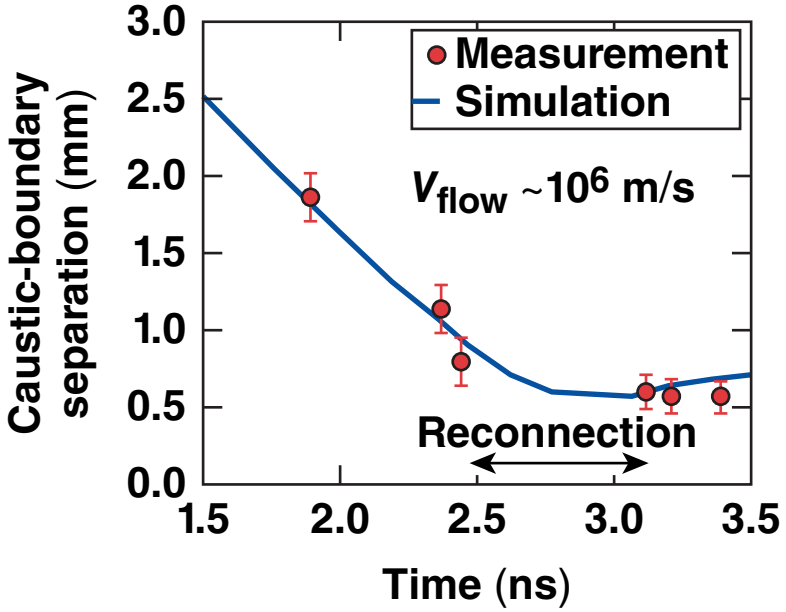
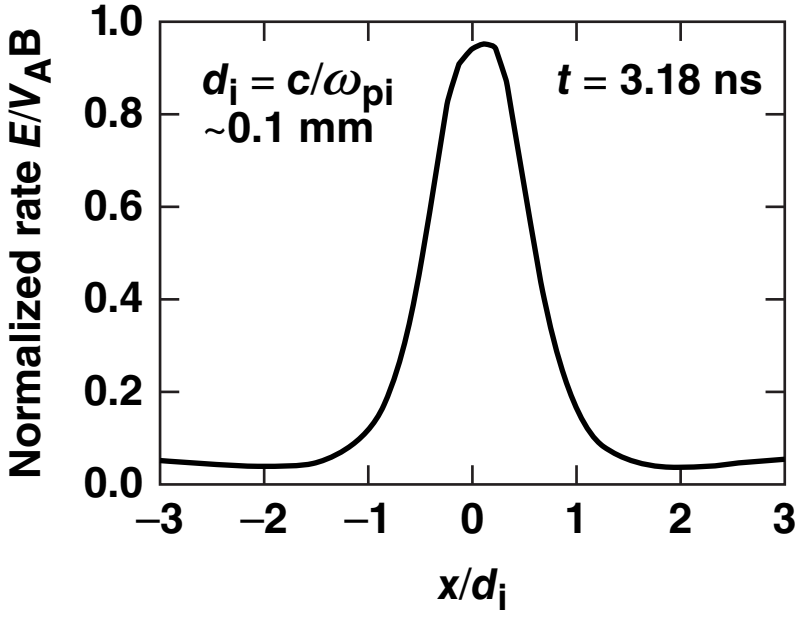
Reconnection is strongly driven and fast, with a rate comparable to the Alfvén rate

- The flow is strongly supersonic and super-Alfvénic ($V_{flow}/c_s \sim 5$, $V_{flow}/V_A \sim 5$)
- Reconnection happens within a 2.5- to 3-ns window
- The reconnection rate is comparable to the Alfvén rate





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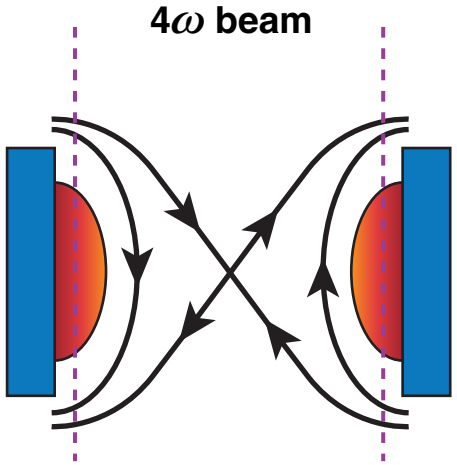
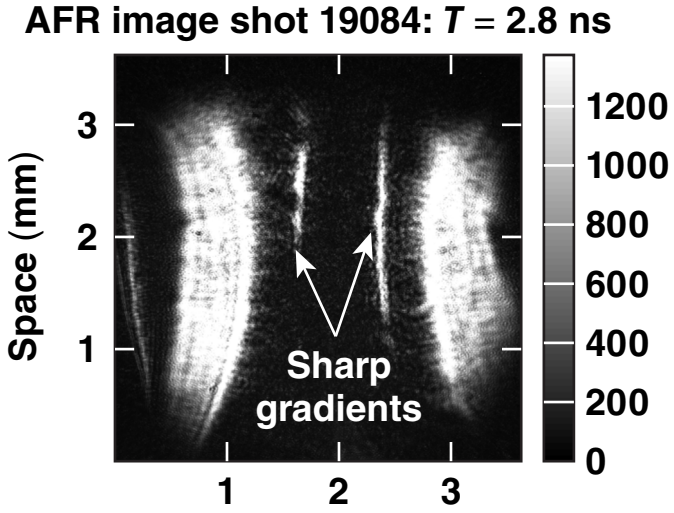
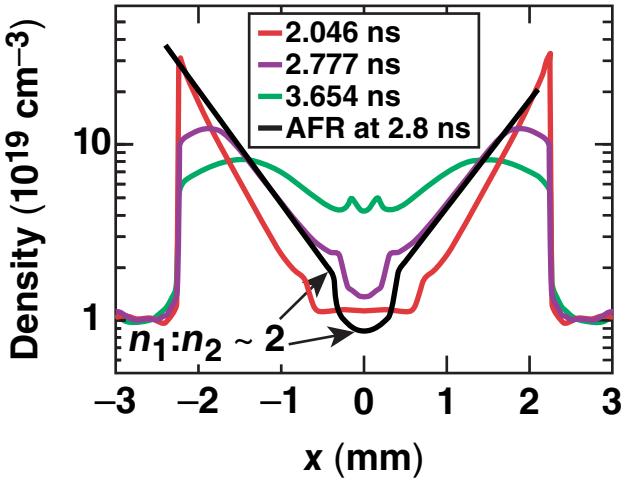
Simulated and measured density profiles may indicate a presence of collisionless shocks structures







- The plasma density profile is measured by 4ω angular filter refractometry (AFR)*
- The AFR measured density profile agrees with simulations; both exhibit similar sharp structures
- The density jump of n_1:n_2 ~ 2 and a width of 50 to 100 μm $\ll \lambda_{ii}$ ~ 100 mm may indicate a presence of collisionless shocks

*D. Haberberger *et al.*, Phys. Plasmas 21, 056304 (2014).

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Summary/Conclusions

Reconnection of an external magnetic field was observed in a high-energy-density (HED), laser-produced plasma

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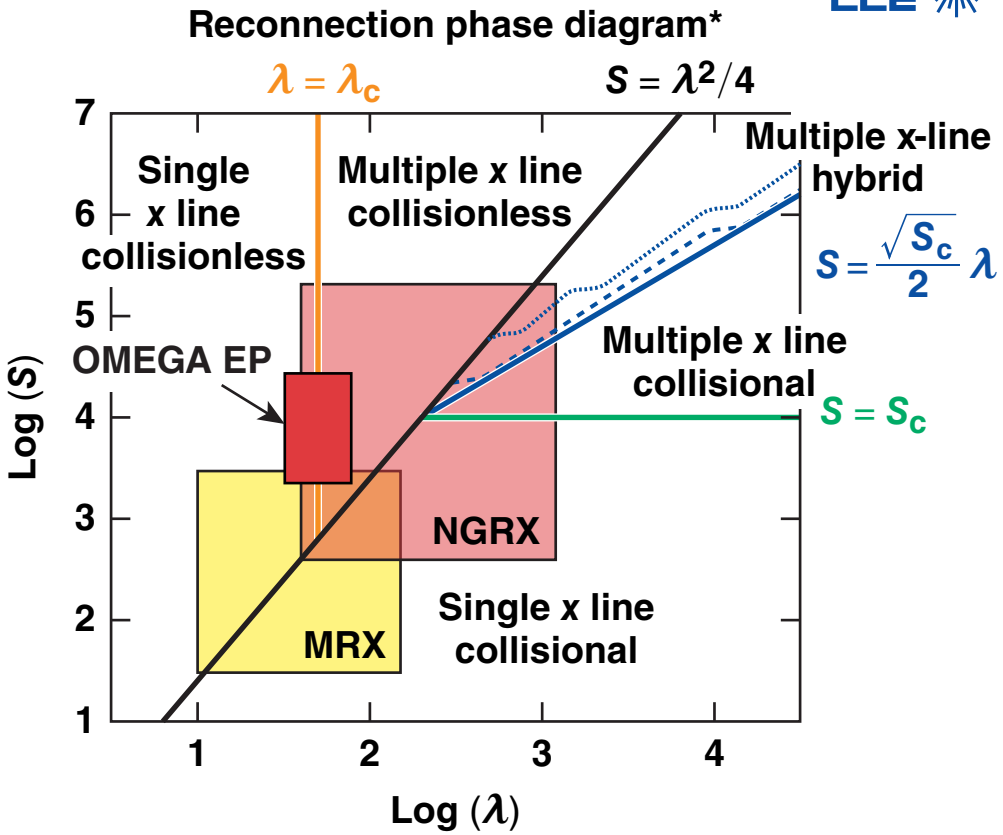
*G. Fiksel *et al.*, Phys. Rev. Lett. 113, 105003 (2014).

By varying the plasma parameters, various reconnection regimes can be studied

n_e (cm^{-3})	1×10^{19}
T_e, T_i (eV)*	500
B (T)	30
V_{flow} (m/s)	1×10^6
V_A (m/s)	2×10^5
c_s (m/s)	2×10^5
β	4
S	1×10^4
d_i (mm)	0.1
L (mm)	3
λ_{ii} (mm)	100



MRX: magnetic reconnection experiment
NGRX: next generation reconnection experiment

The experiment is well positioned to study single and multiple reconnections in collisionless and collisional regimes.

*H. Ji and W. Daughton, Phys. Plasmas 18, 111207 (2011).

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