Multi-messenger diagnosis of sub-kilotesla laser-driven EM fields

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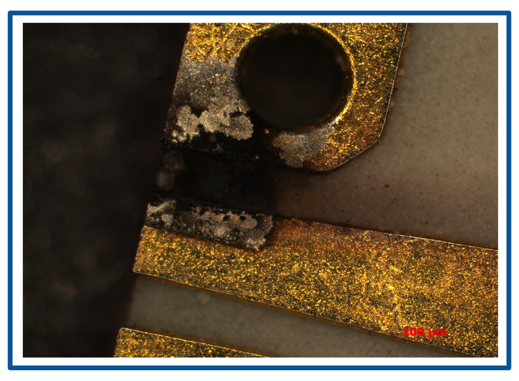

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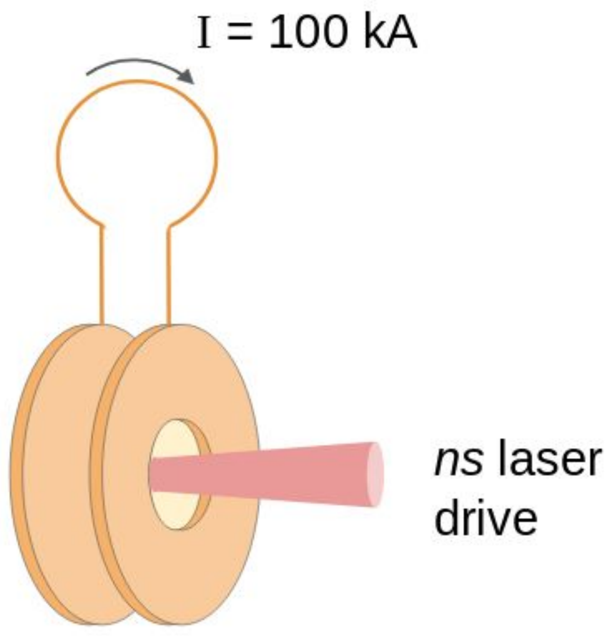
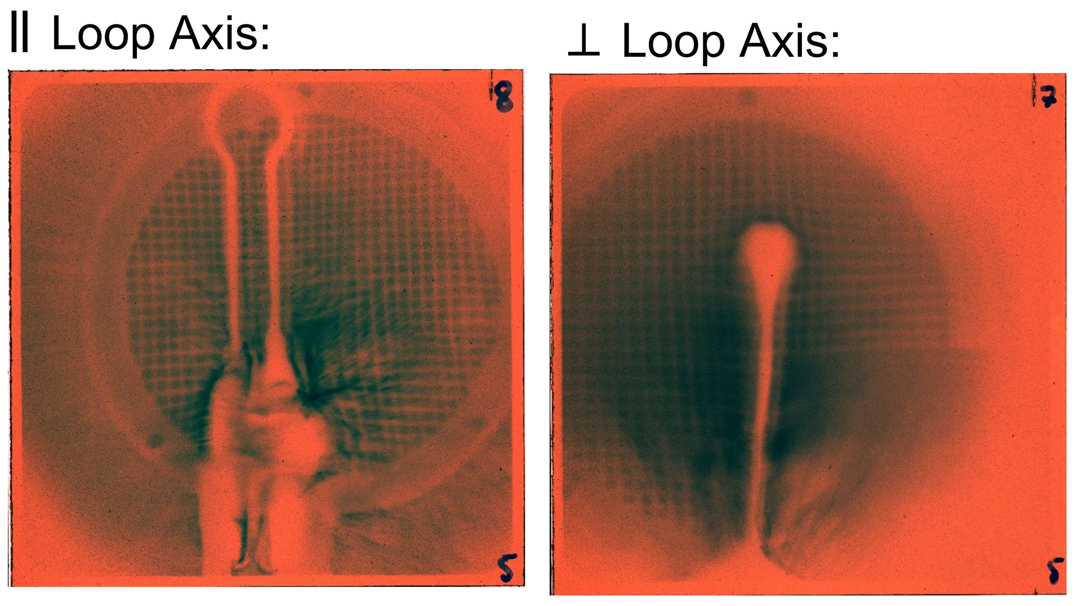
Intense quasi-static B-fields exceeding 400 T have been generated in mm^3 volumes using laser-driven diodes. Measurements from B-dot probes, proton radiography, miniature Rogowski coils and a voltage stripline assembly were combined to map the EM field evolution in unprecedented detail.

Capacitor coil concept

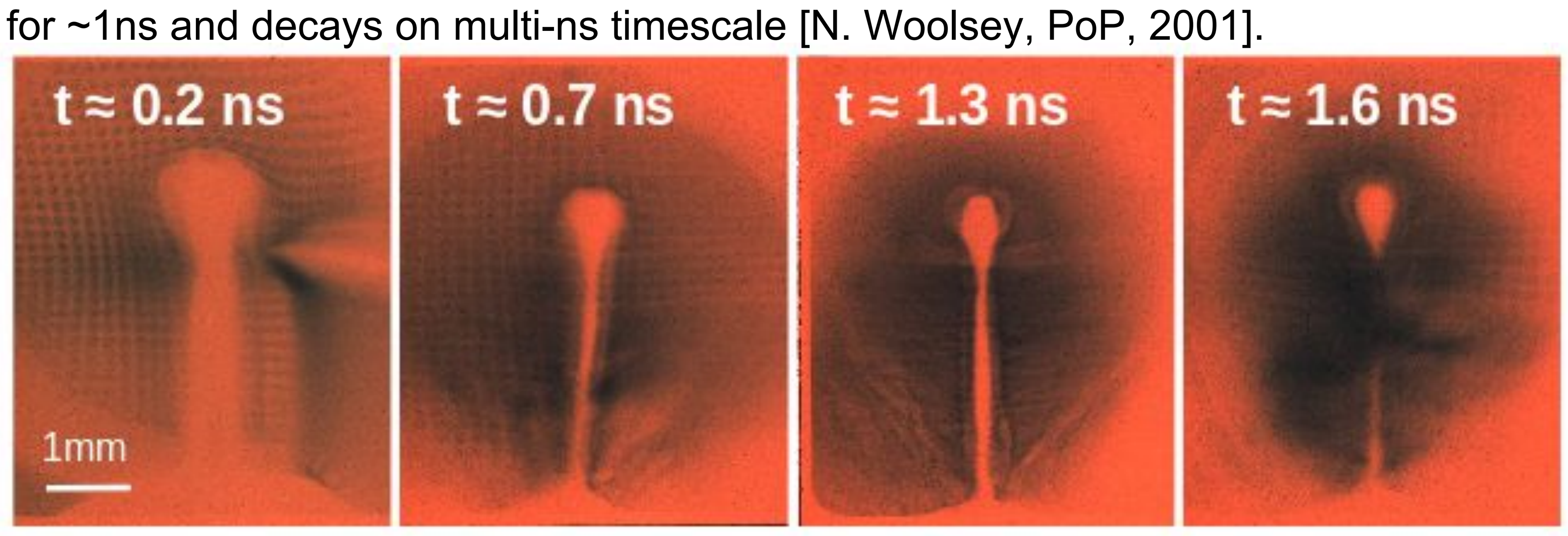
- ○ Laser establishes inter-plate voltage that discharges through a wire loop and generates a B-field.
- ○ The current source operates like a plasma diode and is limited by the hot electron temperature and diode impedance [V. Tikhonchuk, PRE, 2017].





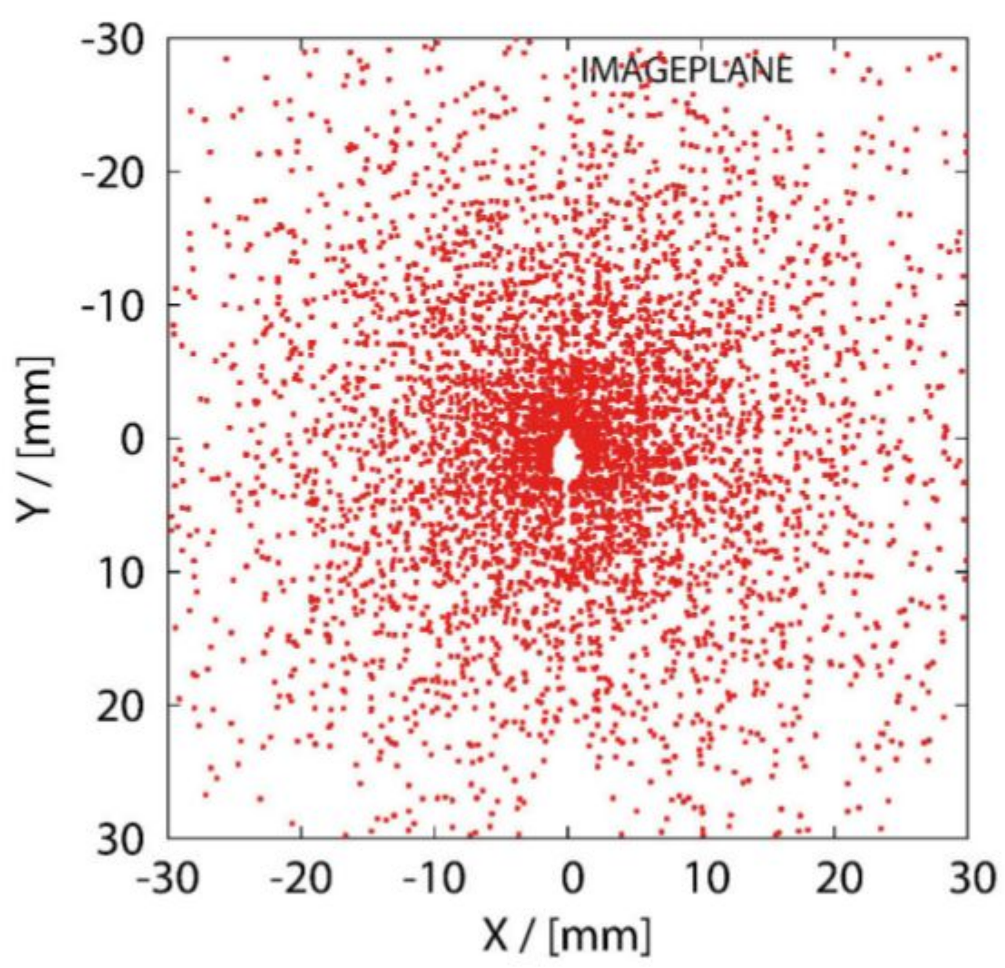
ABOVE : Orthogonal proton probing allows us to differentiate between E and B-fields.

BELOW : B-field rises to a peak over 1ns laser drive (B > 100 T), then remains static for ~1ns and decays on multi-ns timescale [N. Woolsey, PoP, 2001].



3D Biot-Savart Solver and Particle Pusher (PAFIN)

A proton radiographic code - PAFIN - is being developed to diagnose field geometry and magnitude [M. Ehret, MSc thesis, 2015]. PAFIN automatically generates a meshed EM field that particles travel through in leapfrog or RK4 schemes.

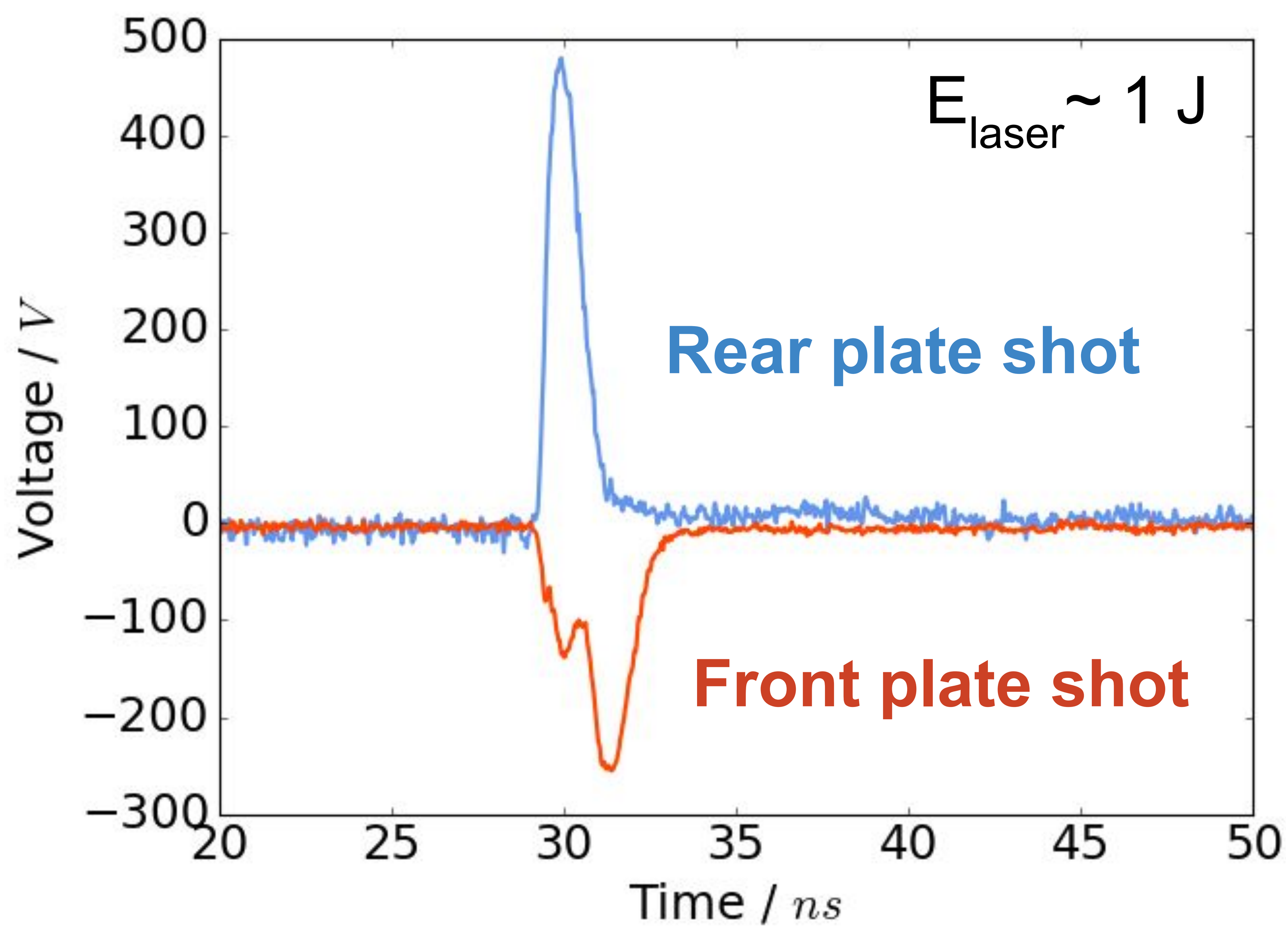


Static field solution for 10 MeV protons passing across a loop with a 10kA current for experimental configuration outlined in [J. Santos, NJoP, 2015].

B-field diagnosis using protons is **complicated** by hot electrons ejected from the laser spot. We correct for this by inserting gaussian/toroidal charge profiles into our simulations.

Voltage stripline concept

- ○ The capacitor coil plates were attached via copper rods to the top of a printed circuit board, which in turn was connected to a HV attenuator, RG402 coaxial cables and finally an oscilloscope.
- ○ For the first time, this allows us to make **direct measurements of the target voltage profile.**



RL circuit exponential decay: Two distinct decay regimes with different associated impedances.

R ~ 8 Ω ($t - t_{peak} < 1$ ns)
R ~ 1 Ω ($t - t_{peak} < 10$ ns)

Laser energy scan. Peak voltages scale with B-dot probe B-field measurements.

E_{laser}	V_{peak}	B_{peak}
100 mJ	0.1 kV	< 0.1 T
1J	0.5 kV	
100 J	4.4 kV*	
180 J	5.4 kV	~ 25 T

*neglecting 3.3 kΩ resistor

Summary and Outlook

- ○ We have achieved robust, **multi-messenger** B-field diagnosis using inductive probes, a voltage stripline and proton radiography.
- ○ Theoretical models of laser diode operation are constrained by the target voltage profile.
- ○ 3D simulations are improving our knowledge of particle and field dynamics.