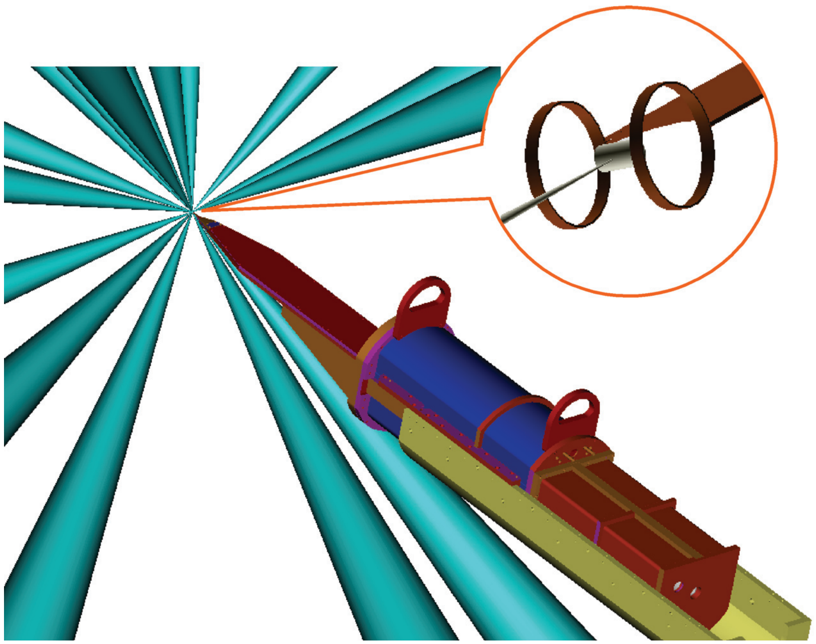
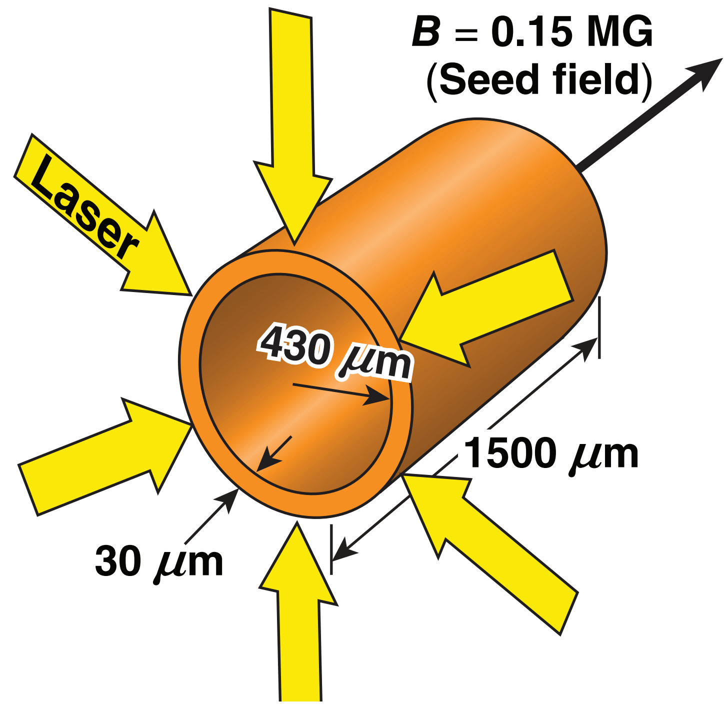
A Compact, TIM-Based, Pulsed-Power System for Magnetized Target Experiments on OMEGA





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Summary

A compact, self-contained magnetic-field generator was built for magneto-inertial fusion experiments on OMEGA

- The system (MIFEDS)[1] seeds a fast (~400 ns), 0.1 to 0.15 MG magnetic pulse in a cylindrical target via a double coil.
- The magnetized target is imploded by OMEGA to compress the internal magnetic flux to high values.
- The discharge does not affect the target position before the OMEGA shot.
- The upcoming experiments (November 2006) will use proton radiography to detect the compressed magnetic fields.

E15140

[1]MIFEDS—Magneto-Inertial Fusion Electrical Discharge System for OMEGA

Collaborators

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Motivation

Seeding macroscopic homogeneous *B*-fields in ICF implosions can enable many MIF experiments

- The compression of the seeded magnetic field to tens of megagauss:[1]
  - inhibits the electron thermal transport out of the ICF hot spot
  - can pinch the relativistic electrons generated by the ignition pulse in fast-ignition implosions.
  - provides conditions for laboratory astrophysics experiments
- Can test experimentally how magnetic fields in the corona may be affecting the inhibition of thermal flux in the conduction zone.

[1]Compressed fields of >10 MG simulated with *LILAC-MHD*, starting from 0.1-MG seed field (see N. W. Jang, JO2.00012).

Requirements

A static homogenous field is required throughout the target volume

- The small interaction volume at TCC requires low-mass, single-turn coils (low-inductance system).
- The current rise must be fast in order to minimize the action integral that determines the lifetime of the small coil (due to Joule heating).
  - seeking min $\left[\int i^2(t)\,dt\right]$, where i^2_{max} is fixed by design
- High voltages are needed to maximize energy ($E_{stored} = CV^2/2$) density.
- The energy must be delivered via a low-impedance transmission line through a fast switch.

A TIM[1]-based, fast pulser delivers energy efficiently, while reducing the transmission distance and EMI issues

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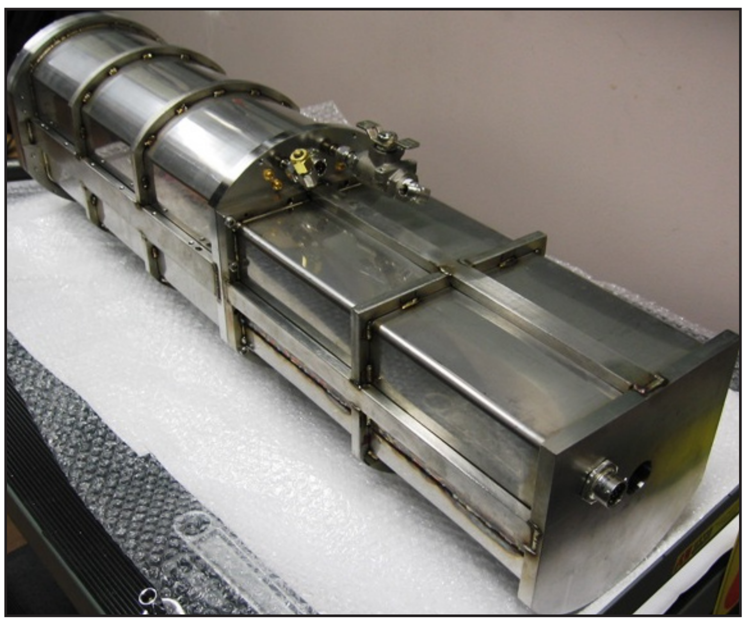
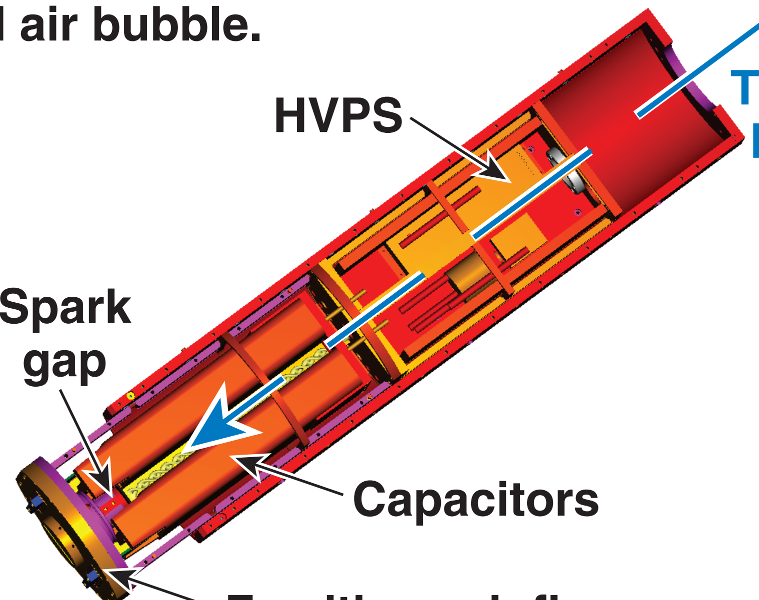
- It is a fast (150-ns-pulse rise time) capacitive discharge system that can safely store up to 130 J of energy (at 36 kV).
- A laser-triggered spark gap couples the energy into a low-inductance coil via a low-impedance transmission line.
- The device is housed in a shielded air bubble.





[1] TIM—ten-inch manipulator; a versatile diagnostic insertion port on the OMEGA target chamber.

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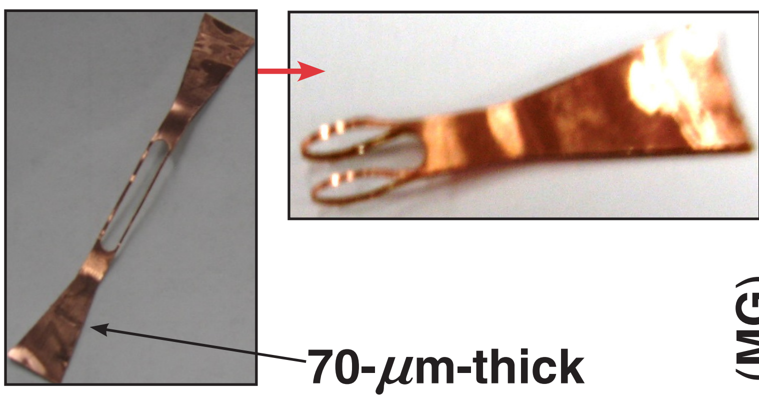
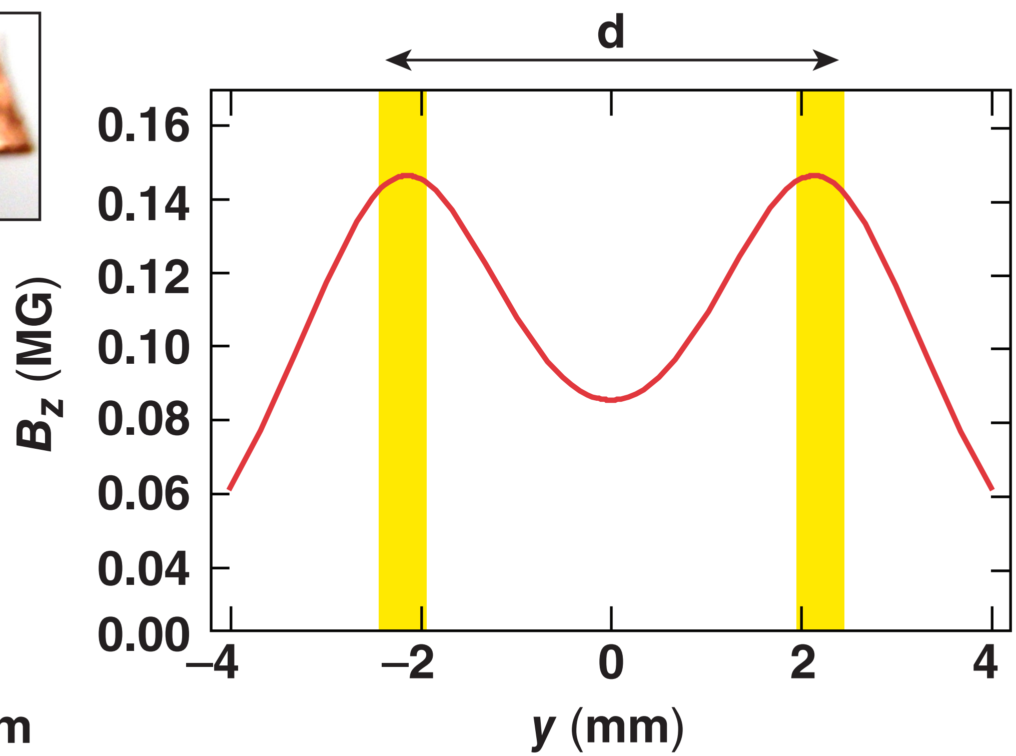
The magnetic field is generated in a double-coil configuration suitable for OMEGA implosions

- Coil separation was chosen for optimum beam illumination and to avoid possible mechanical or electrical contact with the target.

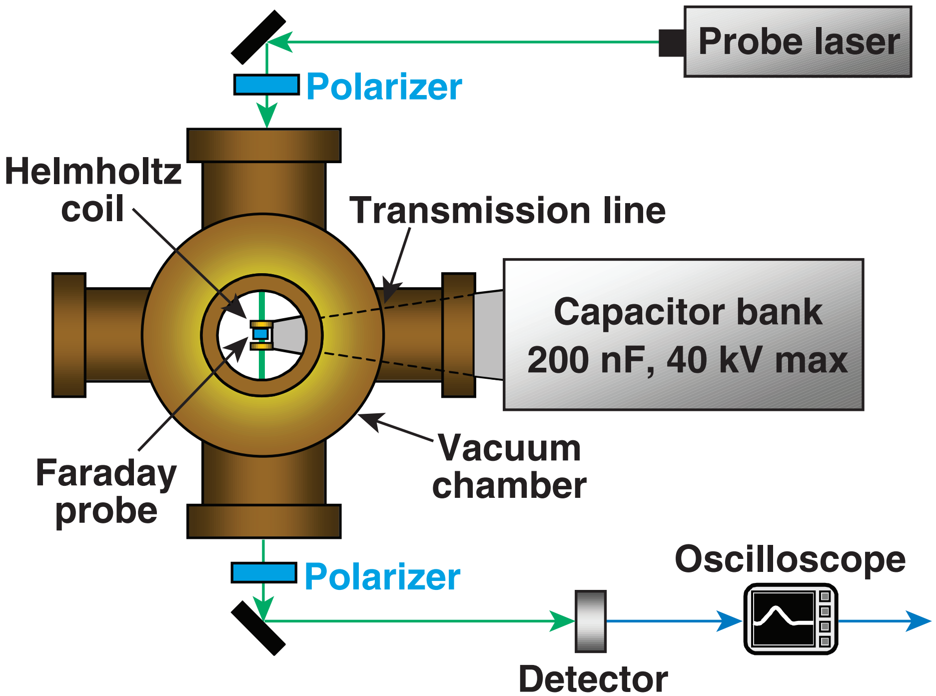




- The coil parameters are:
  - coil separation d = 4.4 mm
  - radius R = 2 mm

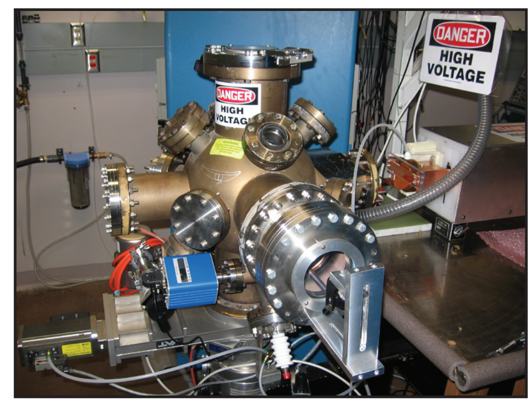
[1] O. Chubar, P. Elleaume, and J. Chavanne, J. Synchrotron Radiat. 5, 481 (1998).

A seed magnetic field of 0.1 to 0.15 MG was generated with the prototype system charged to 25 to 30 kV

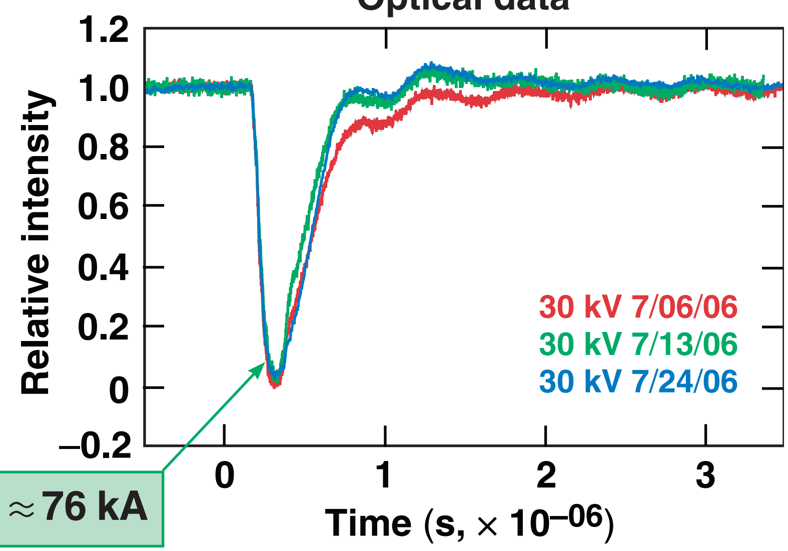


$$I_{DET}(t) = I_0 \cos^2[\theta_{rot}(t)]$$
$$\theta_{rot}(t) = V\overline{B}_z(t)d_z$$
$$d_z = 1\text{ mm}, V = 100\text{ rad/MGcm}$$

Benchtop prototype



Optical data



$\overline{B}_{z_{max}} \approx 0.15$ MG, $i_{max} \approx 76$ kA

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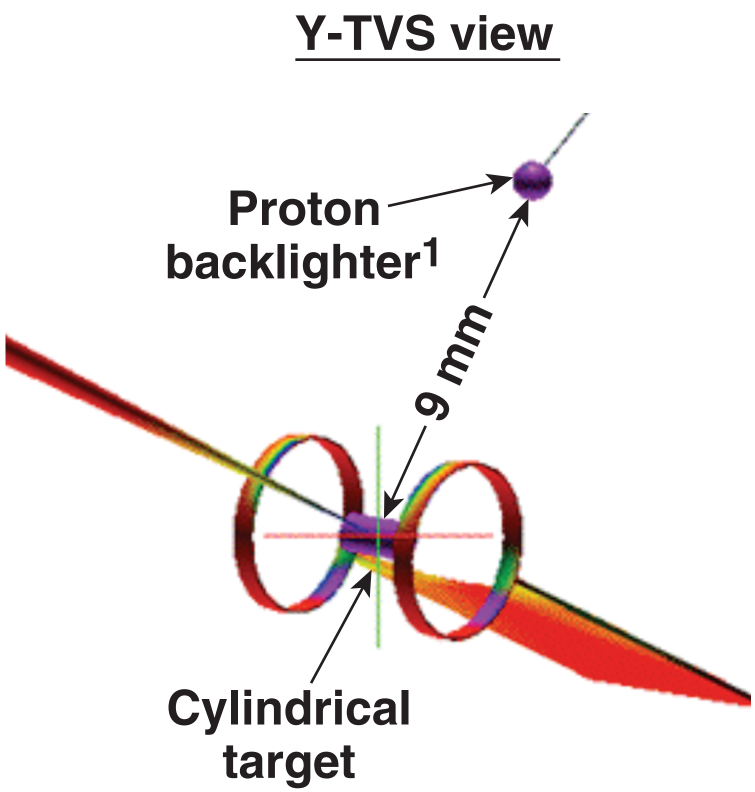
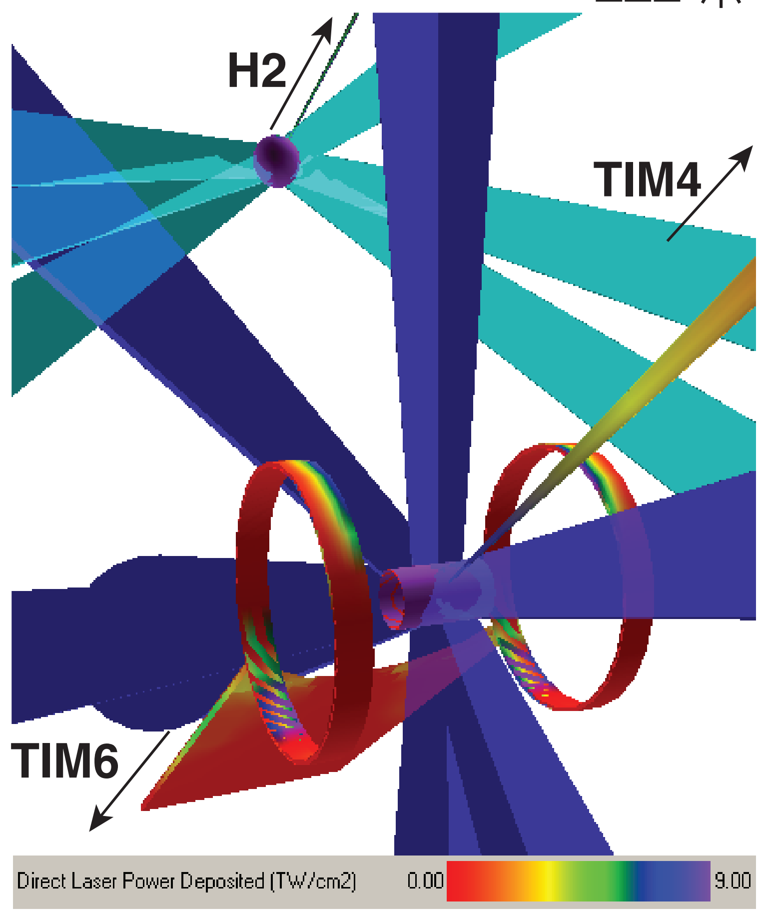
The target is compressed by 40 OMEGA beams while 20 are used for proton radiography





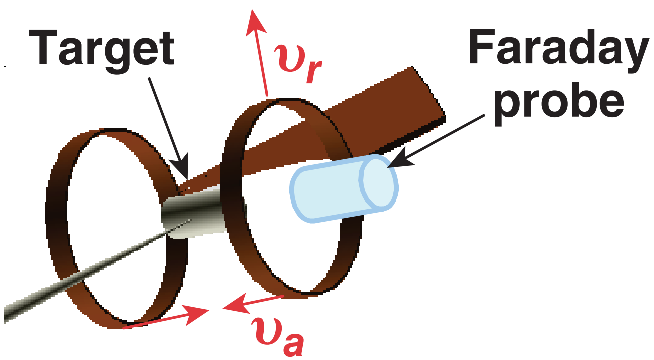
Only about 1% of the directly deposited laser energy is intercepted by the coils.

E15146

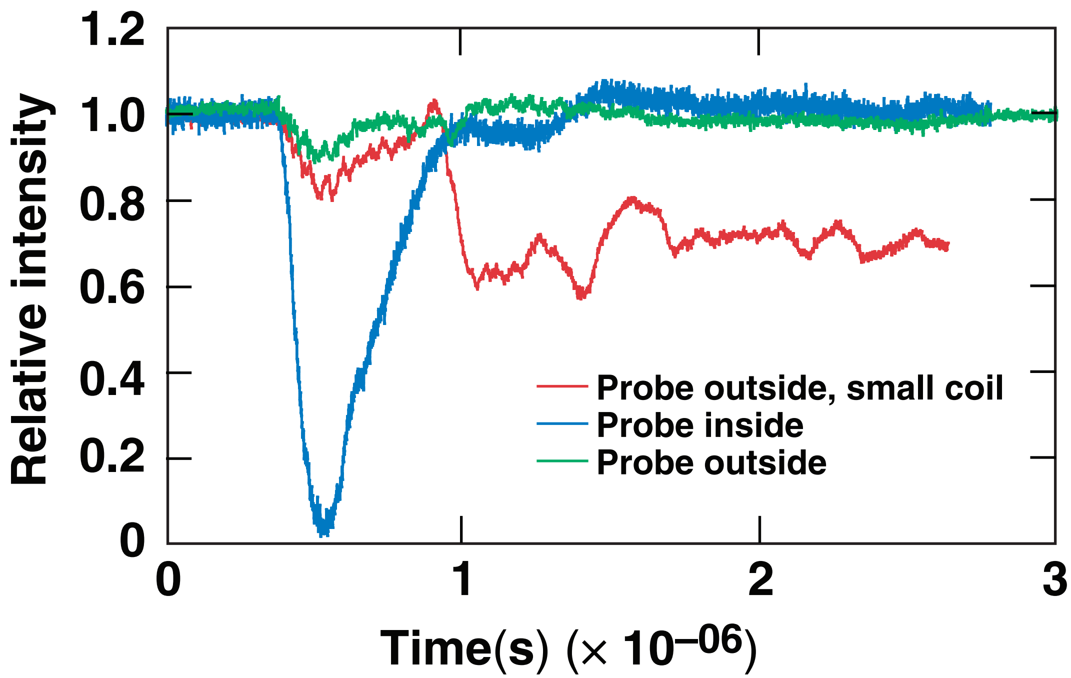
[1]C. K. Li *et al.*, Phys. Rev. Lett. 97, 135003 (2006).

On the timescale of the magnetic pulse (~400 ns) the target remains unaffected by the coil discharge

- A cylindrical shell was placed between the coils to check target survivability after discharge (but before the laser shot).



- Axial compression
  - $\upsilon_{a\ max} = 67\ \mu m/ms$
- Radial expansion
  - $\upsilon_{r\ max} = 68\ \mu m/ms$



The magnetic impulse reaction time of the coils is much longer than the pulse rise time.

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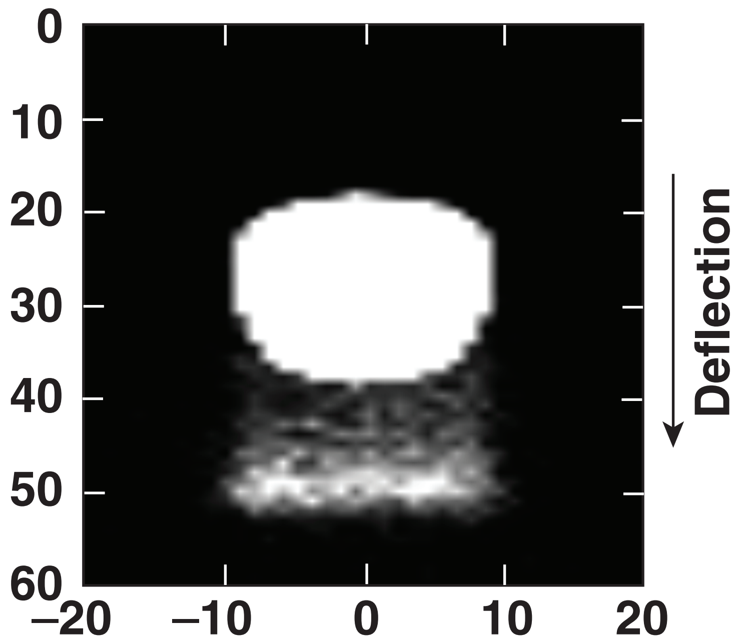
Proton radiography is used as the primary diagnostic in the flux compression experiments



Geant4 simulation of the proton deflection by a 30-MG compressed flux (20 μm × 1.3 mm).

- Proton source is a Gaussian with FWHM = 45 μm (yield ~5 × 10^8 *p*).[1]
- Distance to the CR-39 detector is ~30 cm.
- Approximately 1.5 × 10^7 protons are deflected by either the background (seed) field or the compressed shell.
- Approximately 2 × 10^5 protons are deflected by the 20-μm-wide compressed cylindrical core.

E15148

[1] C. K. Li *et al*., Phys. Rev. Lett. 97, 135003 (2006).

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