Nevada Terawatt Facility (NTF)
Physics Department
College of Science
University of Nevada, Reno

The Nevada Terawatt Facility: Training Students in the Field of High-Energy-Density Plasma Science

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UNR Physics Department
NTF Director

National Security Forum
July 18th, 2017

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Outline

1. Collaborators and clients
2. Motivations- Why pursue HED Plasma Science?
3. Census of UNR students & professors
4. What is High-Energy-Density (HED) Plasma Science?
5. Where are our students now?

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1. NTF Collaborations & Synergistic Activities

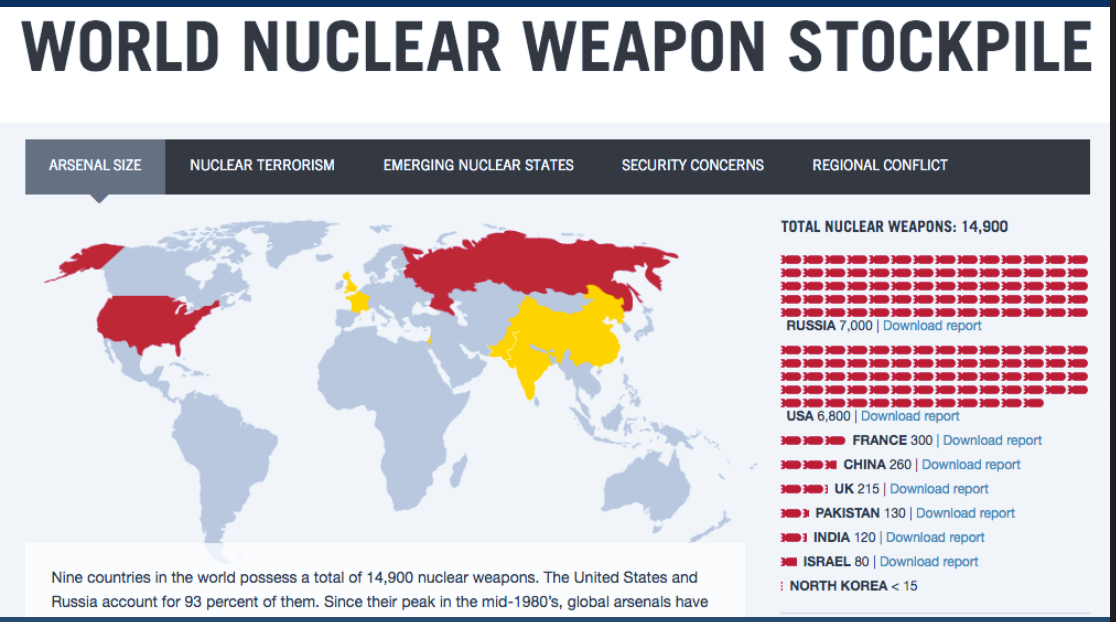
Ongoing

- Sandia – Z-pinch Physics, Zeeman Spectroscopy & Flyer Design
- UCSD – Proton Deflectometry of Z-pinched Plasmas (NSF), X-ray Thompson Scattering, Colliding Jets
- NSTec – Neutron sources, detection and modeling (MCNP), laser & spectroscopic diagnostic development, advanced targets
- LLNL & ASU – Novel X-pinch plasma Driven Shocks
- MIFTI/UCSD – Staged Z-pinch Fusion (ARPA-e)
- U Toledo- Lab Astrophysics (NSF-REU)
- LANL – Opacities, Plasma Polarization Spectroscopy, Molecules in Plasmas, etc.
- Voss Scientific- LSP modeling
- Digital Solid State Propulsions- pulsed power design

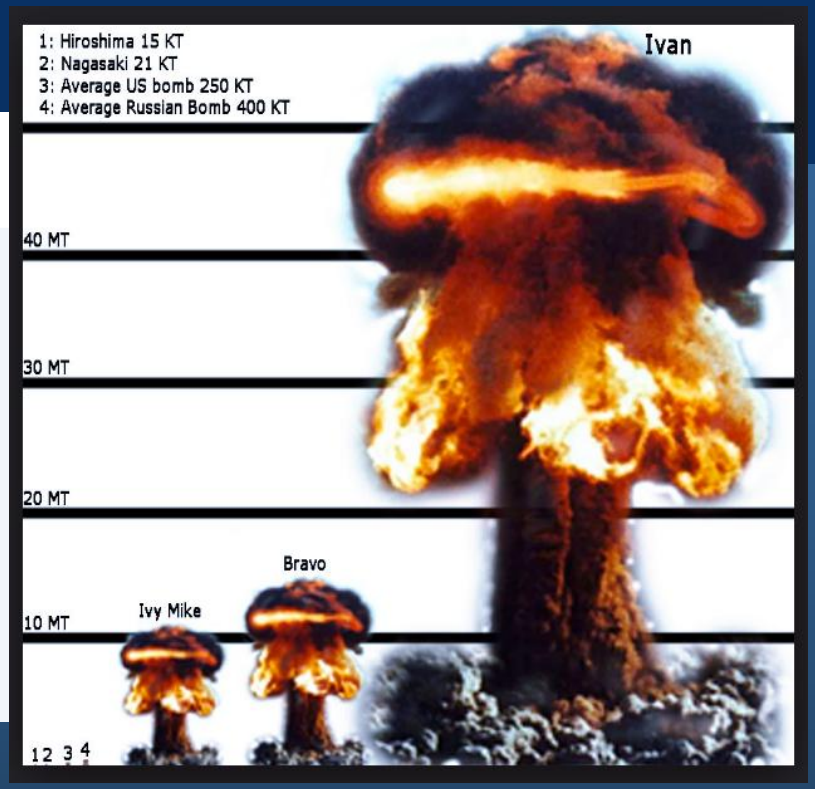
Planned/ in development

- Horiba, L3, Raytheon, Riverside, etc.

2. Motivations. Nuclear weapons are still with us…



http://www.ploughshares.org/world-nuclear-stockpile-report



2. Motivations. Stewardship of the U.S. Nuclear Weapons Stockpile. Making NTF the Test Site for the Test Site...

- National Nuclear Security Administration (NNSA) is a semi-autonomous agency within DOE that oversees the nuclear weapons complex (FY2017 budget $12.9B- the majority of the DoE budget)
- The NNSA mission in a nutshell: Maintaining a safe, secure and effective nuclear deterrent.
- The NNSA Stockpile Stewardship program was designed to to ensure reliability and maintenance of US nuclear weapons w/o nuclear testing (tests stopped in 1992)- "Where's the Kaboom!" We don't know if the weapons will work…
- Stewardship is achieved through science, engineering, simulation and sub-critical experimentation (SCE)
- SCE is carried out at the Nevada National Security Site (NNSS)
- The NNSA workforce is graying! A recent wave of retirements is jeopardizing institutional memory. NNSA has created the Stockpile Stewardship Academic Program to address this shortage in expertise.

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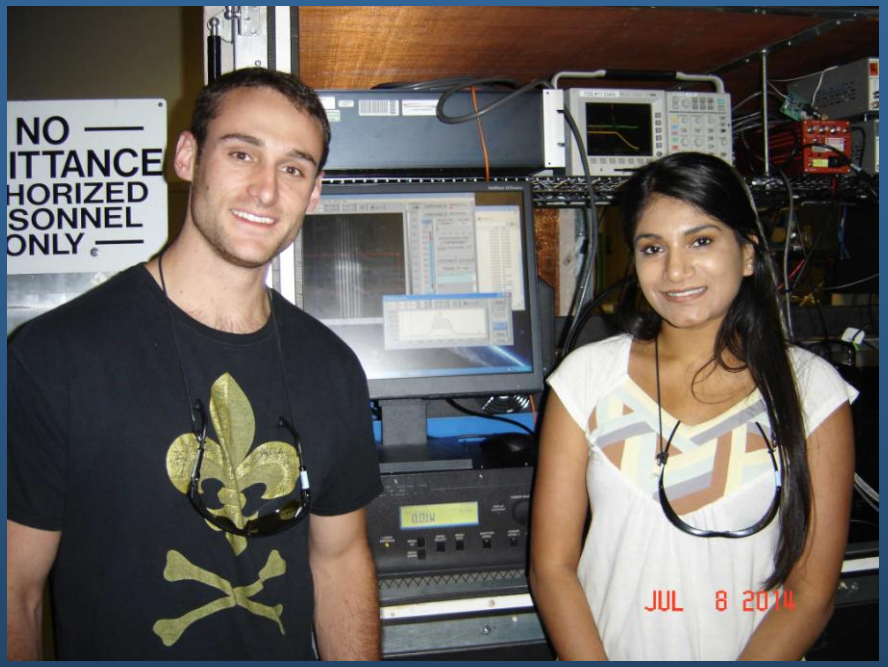
3. A Census of UNR HED Physics Student Researchers/Advisors

Graduate Students	**Advisors**
Angermeier, Alex	Covington
Bilkhu, Nuvi	Covington
Daykin, Tyler	Sawada
Dutra, Eric	Covington
Haque, Showera	Neill
Hutchinson, Trevor	Bauer
Iratcabal, Jeremy	Covington
Johnson, Zach	Covington
Mayes, Dan	Mancini
Petkov, Emil	Safronova
Shultz, Kimberly	Kantsyrev
Stafford, Austin	Safronova
Swanson, Kyle	Ivanov
Wallace, Matt	Neill



Undergraduate Students	
Beatty, Cuyler	Covington
Lopes, Ethan	Covington

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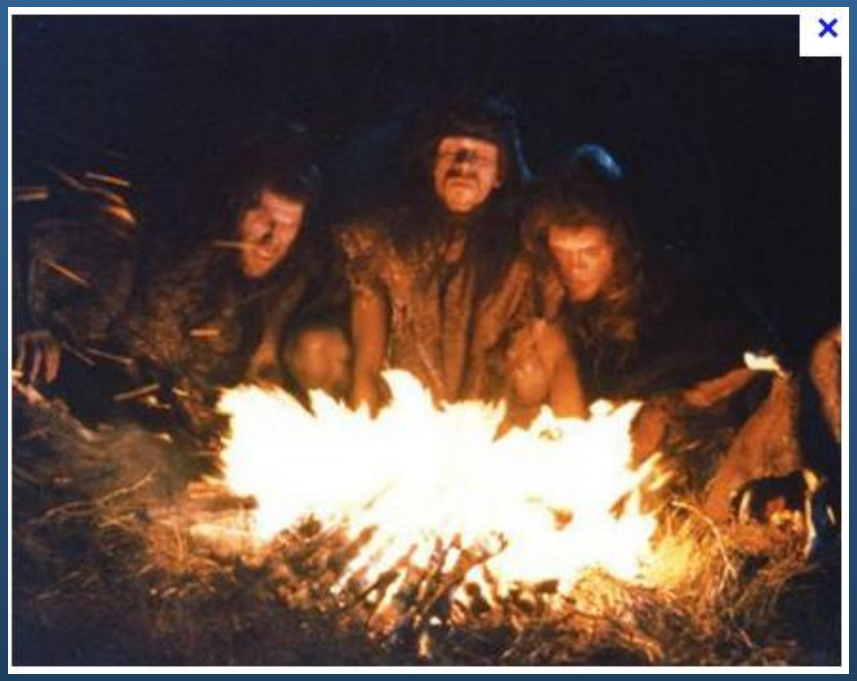
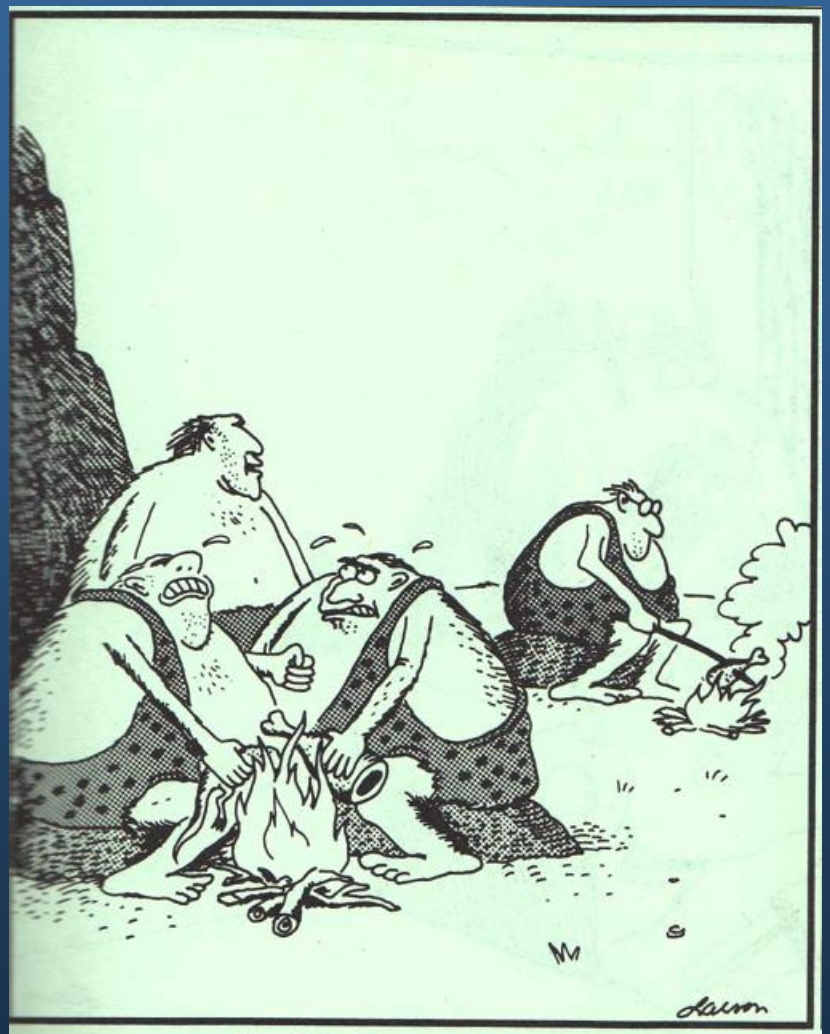
4. What is HED Plasma Science?

Human beings have been studying plasma for quite awhile….



Early Plasma Physics Research Team



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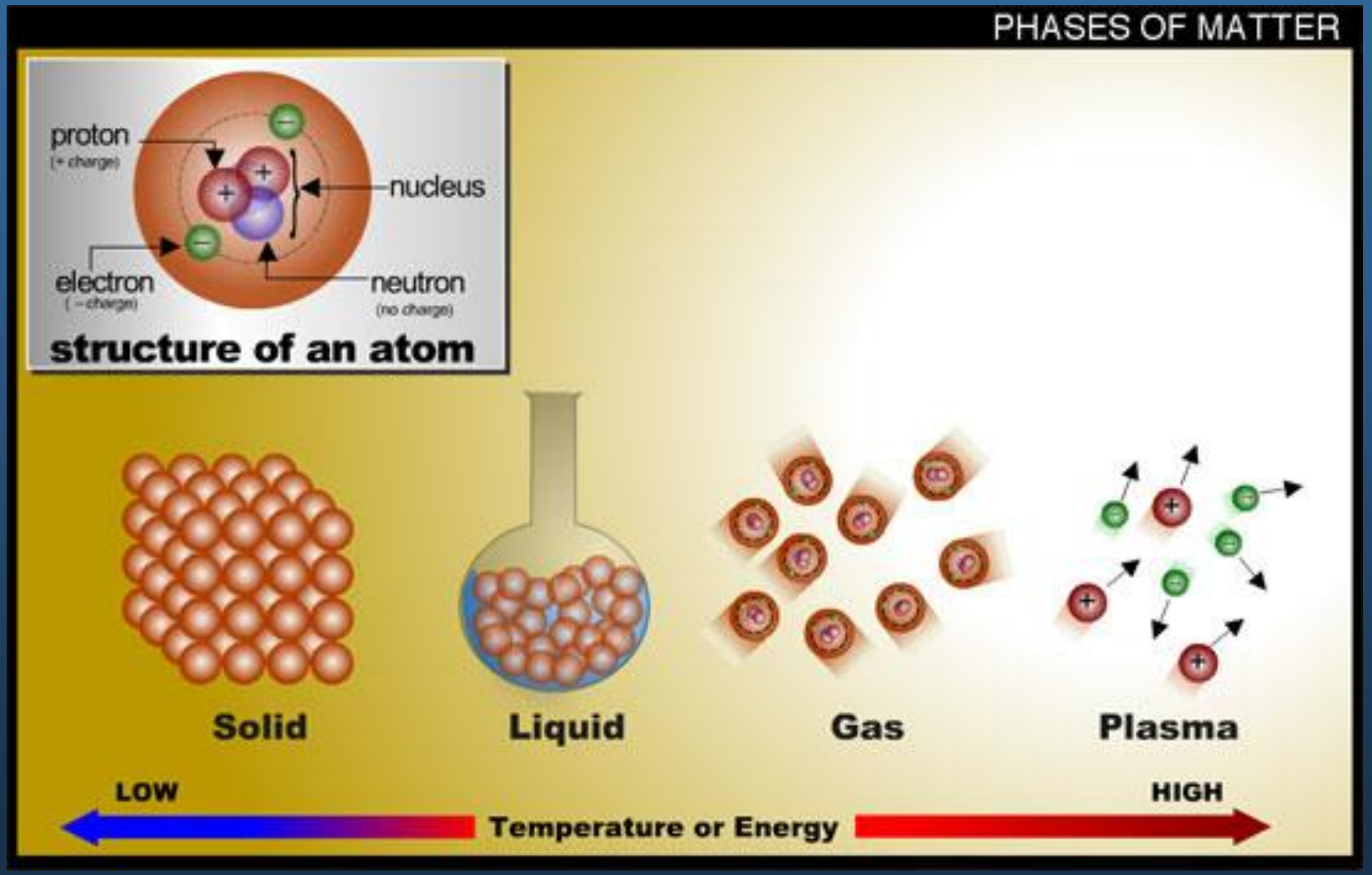
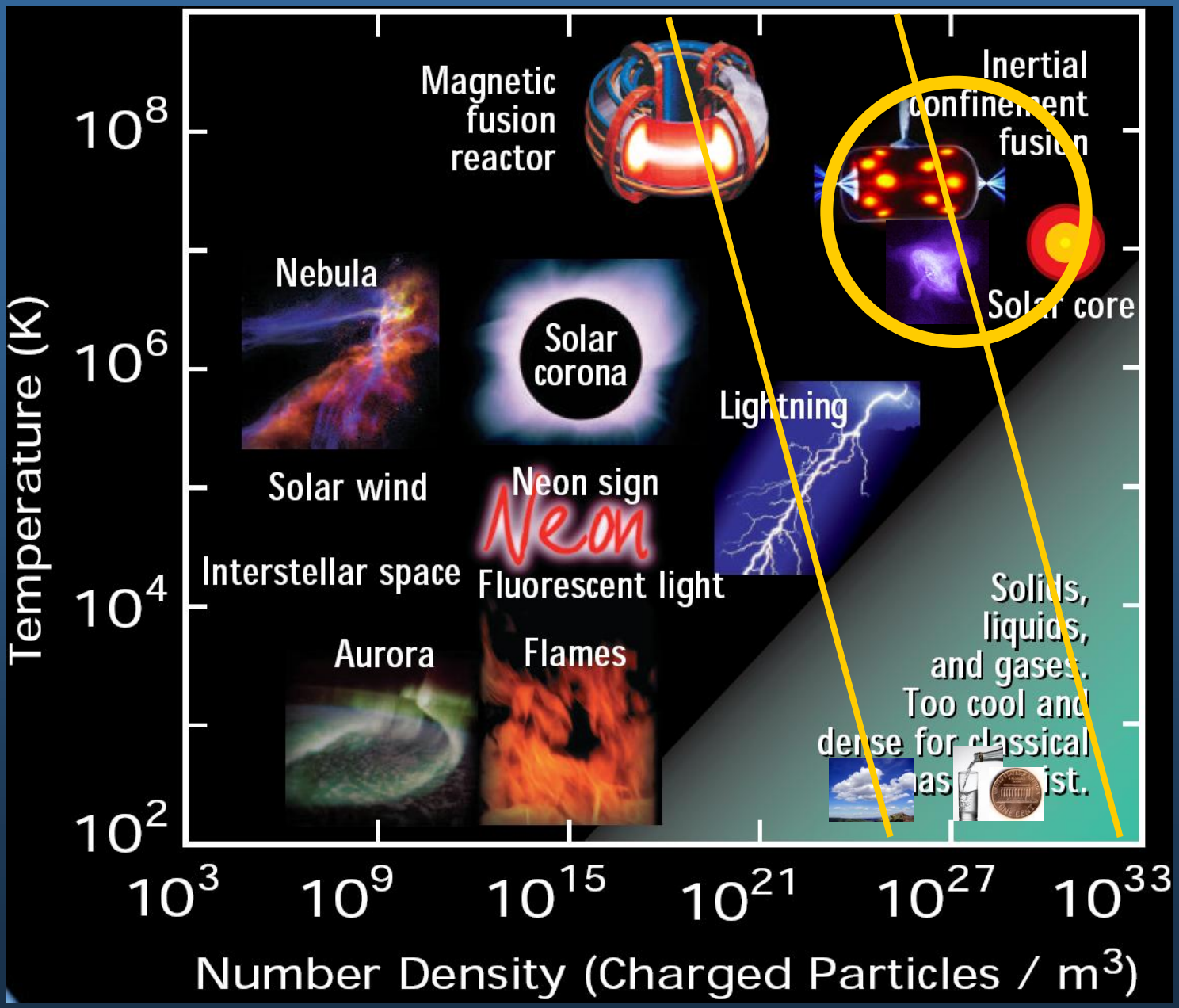
Q: What is plasma?
A: The 4th phase of matter.



Courtesy: NASA AMES

High Energy Density Plasmas that can be studied at NTF



Contemporary Physics Education Project (2006)

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Take away concepts…

Q1. How do we make high-energy density plasmas?

A1. We store electrical energy in capacitors and

i) Quickly dump the electrical energy into a material target, or

ii) Convert the stored electrical energy to light (photons) in a lasing medium and then tightly focus the light on a target. This happens very quickly…

Q2. What is unique about NTF Plasmas and why are we so excited about exploring this regime?

A2. These are extreme plasmas that have both high temperatures, densities and field strengths like those found in nuclear explosions. HED plasmas also exhibit unanticipated behavior.

This is an area ripe for discovery! Neutron science, Isotope Production, Advanced Energy Concepts, Particle Beam Accelerators, Astrophysics etc.

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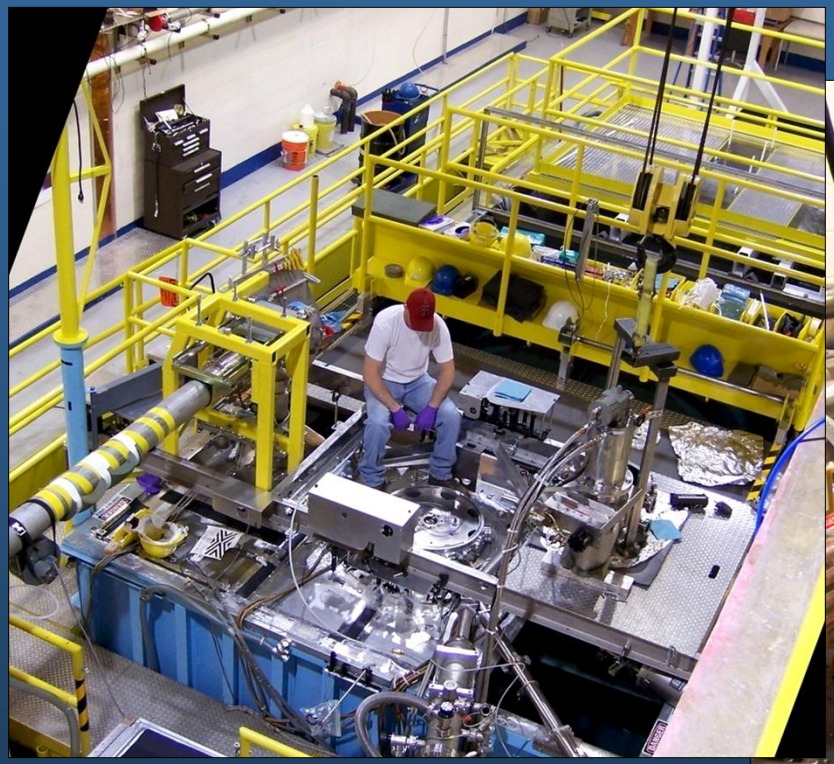
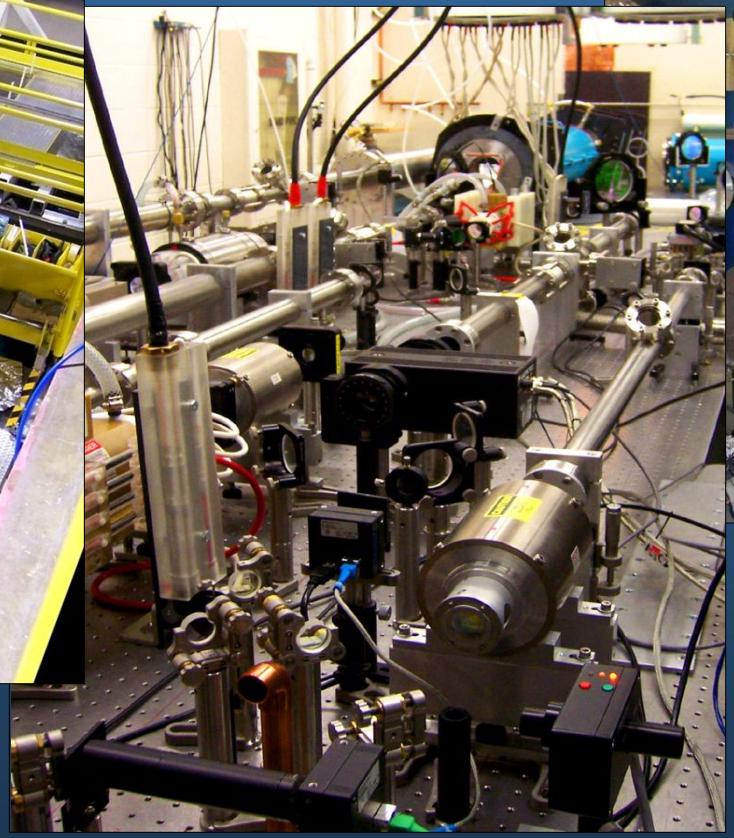
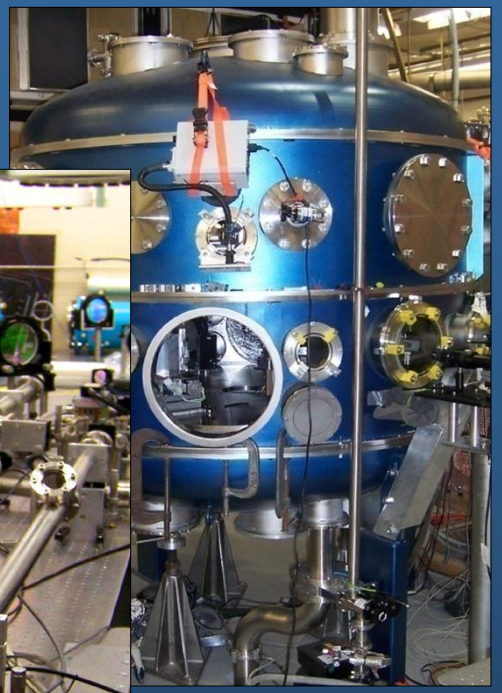
Major HED Plasma Research Machines



Zebra Z-pinch, 1MA @ 2MV

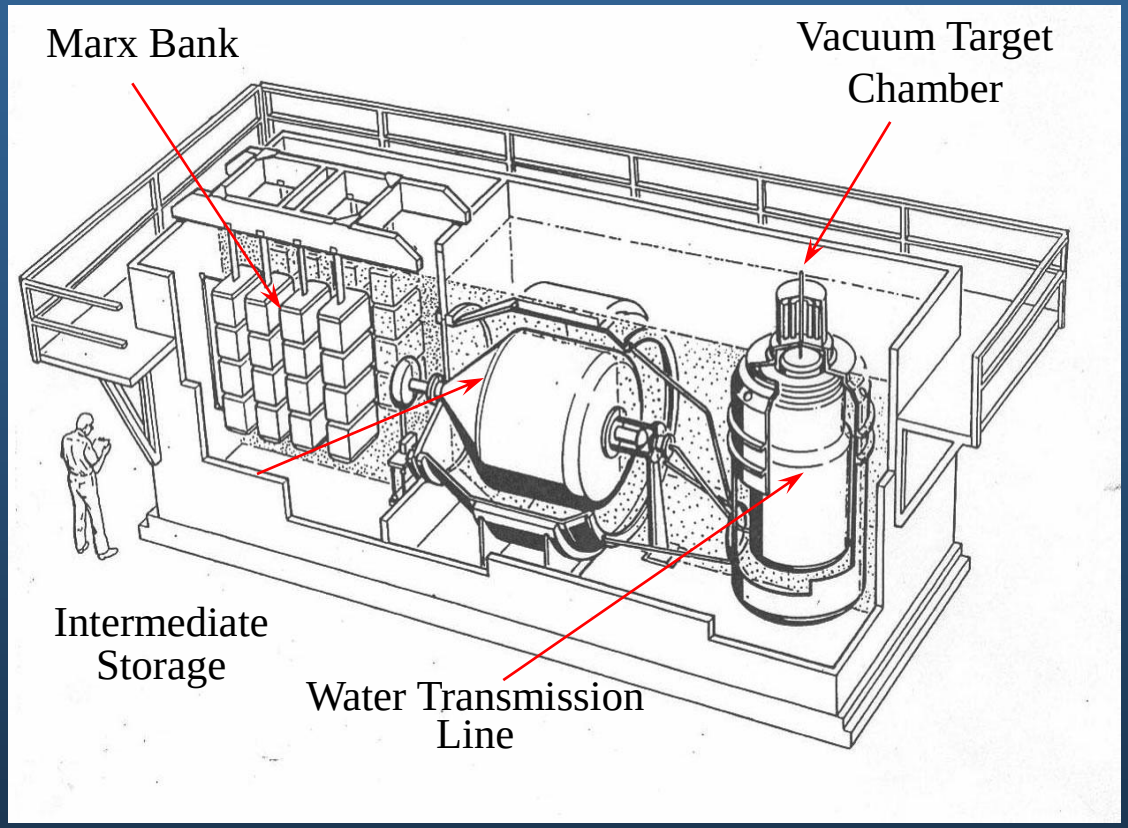




Leopard Laser 100J, 1 ns or 15 J, 350fs

Cheetah Laser 1.5J, 25 fs, 5 hz

NTF Zebra Z-pinch Accelerator- a short course…
Note: This was intended to achieve breakeven at LANL in the 1980s…



All Energy is delivered to target in 100 billionths of a second!

Vacuum Chamber w/ Target

Marx Bank (150 kJ) → **Intermediate Storage** → **Water Transmission Line**

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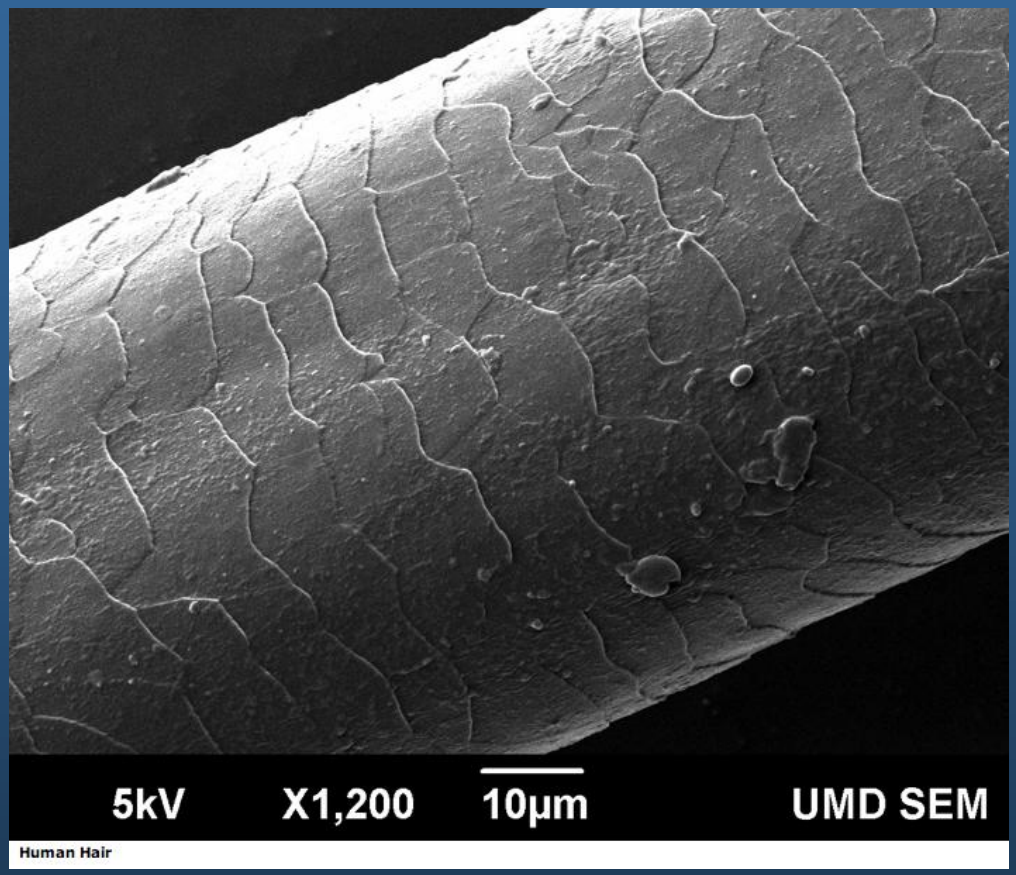
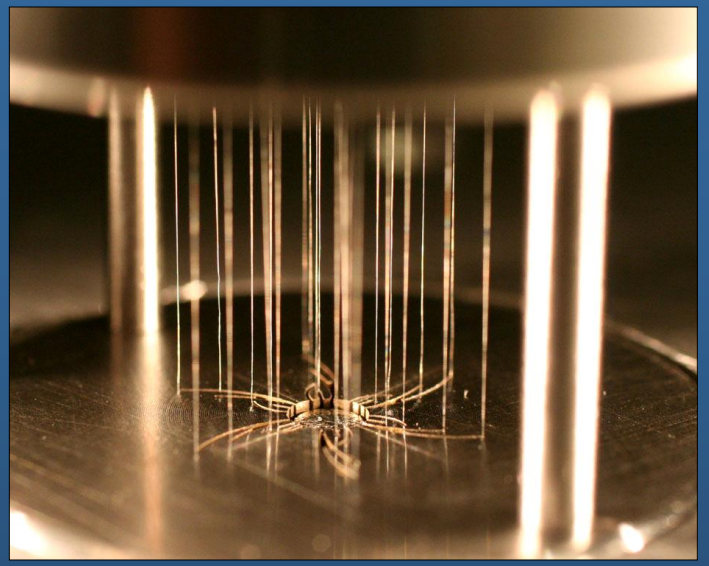


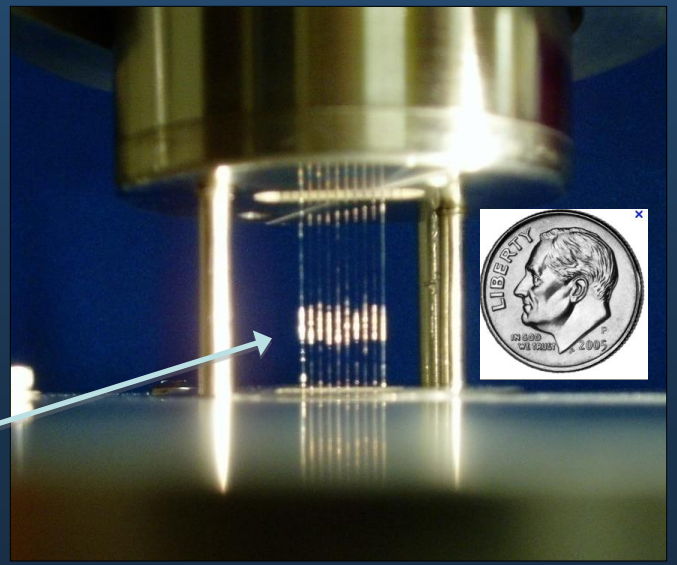
Micrograph of a strand of hair
(diameter ~100 microns)

Nested quadruple array



V. Ivanov

Planar wire array



Typical wire diameter
(10 microns)

V. Kantsyrev

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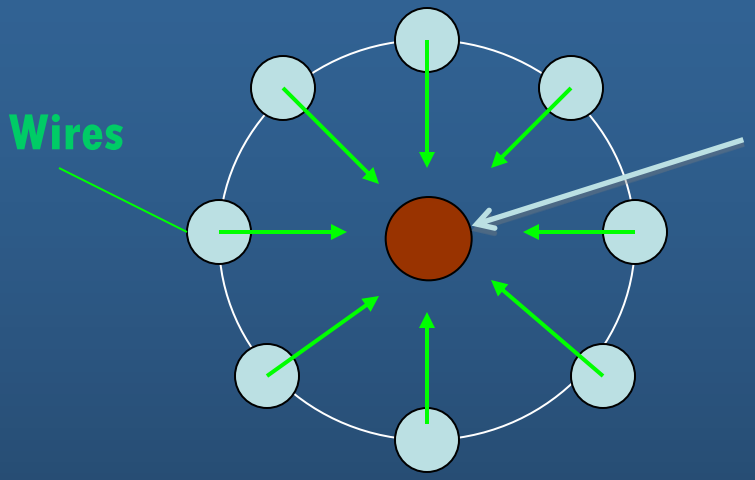
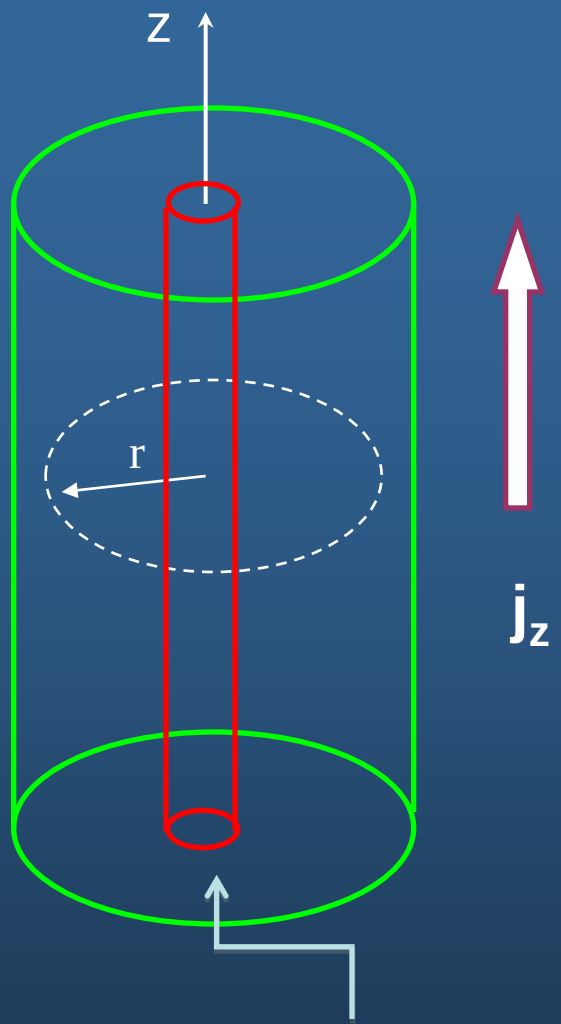
Current in the wire array ~ 1 MA



All forces act towards the center!

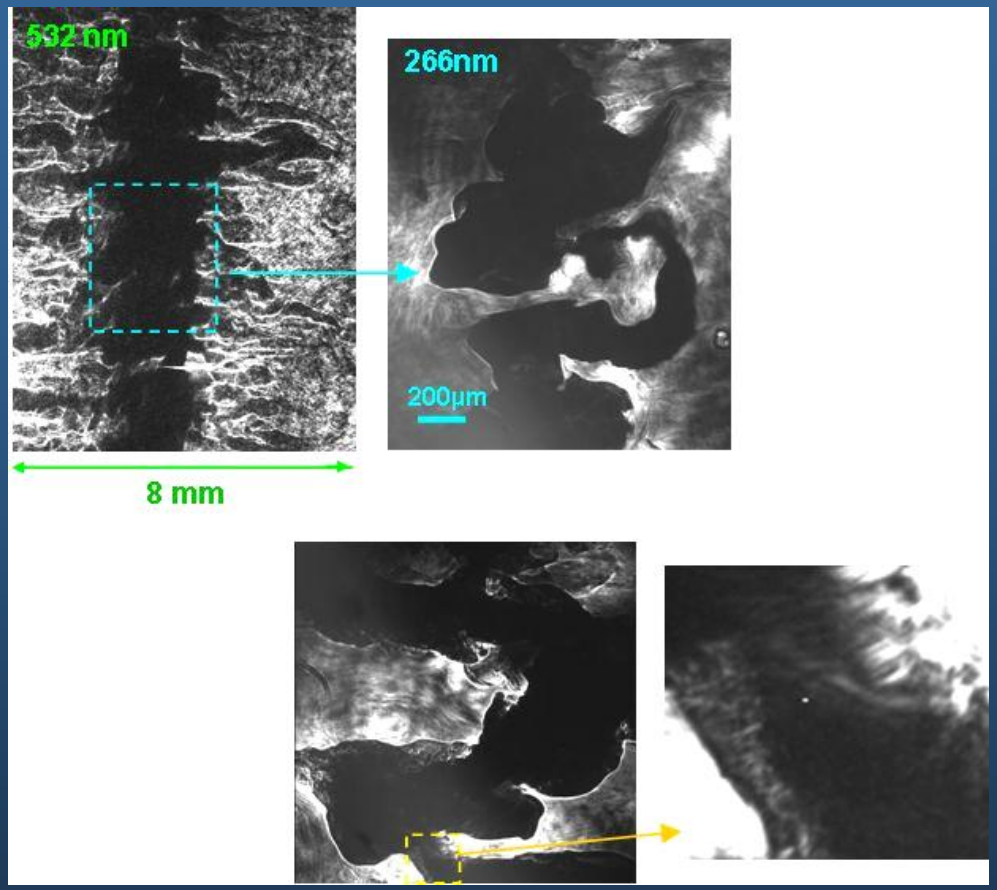


Note: Power = Energy divided by Time

$$P = \frac{150{,}000\ J}{100 \times 10^{-9}\ s} = 1500000000000\ W = 1.5\ TW$$

Theory indicated this would achieve fusion…

Experimental Images of the plasma column… Instabilities form and the plasma cools far to quickly!



*Lower absorption of UV reveals details in denser plasma**

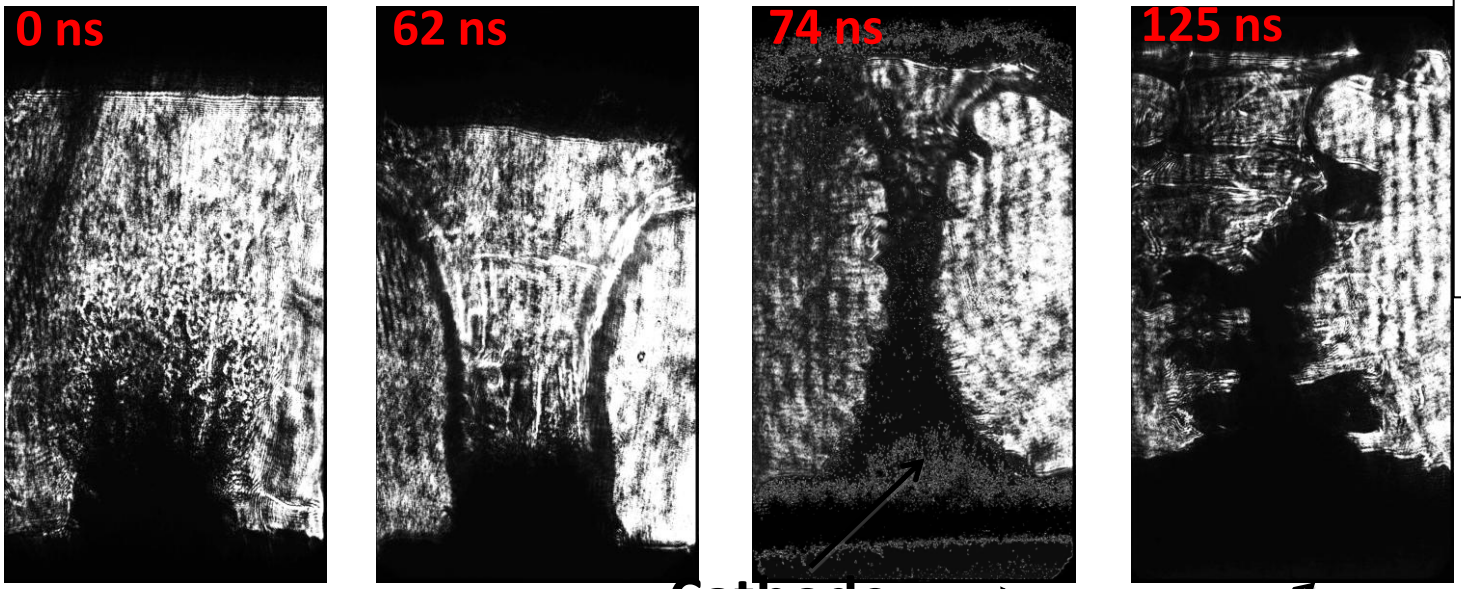
"You can't fool Mother Nature!"

Unintended benefit: Z-pinches are the brightest laboratory sources of X-rays (~ 20% of stored energy converted).

*:Ivanov et al., IEEE TPS. **38**, 574 (2010)

Unique NTF Developments: Z-pinch Stages of Laser Plume

Anode



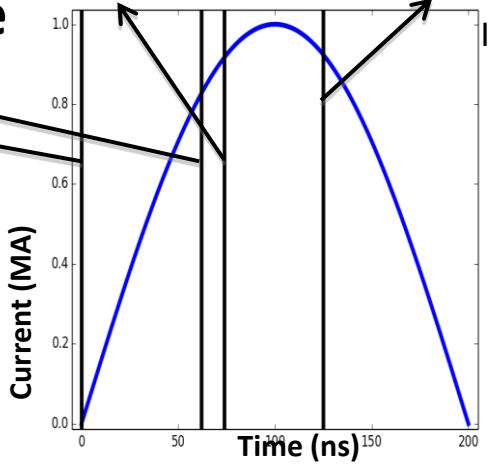
Target Type: C_2D_6

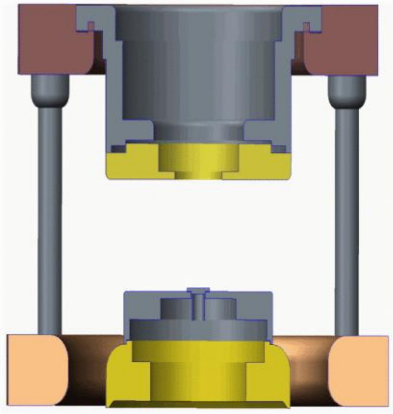
Shot rate:

Up to 8/day

5 mm

Cathode





532-nm shadowgraphy sequence of different Z-pinch shots

5. Where are our students now?

NTF Defense Science Training

Recent UNR Physics PhD Recipients High Energy Density Plasma Physics (12/09-present)

32 PhDs in HEDP Physics- only 4 found positions in Nevada!

Of these- 13* earned B.S. degrees from UNR & 11 attended local area high schools

12 DOE/DOD Lab Post Docs
11 University Post Doc/Research
9- Academy/Industry

2 Defense Industry R&D
6 NNSA Technical Staff Members
3 DoD Technical Staff Members

2009

Time

present

Former Student	Where are they now?	PhD Advisor
Rohini Mishra	Post doc @ UCSD; Stanford	Sentoku
Sandrine Gaillard	Post doc @ FRZ	Sentoku
Tom Awe	Post doc & TSM @ LANL	Siemon/Bauer
Abdel Haboub	Post doc @ LBNL	Ivanov
Milena Angelova	Instructor	Bauer
Ishor Shrestha	Post doc @ UNR	Kantsyrev
Essam Yasin	Post doc @ U Alaska	Sotnikov
Nick Ouart*	NRC post doc & TSM @ NRL	Safronova
Taisuke Nagayama*	Post doc & TSM @ SNL	Mancini
Chris Plechaty*	LLNL Post doc; TSM @ WPAFB	Presura
Mike Bakeman	Industry KLA-Tencor	Sentoku
Ken Williamson*	Post Doc UTSA; TSM @ SNL	Kantsyrev
David Martinez*	Post doc & TSM LLNL	Presura
Penka Wilcox	Instructor- TMCC	Safronova
Peter Hakel*	Post doc & TSM @ LANL	Mancini
Trevor Burris-Mogg*	Post doc @ LANL	Sentoku
Sandra Stein	Industry Raytheon	Presura
Glenn Osborne*	Physicist, China Lake NWC, CA	Kantsyrev
Daniel Papp	Jr. Scientist, ELI-ALPS, Hungary	Ivanov
Yadab Paudel	Asst. Professor, Union College	Sentoku
Heather Johns*	Post doc & TSM @ LANL	Mancini
Philippe LeBlanc*	DRI	Sentoku
Michael Weller	Post doc @ LLNL	Safronova
Tunay Durmaz	Post doc @ UT Houston	Mancini
KC Chartkunchand*	Post doc @ Stockholm Univ.	Covington
Austin Anderson	Post doc @ UNR/NSTec	Ivanov
Tirtha Joshi	Post Doc @ LANL	Mancini
Rishi Pandit	Post Doc @ S. Illinois U.	Sentoku
Kevin Yates	Post Doc @ LANL	Bauer
Erik McKee*	Post Doc @ Helion Energy	Darling
Ben Hammel	Post Doc @ WSU Shock Physics	Darling
Ryan Royle*	Post Doc @ UNR	Sentoku

*B.S. in Physics at UNR

NTF Student Training Opportunities

There are advantages to using small-medium scale facilities.

- Students can get their hands dirty.
- Experiments can evolve in real time based on data.
- Diagnostic development is easier with high rep rates.
- Many paths can be explored in a cost effective manner.
- Risk aversion can be minimized.

Future Experimentalists playing w/ LEGO

Future Theorists playing MineCraft

Thank you for your attention.