Experiments in warm dense matter using an ion beam driver

F. Bieniosek*, M. Leitner*, B.G. Logan*, P.K. Roy*, P. Ni*, J.J. Barnard#, M. Kireeff Covo#, A. Molvik#, L.R. Grisham†

Heavy Ion Fusion Science Virtual National Laboratory (HIFS-VNL)

**Lawrence Berkeley National Laboratory,*

#Lawrence Livermore National Laboratory, †Princeton Plasma Physics Laboratory

H. Yoneda

University of Electro-communications, Tokyo, Japan

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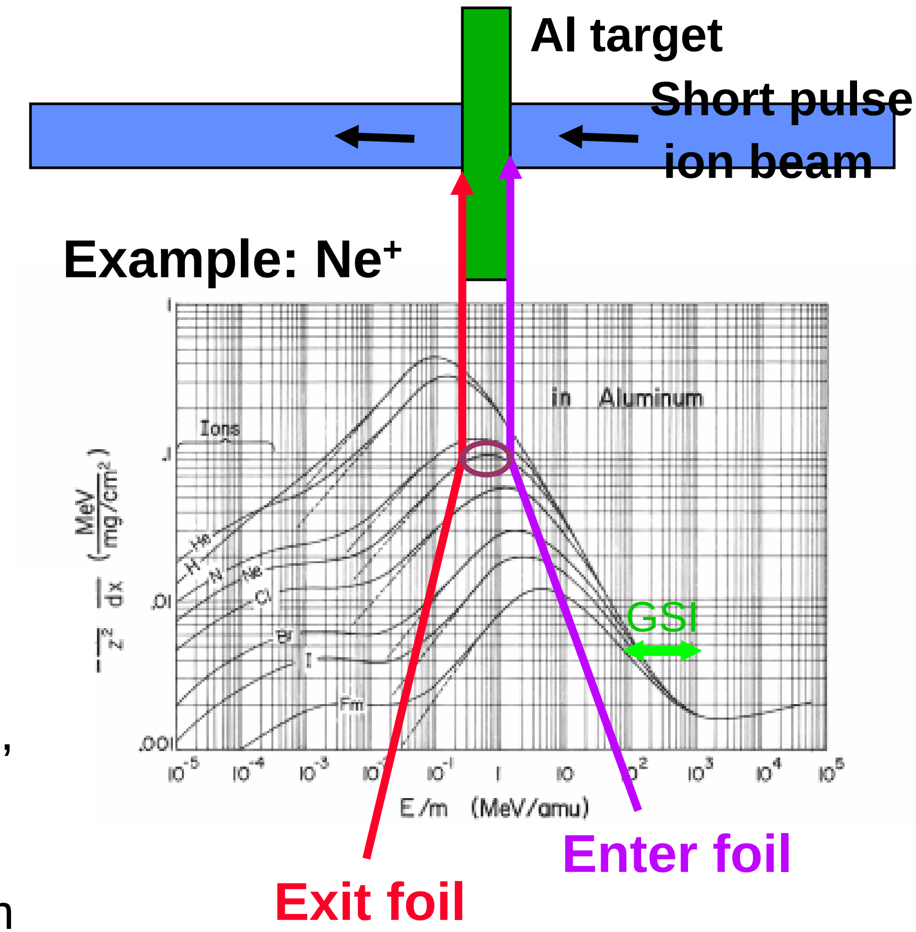
Ion beams provide an excellent tool to generate homogeneous, volumetric warm density matter.

- Warm dense matter (WDM)
  - T ~ 0.1 to 10 eV
  - ρ ~ 0.01 -1 * solid density
- Techniques for generating WDM
  - High power lasers
  - Shock waves
  - Pulsed power (e.g. exploding wire)
  - Intense ion beams
- Diverse applications: HED astrophysics, HED laboratory plasmas, ICF, materials science
- We plan to develop an accessible, open facility with dedicated beam time

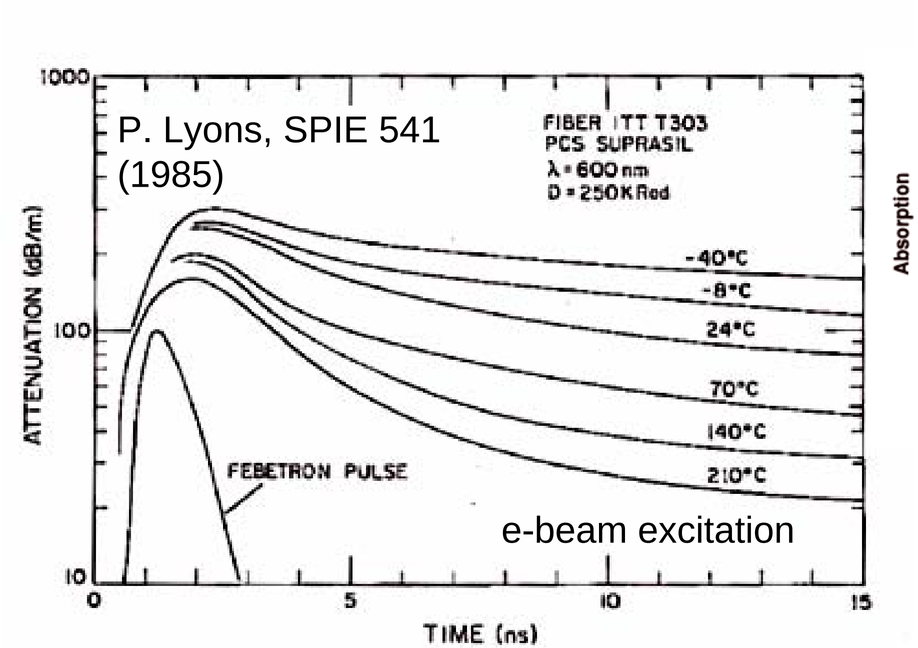


L. Grisham, Phys. Plasmas 11 (2004) 5727.

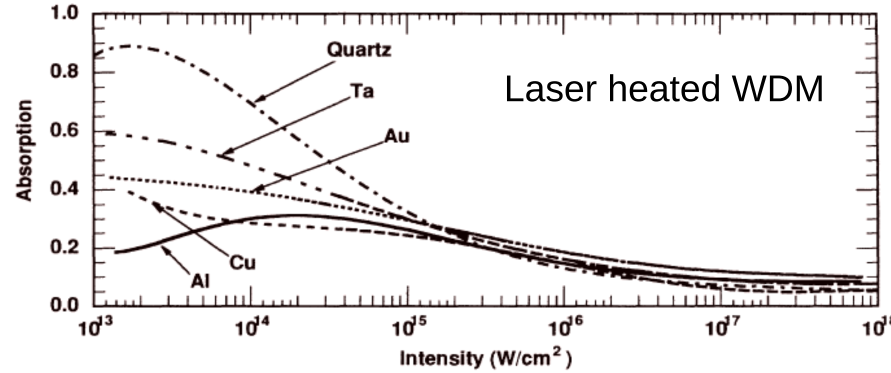
What are the advantages of ion beam drivers for WDM experiments?

- **Precise control** of energy deposition
- **Uniformity** of energy deposition (<~ 5%)
- **Large sample sizes** compared to diagnostic resolution volumes (~ 1's to 10's μ thick by ~ 1 mm diameter)
- Ability to heat **all target materials** (conductors and insulators, foams, powders, ...)
- A **benign environment** for diagnostics
- **High shot rates** (≤10 sec.)
- Potential for **multiple** beamlines/target **chambers**

Transient darkening of quartz at low temperature is a route to study of transient darkening in WDM.

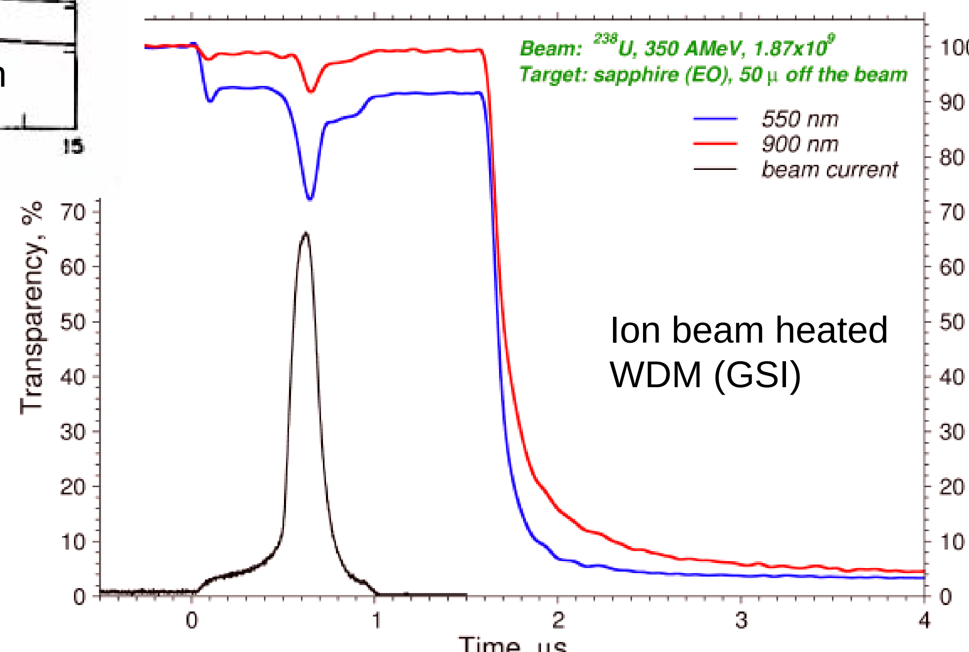


D.F. Price, et.al., PRL 75, 252 (1995)

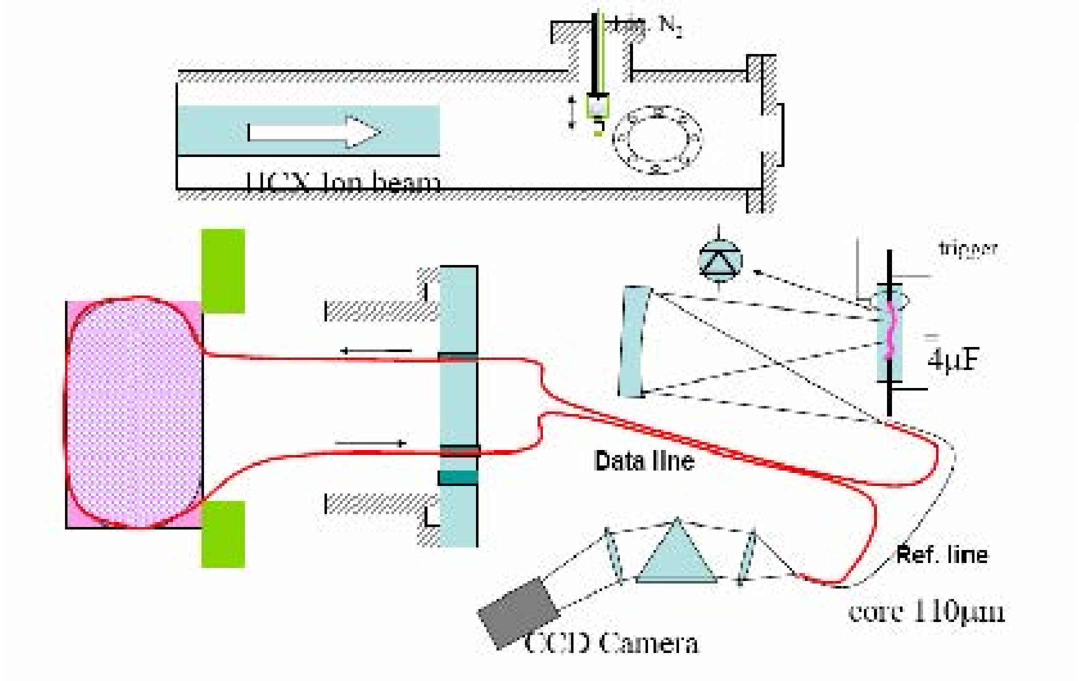


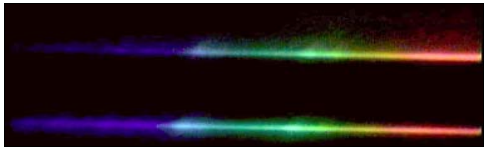
In quartz, electrons excited from 2s, 2p (ground state) to 3s leave holes in ground state to absorb photons in both cases. Measure decay rate of excited electrons by studying decay of absorption and emission rates.

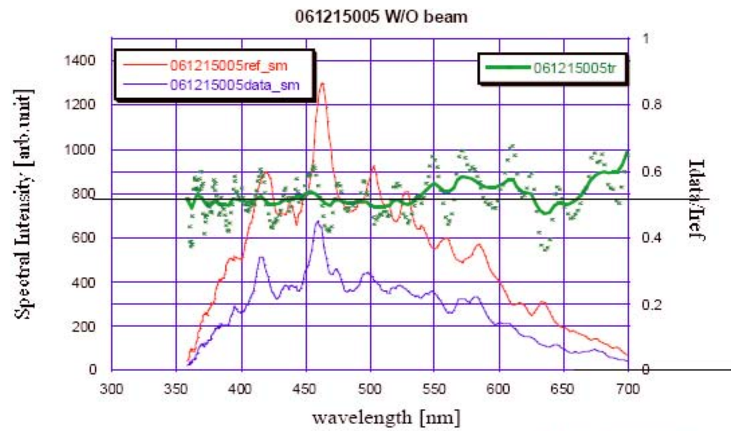
Significance: interpret WDM data, possible temperature measurement, fast switching of optical properties



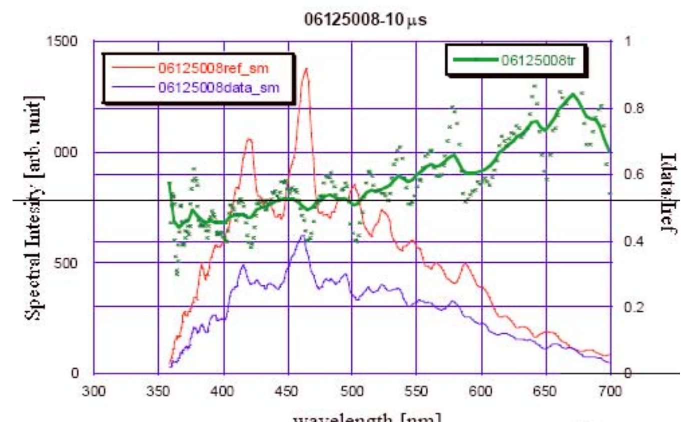
Initial transient darkening experiments in quartz fiber on HCX (with H. Yoneda, U. of Electro-communications, Tokyo).







No beam

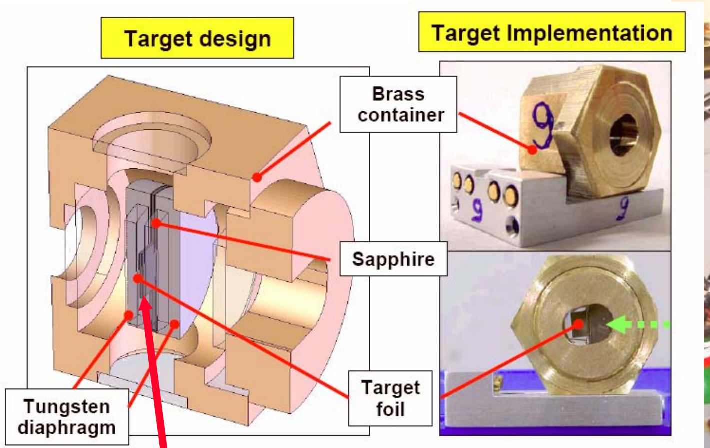


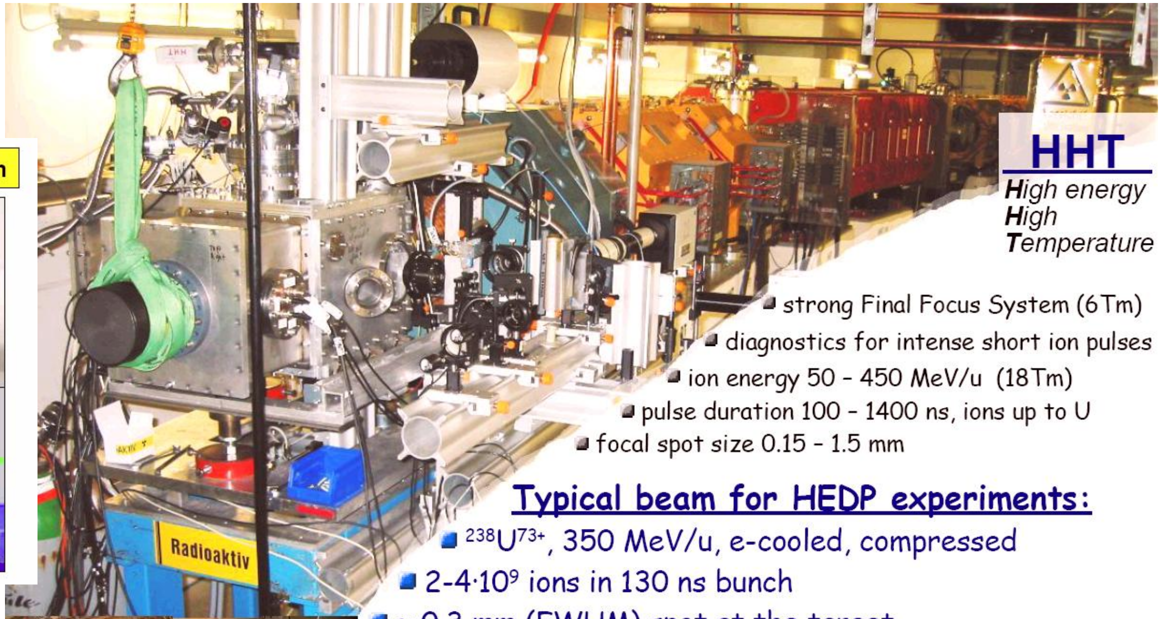
$10\mu s$

Optical transmission experiment: look for difference in fiber transmission with and without beam.

Further optical transmission or conductivity experiments are planned.

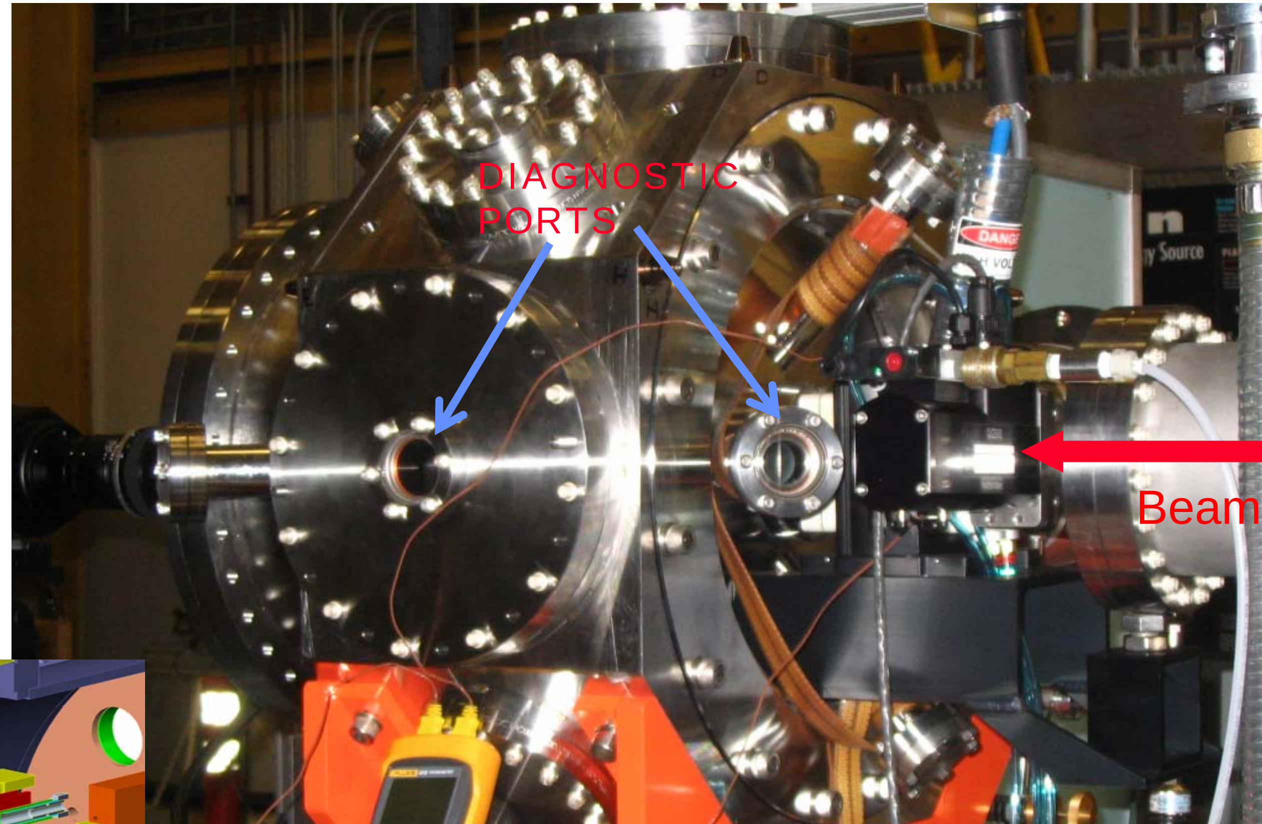
Experiment using LBNL porous targets at GSI HHT target station (with GSI Plasma Physics group; IPCP Chernogolovka; ITEP Moscow).





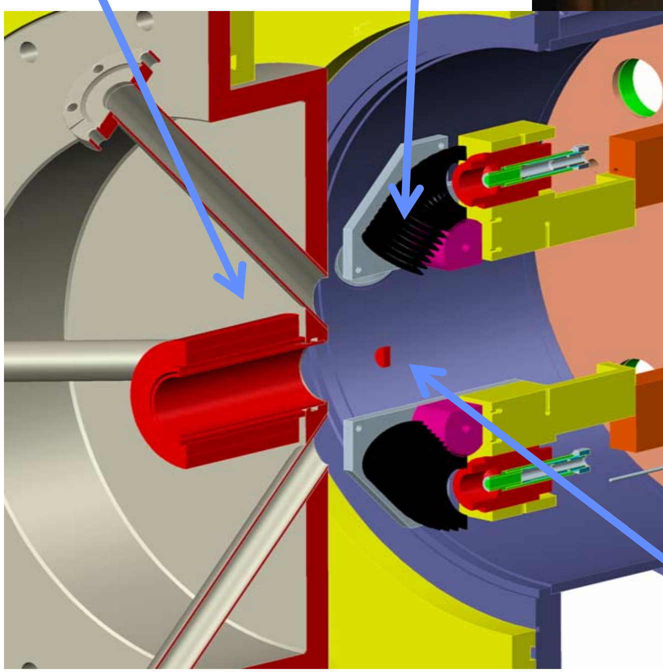
- Replace target foil with porous material.
- Study effect of pore size on target behavior using existing diagnostics.
- LBNL targets: Au (50 nm pore size), Cu (50 micron pore size). See Paper WEOCC02, P. Ni, et. al. for experimental results.

WARM DENSE MATTER EXPERIMENTS PROTOTYPE TARGET CHAMBER

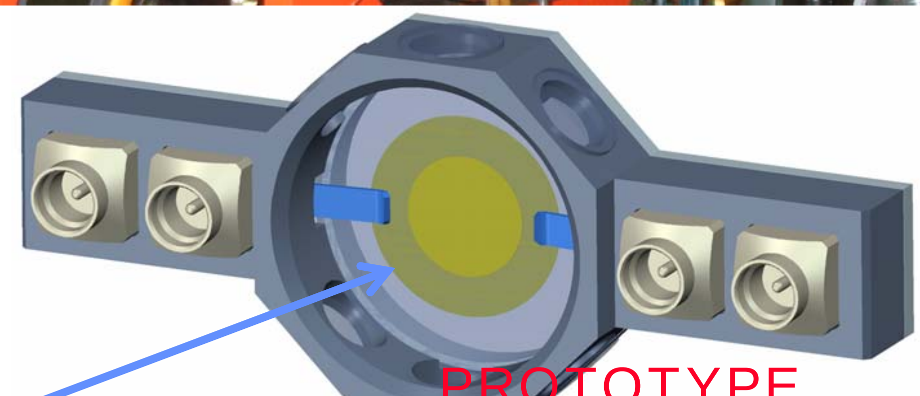


PLASMA INJECTION

FINAL FOCUS SOLENOID



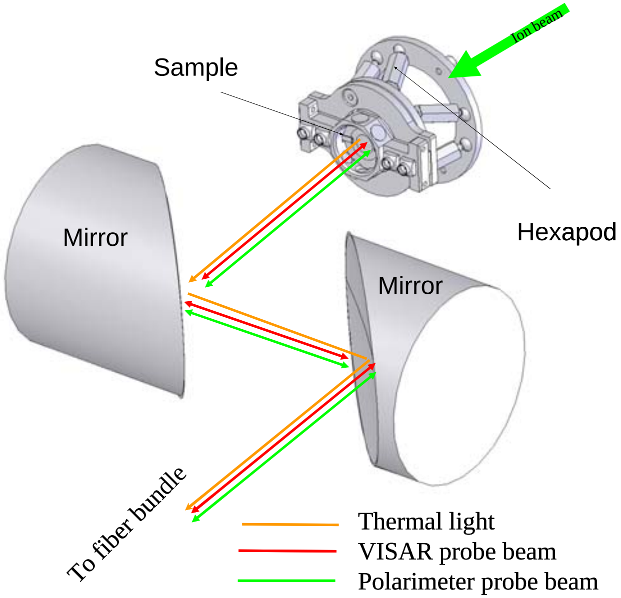
TARGET



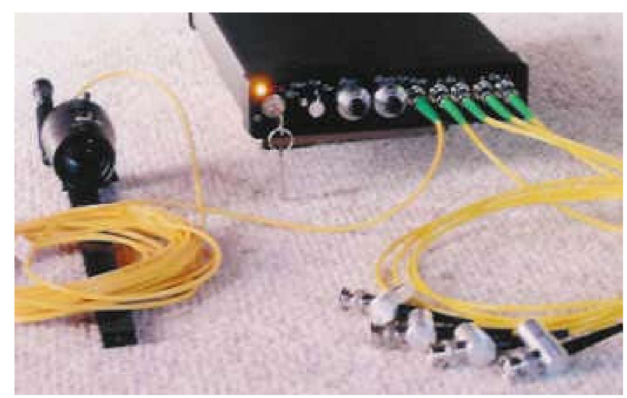
PROTOTYPE TARGET MODULE

We are developing target diagnostics for first target experiments on NDCX-I this year.

- **Fast optical pyrometer**
  - **fast response (~150 ps) and high sensitivity at lower threshold temperature**
  - **Temperature accuracy 5% for T>1000 K**
  - **Position resolution < 400 micron**
  - ***To be assembled later this year***

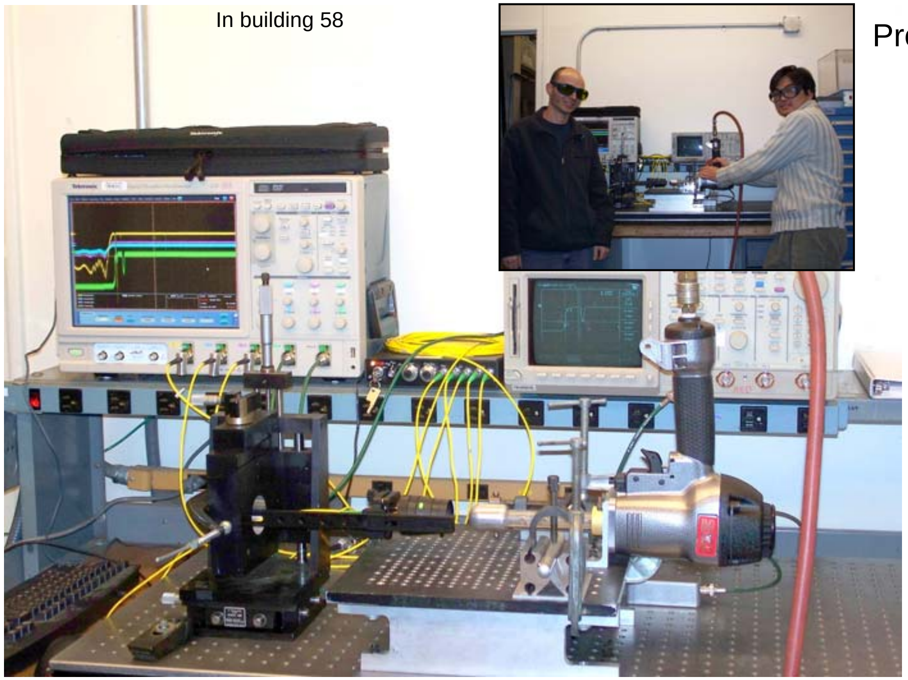


- **Fiber-coupled VISAR system – *bench test completed***
  - **Martin Froescher & Associates**
  - **ps resolution**
  - **1% accuracy**



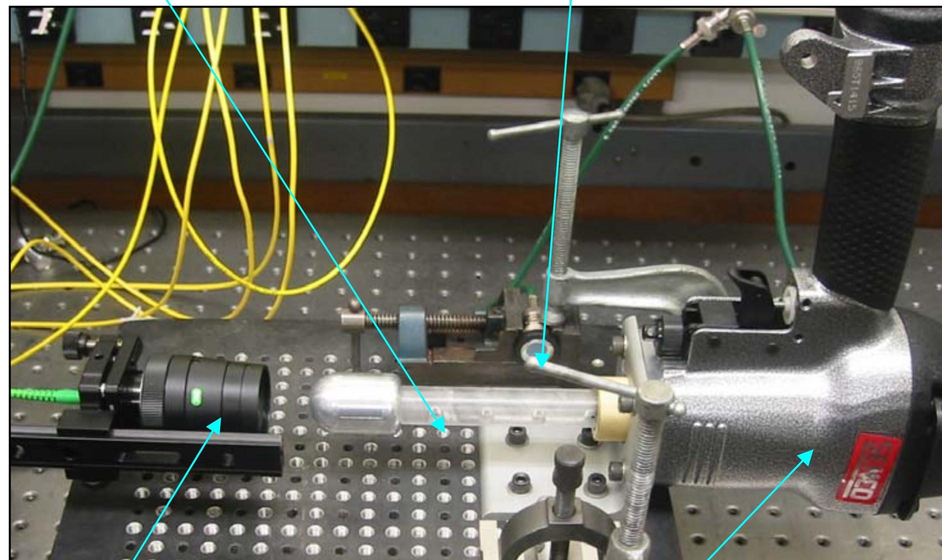
- **Hamamatsu visible streak camera with image intensifier**
  - **ps resolution**
  - ***To be bench tested***

Testing VISAR



Protection enclosure

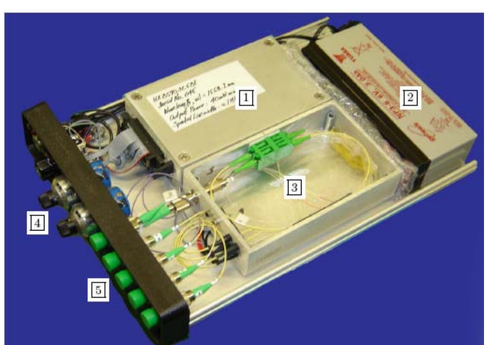
Photo-diode for triggering

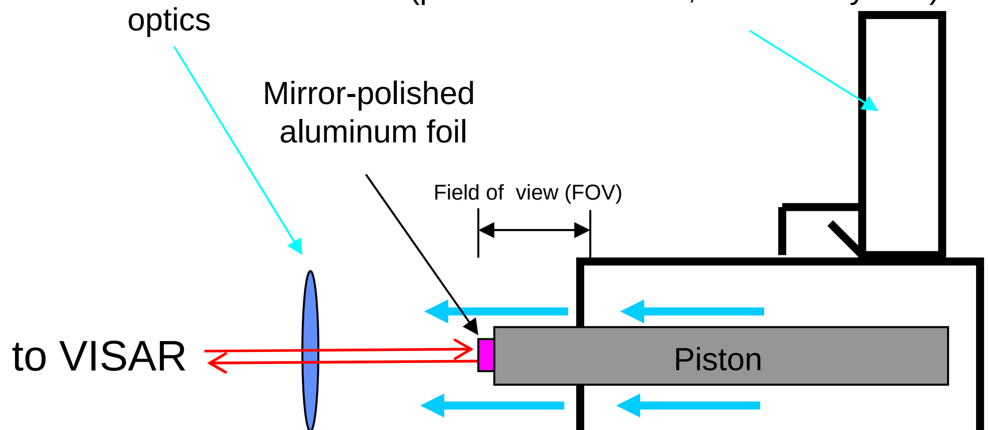


Focusing/collection optics

Nail Gun
(purchased in “Bed, Bath & Beyond”)

Martin, Froeschner & Associates All Fiber
Push-Pull Doppler Velocity Interferometer (VISAR) Systems





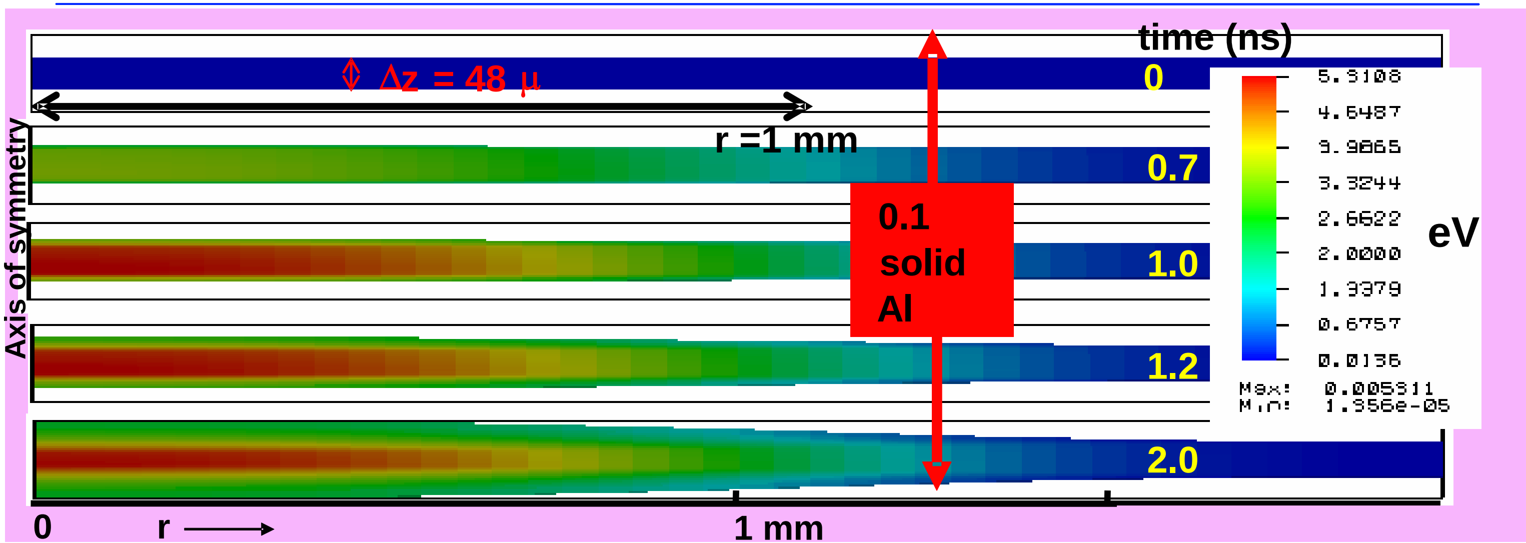
We have identified a series of warm dense matter experiments that can begin on NDCX-I at Temperature < 1 eV.

	Target temp.	NDCX-1 or HCX	NDCX-2
Transient darkening emission and absorption experiment to investigate previous observations in the WDM regime	Low (0-0.4 eV)	√	
Measure target temperature using a beam compressed both radially and longitudinally	Low	√	
Thin target dE/dx, energy distribution, charge state, and scattering	Low	√	
Positive - negative halogen ion plasma experiment	>0.4 eV	√	√
Two-phase liquid-vapor metal experiments	0.5-1.0	√	√
Critical point measurements	>1.0		√

time

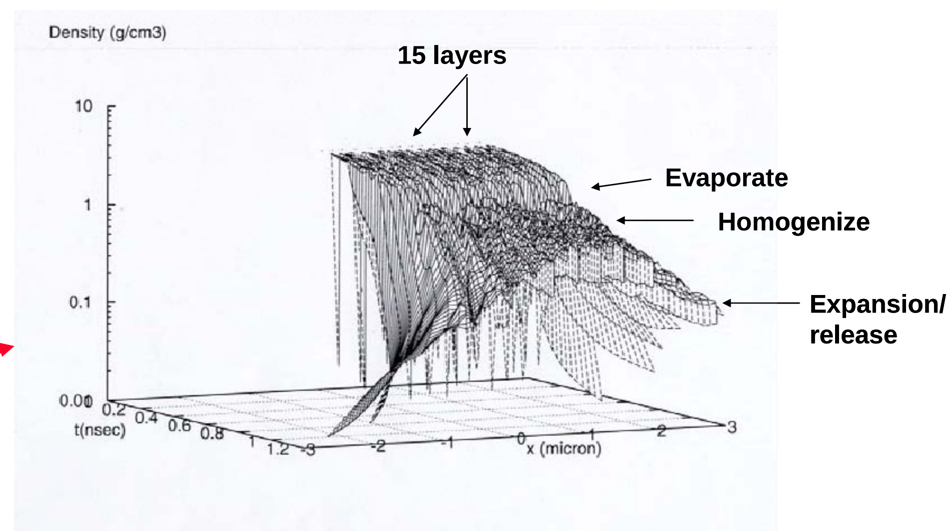
Fabrication of target experiment chamber and implementation of initial target diagnostics for first target experiments in NDCX-1 to be completed before June 2008.

Modeling support is based on codes such as HYDRA (LLNL), DPC (R. More).



HYDRA model of beam heating in a porous target

DPC model of a layered (porous) target



Conclusion

- Warm Dense Matter experiments are beginning
  -- Transient darkening experiments on HCX
  -- Metallic foam studies at GSI
  -- Target heating experiments (~.2 - .5 eV) to begin late this year on NDCX I
  -- 1 eV experiments on NDCX II could begin by 2009 (assuming $1.5M incremental funding in 2008)

- Experiments will have close modeling support to connect experimental measurements with WDM physics – e.g. HYDRA (LLNL), DPC