



Department of Physics
College of Science
University of Nevada, Reno

Zebra Pulsed Power Laboratory at UNR

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Content

1. Zebra generator and Leopard laser
2. Diagnostics
3. Experiments



Zebra and Leopard



Zebra pulsed power generator



Load current 1 MA, up to 1.6 MA with LCM

Current rise time 90 ns (10-90%)

Long current pulse: 0.6 MA / 250 ns

Impedance 1.9Ω

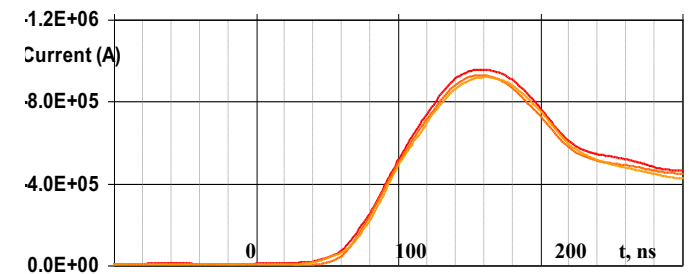
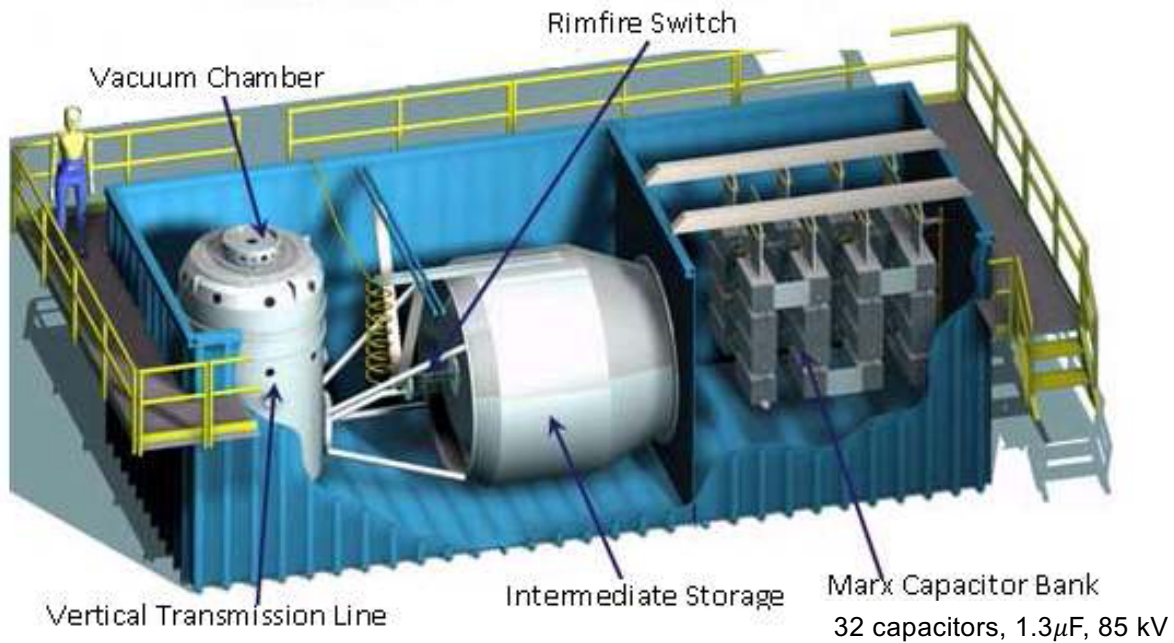
Storage energy 150kJ

>20kJ of x-ray energy from wire arrays,
 $\eta \sim 15\%$, acceleration of fliers,
magnetic fields of 100 - 300 T

B. Bauer et al, 12th IEEE International Pulsed Power Conference (1999)

A. Chuvatin et al., Phys. Rev. Spec. Top.- Accel. Beams **13**, 010401 (2010)

Zebra pulsed power generator

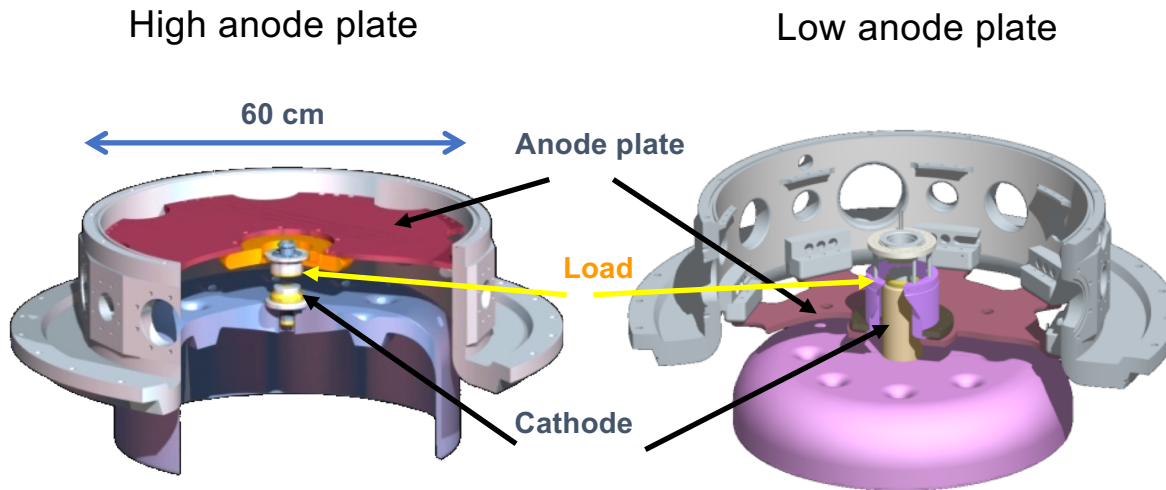


Zebra current pulse (3 Bdots on the anode plate, 2 stack Bdots)

Zebra team: A. L. Astanovitskiy
O. Dmitriev
Students

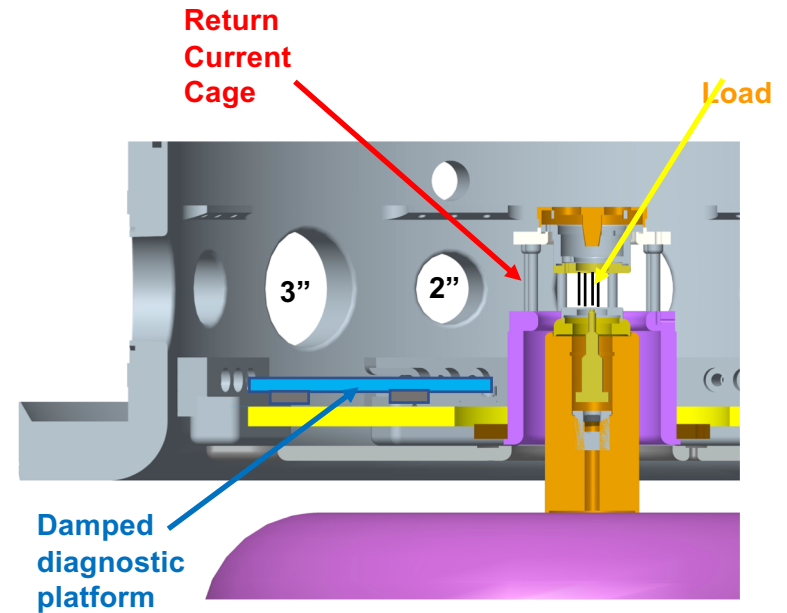


Zebra vacuum chamber



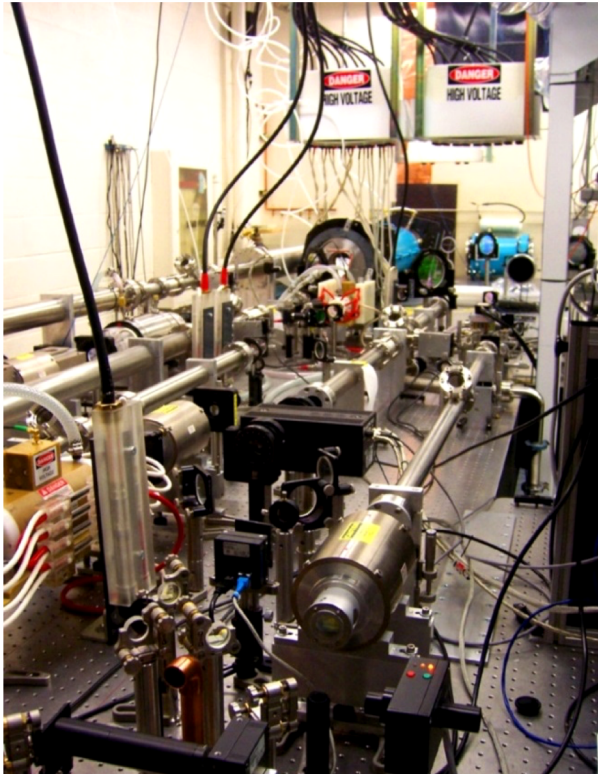
Diagnostics can be installed in the chamber:

After shot shock >200g
e/m pulse
Plasma debris



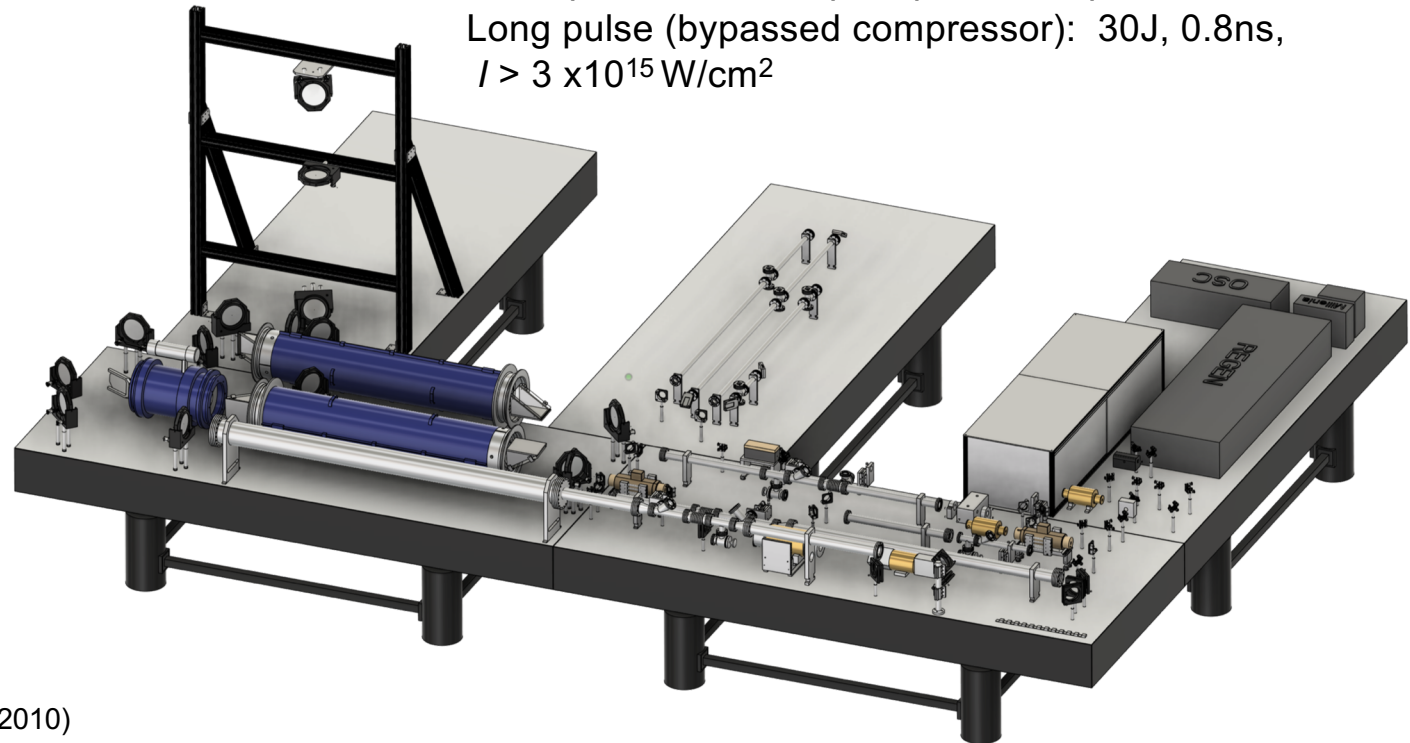
Eight 2" windows
Seven 3" windows
One 4" window for the laser

A 50-TW Leopard laser is coupled with the Zebra generator

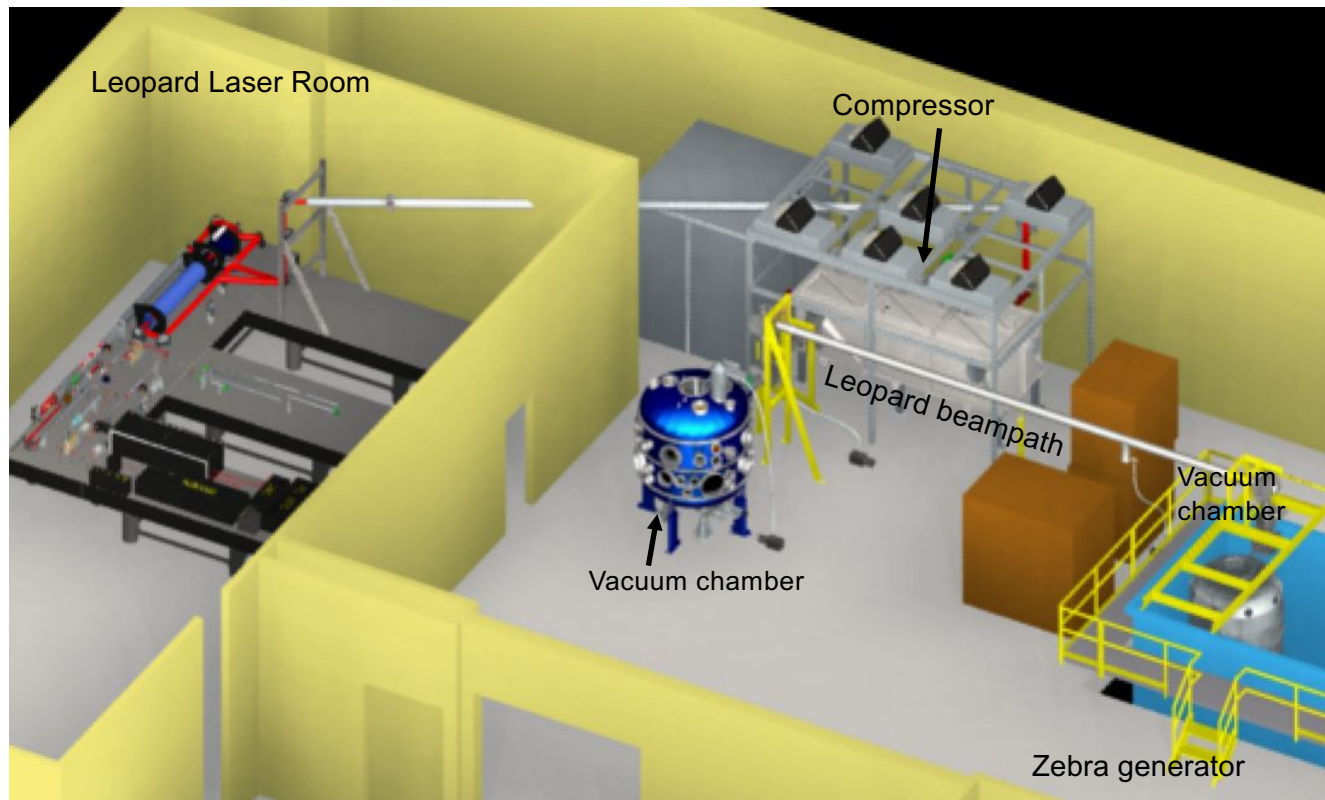


Tsunami master oscillator, 80fs, 80MHz, 300mW;
 Ti:Sa regenerative amplifier, 3nJ -> 1mJ
 Rod amplifiers with mixed Nd glasses, 8J, 1055nm
 2 disk amplifiers 94mm

Short pulse: 15J, 0.35ps, 9 μ m focal spot. $I > 10^{19}$ W/cm²
 Long pulse (bypassed compressor): 30J, 0.8ns,
 $I > 3 \times 10^{15}$ W/cm²



Location of the Leopard laser in the Zebra bay



A Leopard laser beam is relayed from the last disc amplifier on the grating of the compressor.

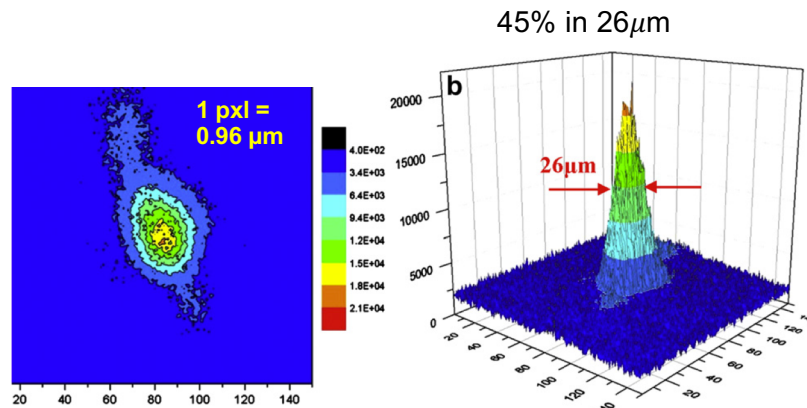
After the compressor, the beam propagates to the Zebra chamber or to the vacuum chamber for laser-only experiments



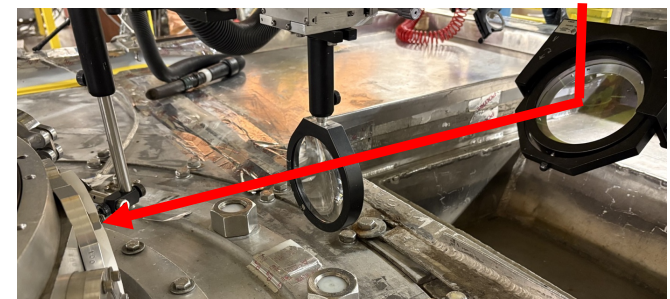
Focusing of the Leopard laser beam

Long pulse

30J, 0.8ns

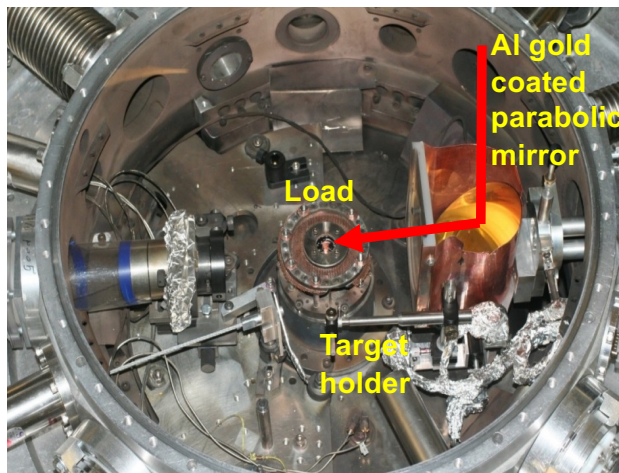


A laser beam can be delivered from the side window or from the top window

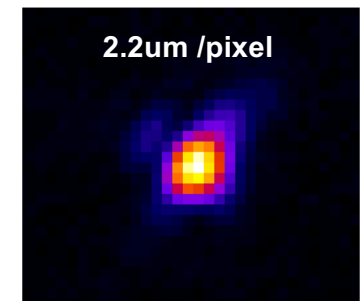
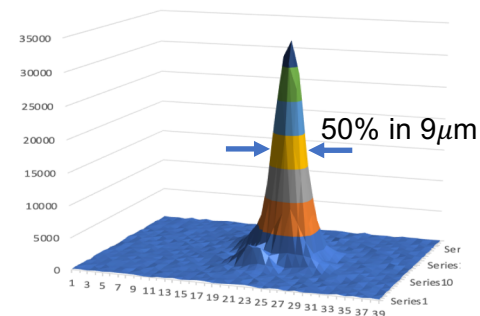


Short pulse

15J, 0.35ps



$I > 10^{19} \text{ W/cm}^2$

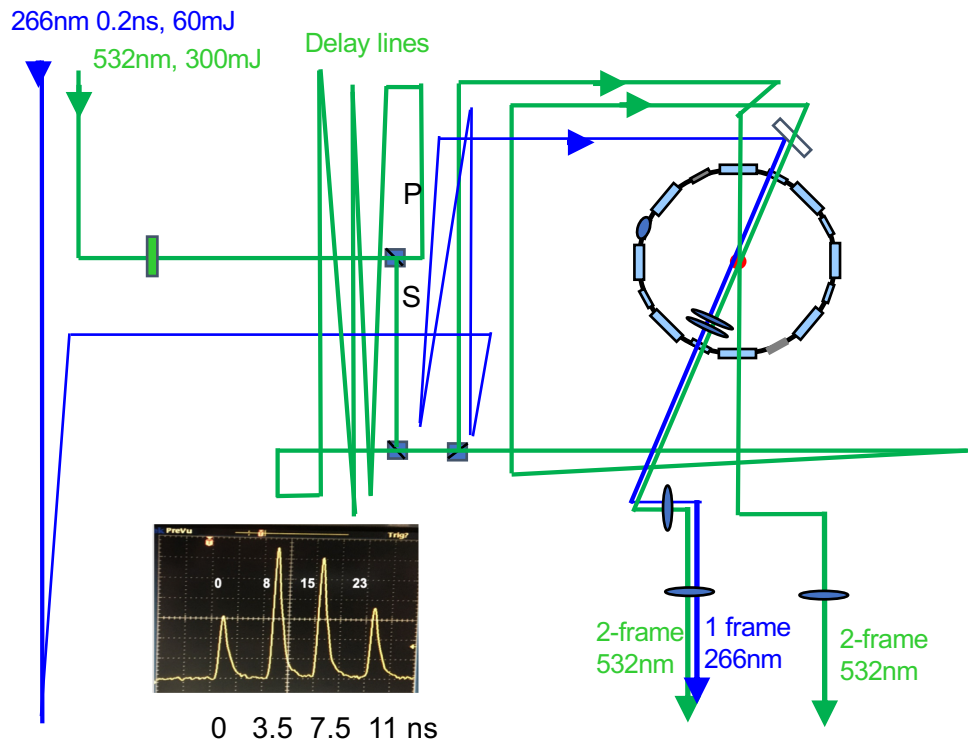




Diagnostics

Laser diagnostics

4-frame side on shadowgraphy at 532nm, schlieren, Mach-Zehnder interferometry +1 frame at 266nm.
Sharing air-wedge interferometers for denser plasmas.



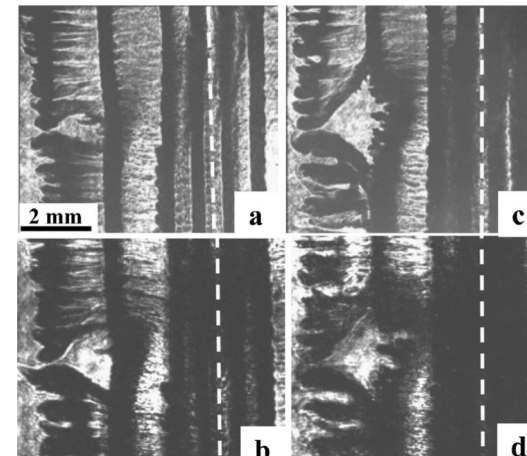
Other options (not core diagnostics but parts are available):

Vertical probing at 266 and 532nm

1064nm probing

Faraday rotation diagnostics at 532nm; at 266nm

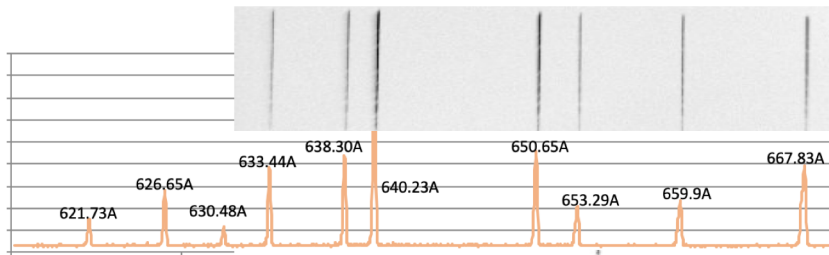
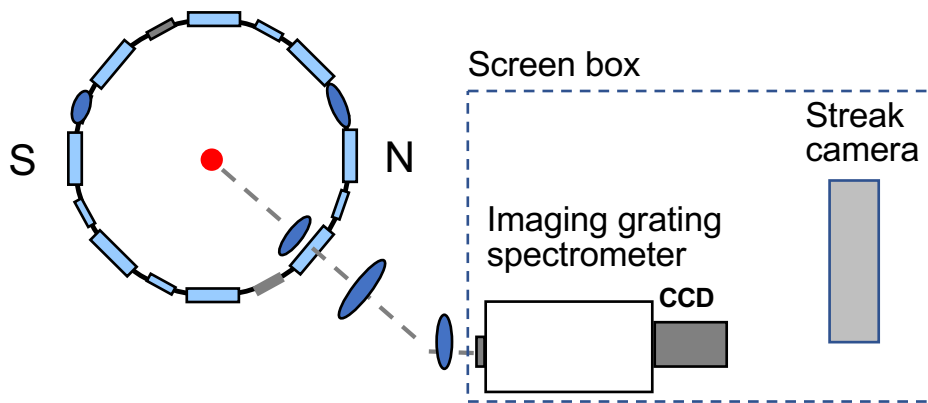
CW lasers are available at 1064, 532 and 405nm



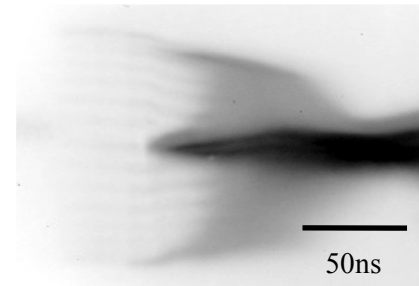


Optical diagnostics

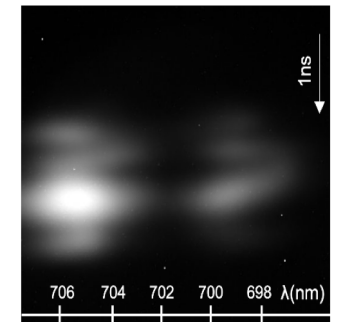
Optical spectroscopy



Optical streak camera (same beampath)



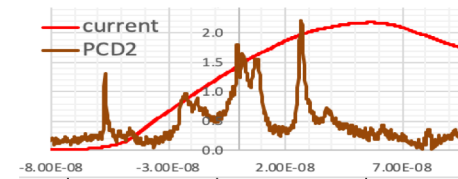
Cylindrical wire array



Two-plasmon decay

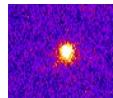
Fast photodiodes 25ps -1ns, avalanche detectors, oscilloscopes 3GHz and 6GHz

Filtered photoconductive diamond diodes with $<1\text{ns}$ resolution

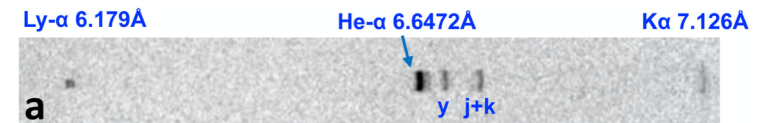


Bolometers for energy of 1-25kJ

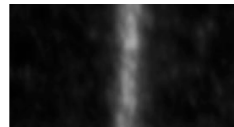
Pinhole cameras



X-ray spectrometers. Bent crystals are delivered by users



X-ray imaging crystals



MCPs (not mounted)



Experiments



Experiments

Zebra experiments:

Z-pinch and X-pinch physics

Gas puffs

X-ray spectroscopy of plasmas

Photoionized plasma

Fliers and shocks

Quadratic Zeeman effect

Zebra/Leopard experiments:

Laser plasma interaction in strong magnetic fields

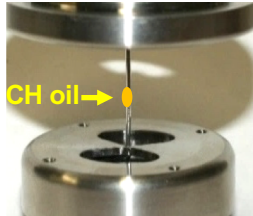
Shock waves in MG magnetic fields

Hard x-ray radiography

Generation of neutrons

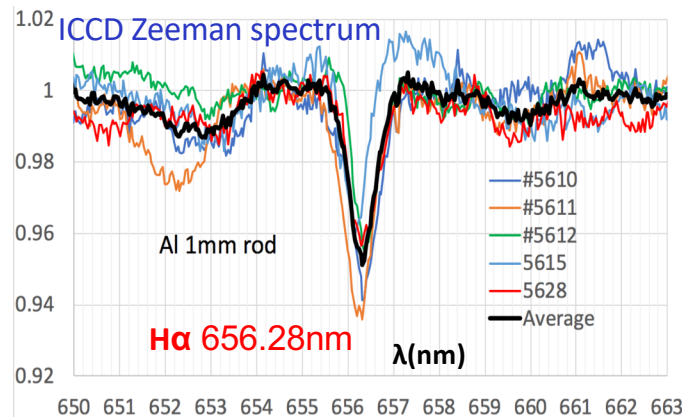
The quadratic Zeeman effect

Rod loads generate 2-3 MG fields on the surface.
Oil is a source of hydrogen

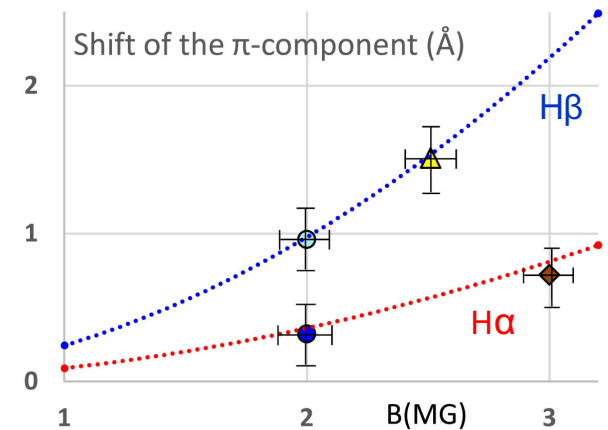


The quadratic Zeeman effect was observed in spectra of white dwarfs in 1-300 MG fields

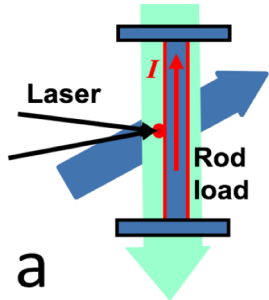
A shift of spectral wings indicates a 2MG field



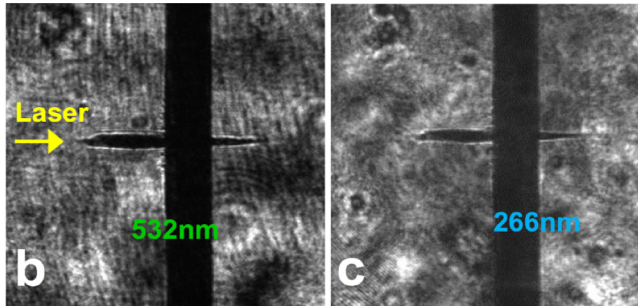
A central π - component is shifted due to the quadratic Zeeman effect



Laser plasma interaction in strong magnetic fields



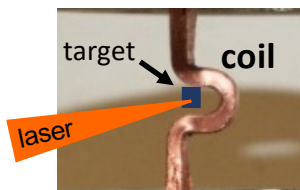
15J, 0.8ns
Azimuthal B



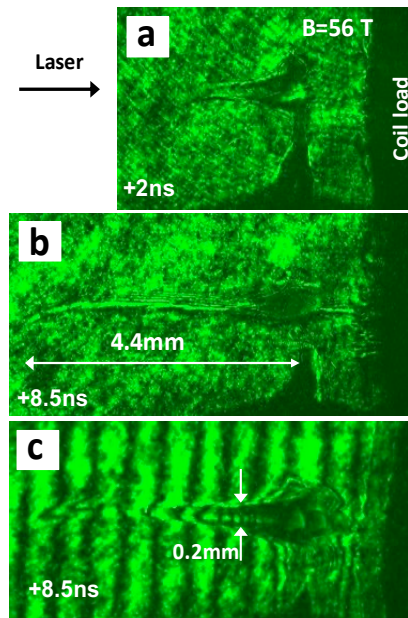
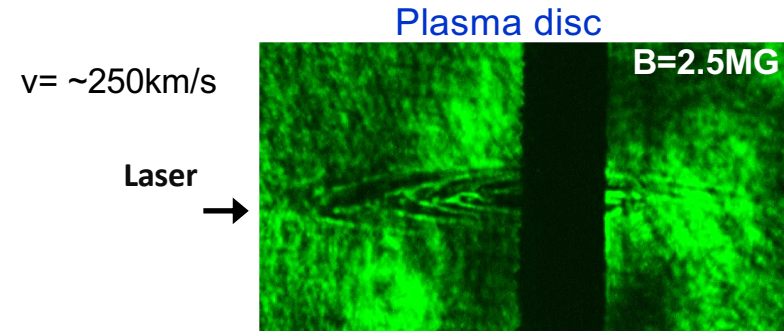
L. S. Leal et al, Phys. Rev. E 109, 015207 (2024)



Axial B



Si 10μm targets, $I > 7 \times 10^{18} \text{ W/cm}^2$



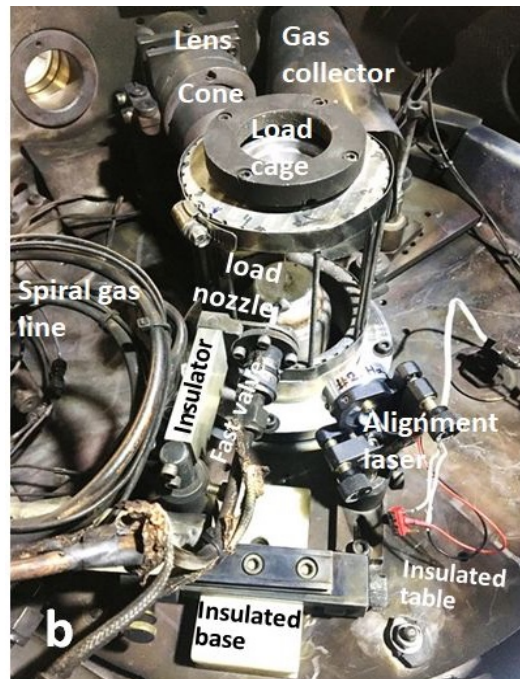
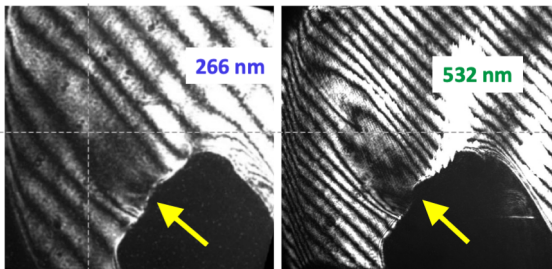
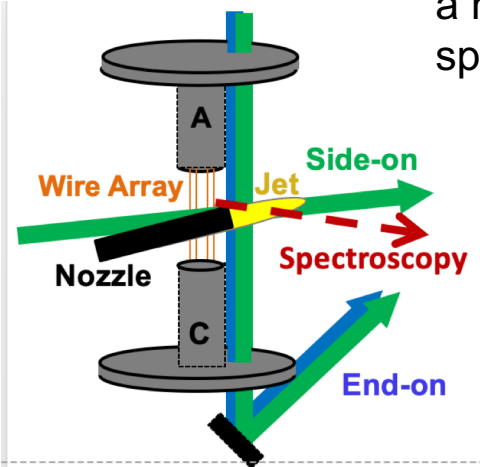
Collimation of the laser plume in the B-field

V. Ivanov et al, PoP 26, 062707, 2019

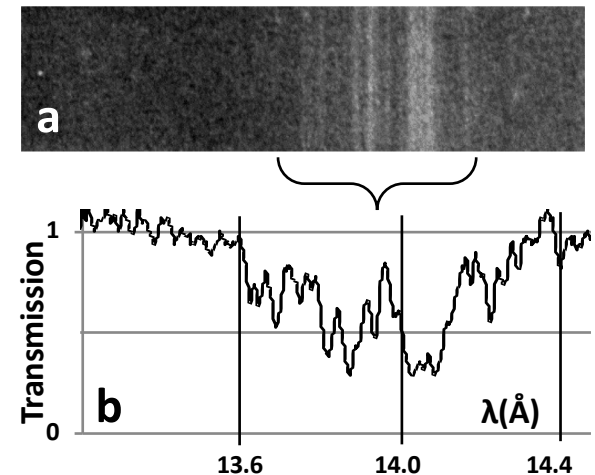


Photoionization and absorption spectroscopy of the Ne gas jet

12kJ x-ray emitted by wire array photoionized a neon jet and was a source for absorption spectroscopy.



KAP cylindrically bent crystal

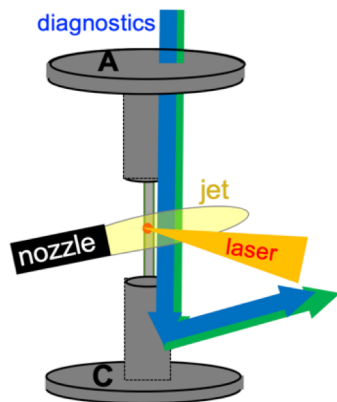


K. J. Swanson et al, APS-DPP (2021)

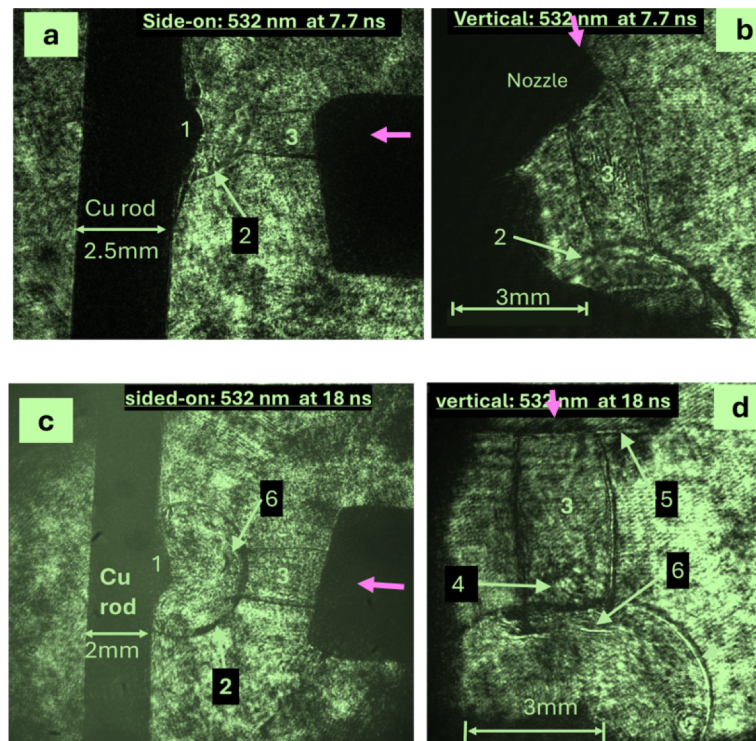


Shock waves in a gas jet in the MG magnetic field

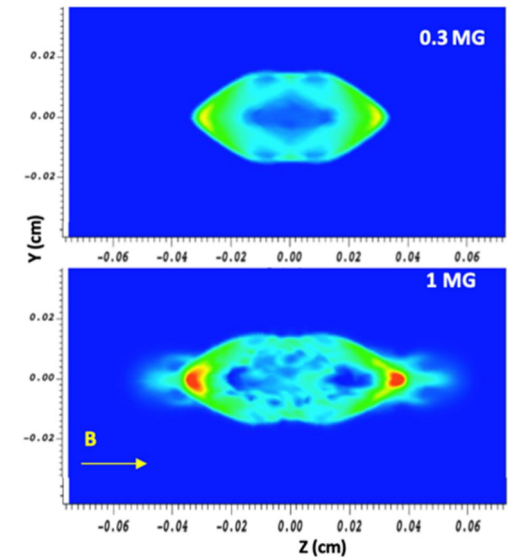
Shock in a hydrogen gas jet



A shock wave velocity is
>1500 km/s



Simulations of L. Leal



Z. J. Minaker et al, PoP 33, 072304 (2026)



ZNetUS experimental campaigns

2025

1. Jonathan Davies (University of Rochester), “Studying Magnetized Shock Physics with Inverse Wire Arrays on Zebra”. Zebra, inverse wire arrays - Leopard, proton radiography.
2. Simon Bott-Suzuki (UCSD), Francisco Suzuki-Vidal (First Light), “Probing the conditions of electromagnetically driven flyer plates on Zebra with X-ray diagnostics”. Zebra, fliers – Leopard, x-ray radiography, short pulse.
3. Petros Tzeferacos (UR), Farhad Beg (UCSD), “ZEBRA Experiments to Study the Stability of Liner-on-target Gas-puff Z-pinches and Validate the FLASH Code”. Zebra – gas puffs.
4. Philip Efthimion, Frances Kraus (Princeton University), “Imaging of Ti X-Pinch Plasmas with High-Resolution X-ray Crystal Spectrometers”. Zebra X-pinches.
5. Maria Pia Valdivia Leiva (UCSD), “Experimental and simulation studies of MagLIF and laboratory astrophysics dynamics through high-resolution phase-contrast diagnostics”, Zebra X-pinches.

2026

1. Hiroshi Sawada (UNR), “Dual-Spectral Broadband X-ray Radiography for Magnetically Driven High-Density Plasma Diagnostics on ZEBRA”. Zebra, WDM – Leopard, short pulse.
2. Vladimir Ivanov (UNR), “Laser initiation of hot spots in X-pinches”. Zebra X-pinches, Leopard long pulse.
3. Arijit Bose (University of Delaware), “Magnetic Pressure–Driven Collimation and Deflection of Coronal Plasma Outflows”. Zebra, magnetic fields – Leopard, long pulse.
4. Petros Tzeferacos (UR), Farhad Beg (UCSD), “ZEBRA Experiments to Study Stability of Liner-on-Target Gas Puff Z-Pinches at Varying Liner Radii”. Zebra – gas puffs, September 2026.



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Conclusions

1. The Zebra generator produces a 1 MA current pulse (up to 1.6 MA with LCM). Zebra generates >20kJ in the x-ray range and 1 - 3MG magnetic fields.
2. A 50-TW laser is coupled with Zebra for plasma experiment and for diagnostics.
3. Core diagnostics can be supplemented by user's diagnostic.
4. The facility and diagnostics allow performing of a variety of plasma experiments

We thank ZNetUS for support