Ni-lined Capsules as Backlighters for Multiple Measurements in High-energy-density Physics Experiments

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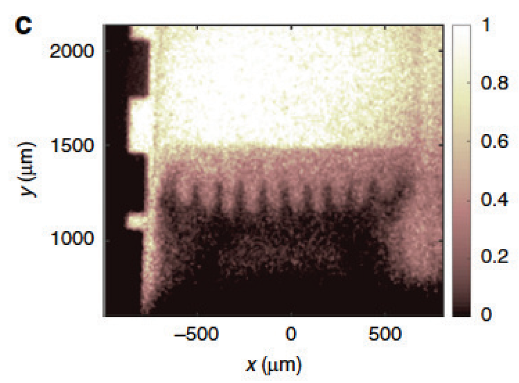
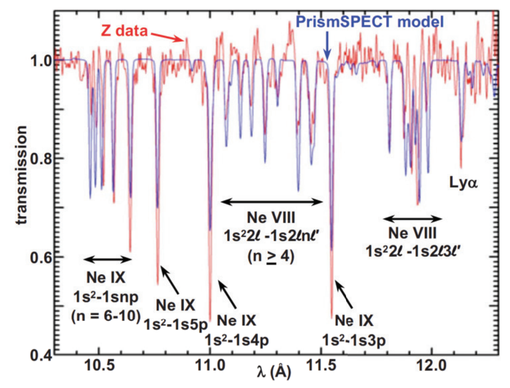
X-ray measurements are needed to probe high-energy-density plasmas

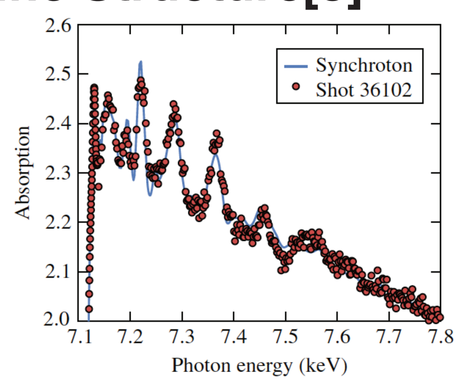
Radiography [1]



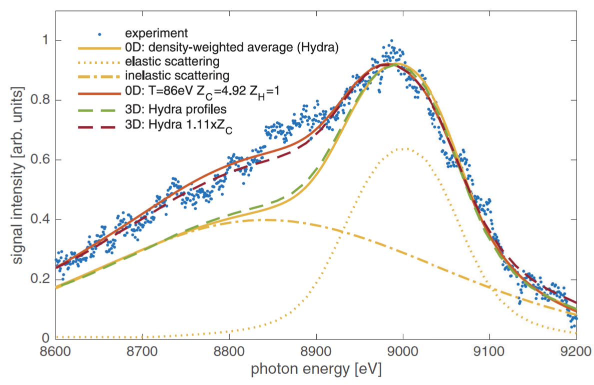
Absorption Spectroscopy[2]



Extended X-ray Absorption Fine Structure[3]



X-ray Thomson Scattering[4]

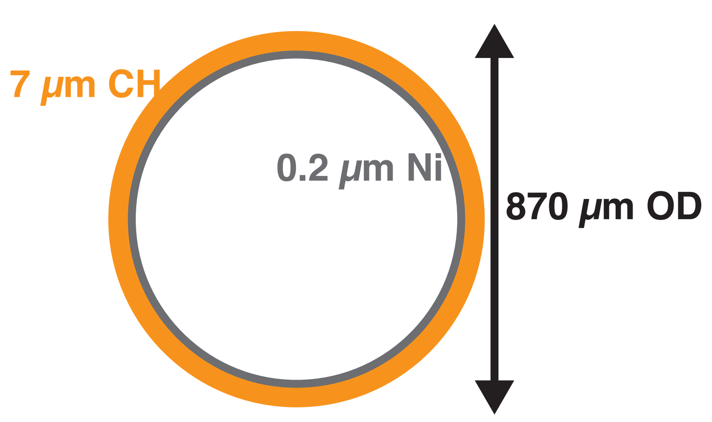


- X-rays can probe interior states of high density plasmas
- Line and continuum are used for different diagnostics
- HEDP experiments typically make a single measurement
- Multiple measurements require complex geometries

Laser-driven capsule implosions produce a bright, short-duration x-ray pulse

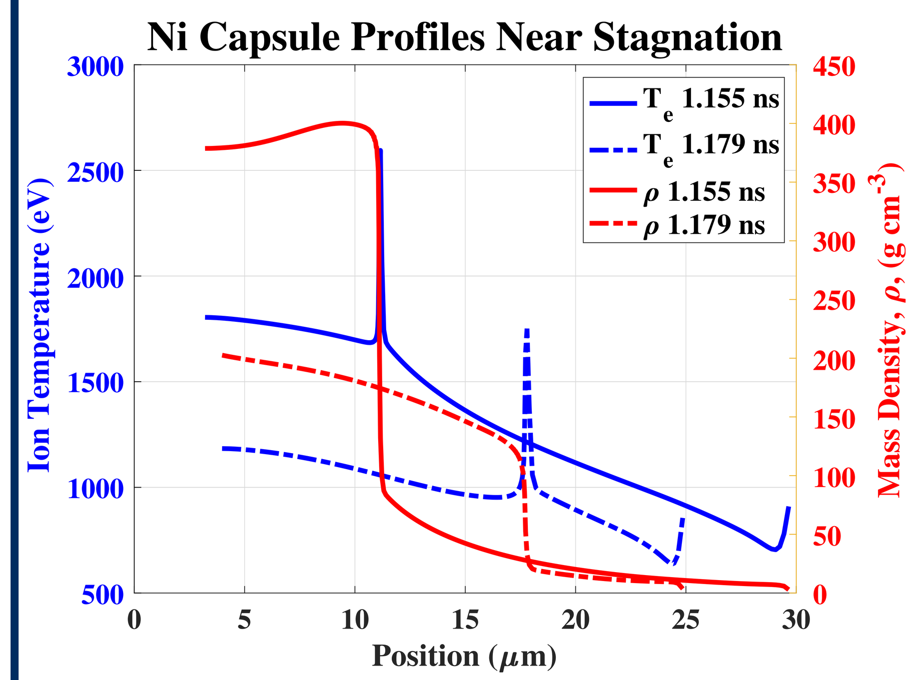
- Lasers ablate the plastic and rocket effect launches converging flows
- Flows converge, converting kinetic energy to thermal energy
- Hot, dense plasma emits bremsstrahlung
- Rebound shock expands and cools the plasma

Ni lining the interior surface of the capsule allows for dual use source



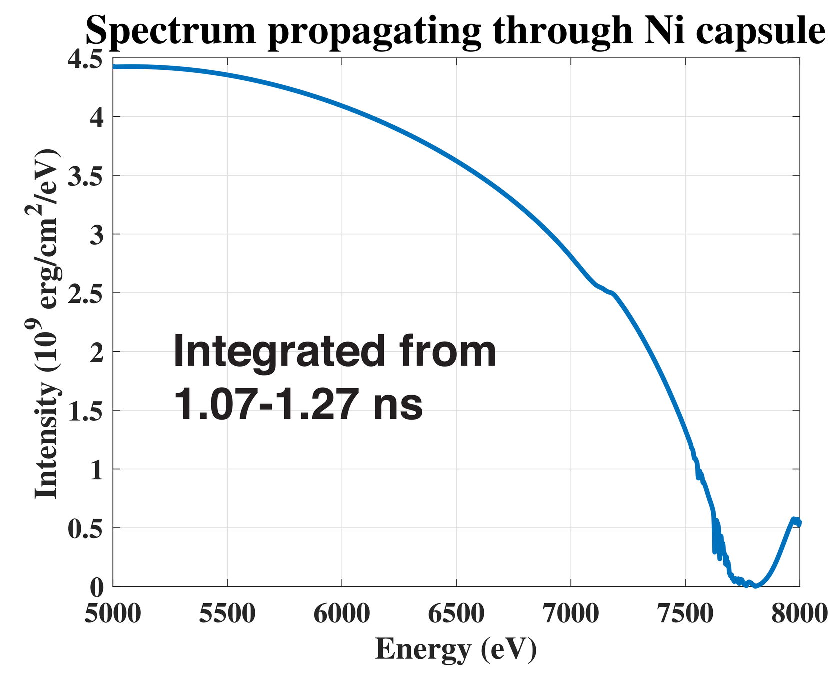
- Ni provides possibility of line emission > 7.5 keV
- Dense, imploded Ni provides bright continuum between 2-6 keV; Bremsstrahlung $\propto Z^2$
- Plastic layer tamps Ni and becomes transparent

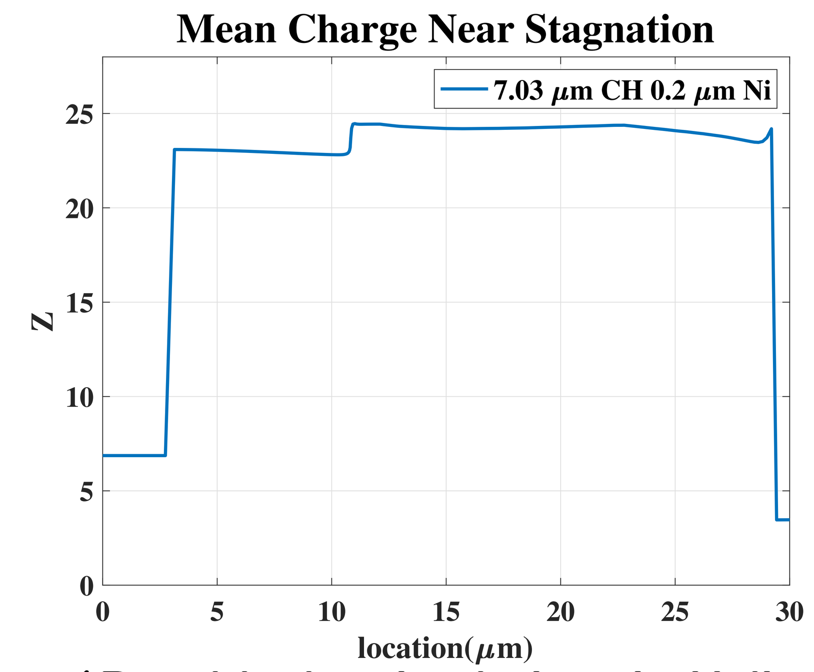
1D Radiation hydrodynamics simulations show similar performance with standard capsules, but different physics

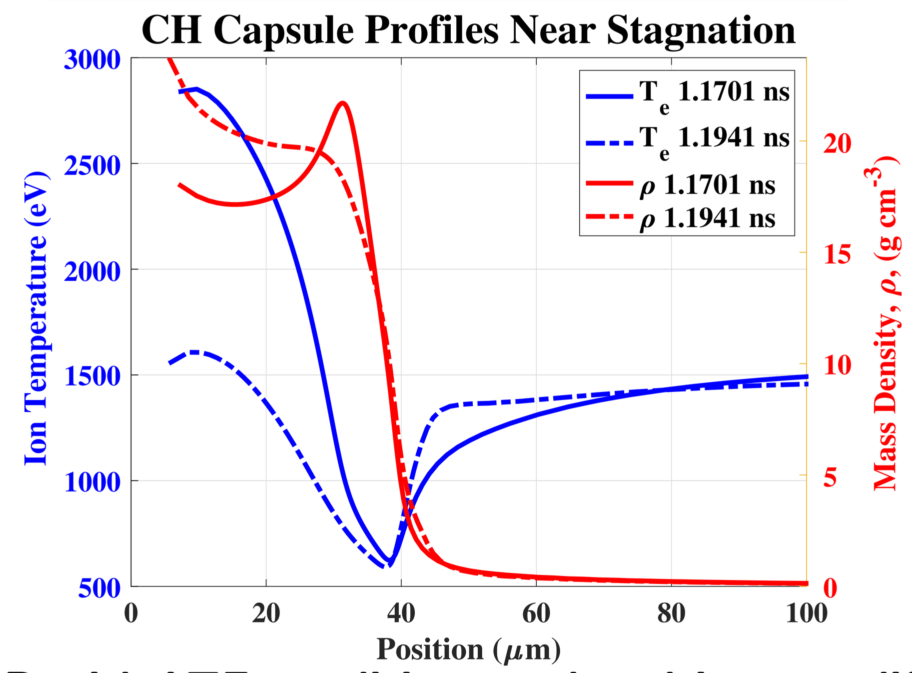


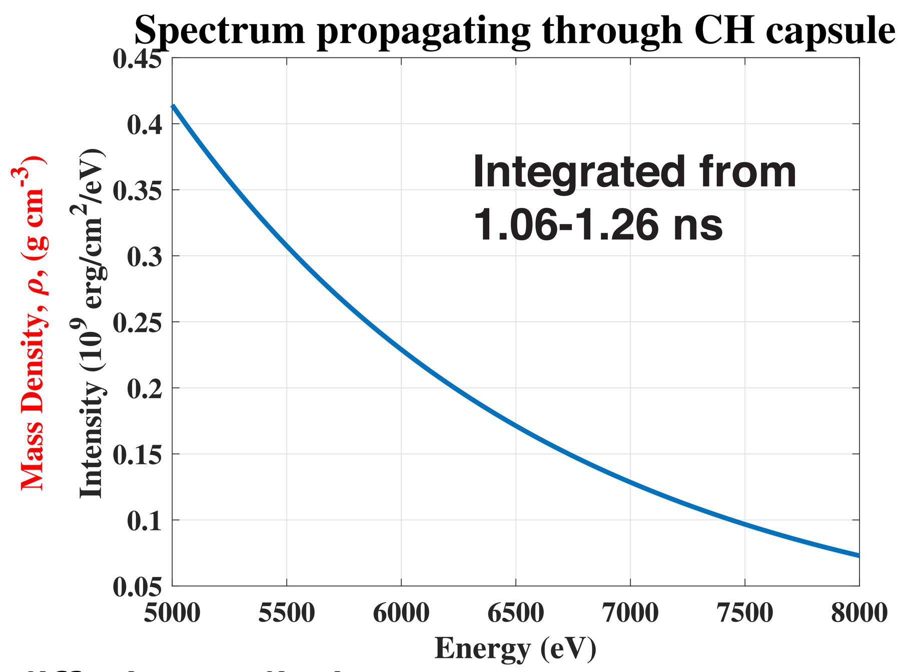
- Shock strength parameter: $Q = \frac{2\sigma u_s^5}{\rho R^4}$
- Radiative cooling threshold: $R_r = \frac{(\gamma+1)}{\gamma}\frac{4\sigma T_{init}^4}{\rho u_s^3}$
- In Ni: $u_s \approx 300$ km s^{-1}; $\rho \approx 50$ g cm^{-3}; $\gamma = \frac{4}{3}$; $T_{init} \approx 2000$ eV
- $Q_{Ni} = 74$
- $R_{r,Ni} = 53$
- Results suggest Ni capsules will have radiative rebounding shock and CH capsules will not

σ: Stefan-Boltzmann Constant	u_s: Shock Velocity
R: Gas Constant	γ: Polytropic Index
ρ: Mass Density	T_{init}: Post-Shock Temperature







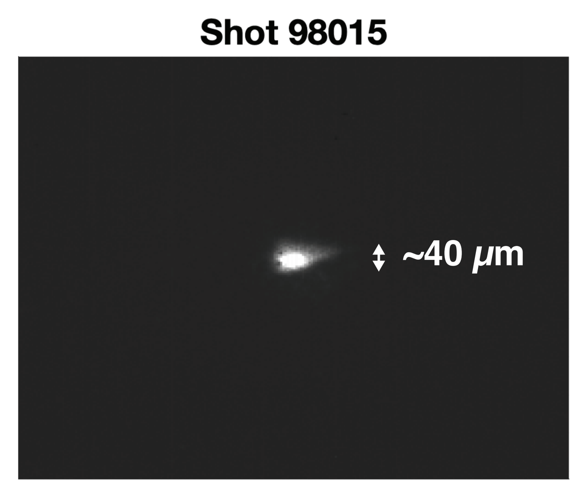


- 1D rad hydro simulations in Helios-CR with LTE conditions and multi-group diffusion radiation transport
- Spectral calculations trace a single ray with a 10x10 table in density and temperature for opacity

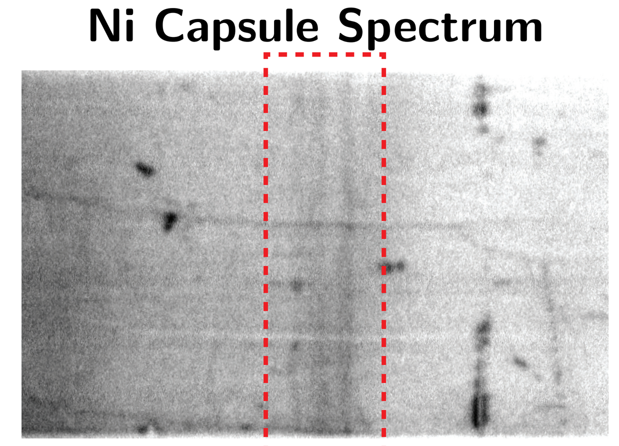
Experiments show bright continuum emission and weak line emission

Diagnostics
Flat LiF spectrometer (5.4-8.6 keV)
Framing camera
Flat PET spectrometer (2.5-4 keV)

Shot 98015

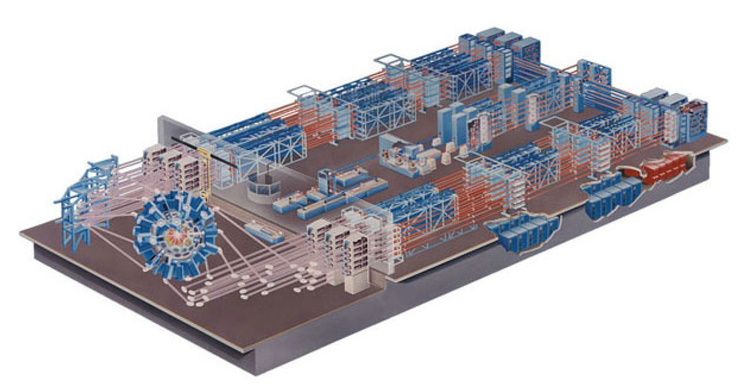


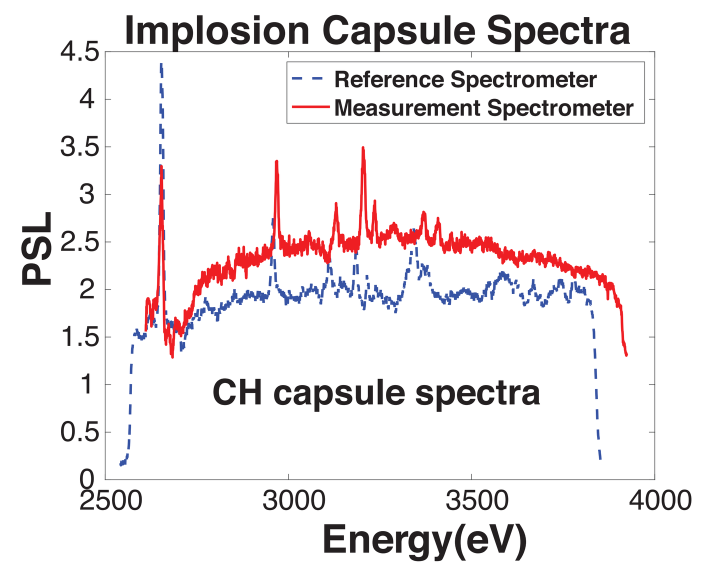
Ni Capsule Spectrum

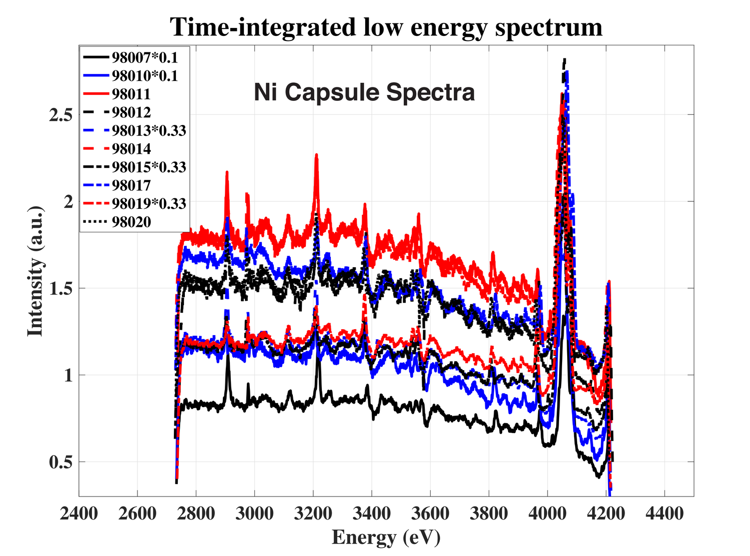


Ni k-shell lines

Omega Laser Facility

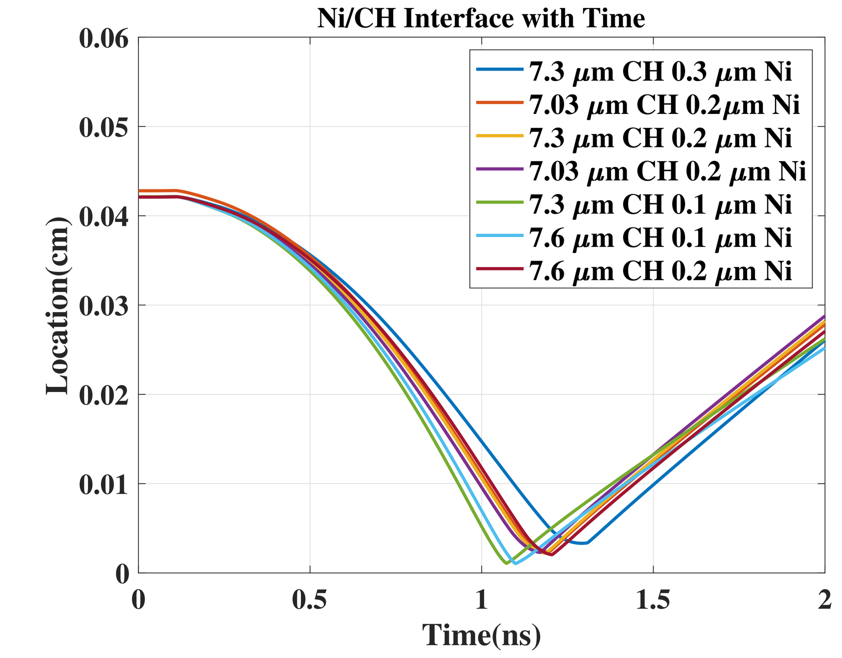


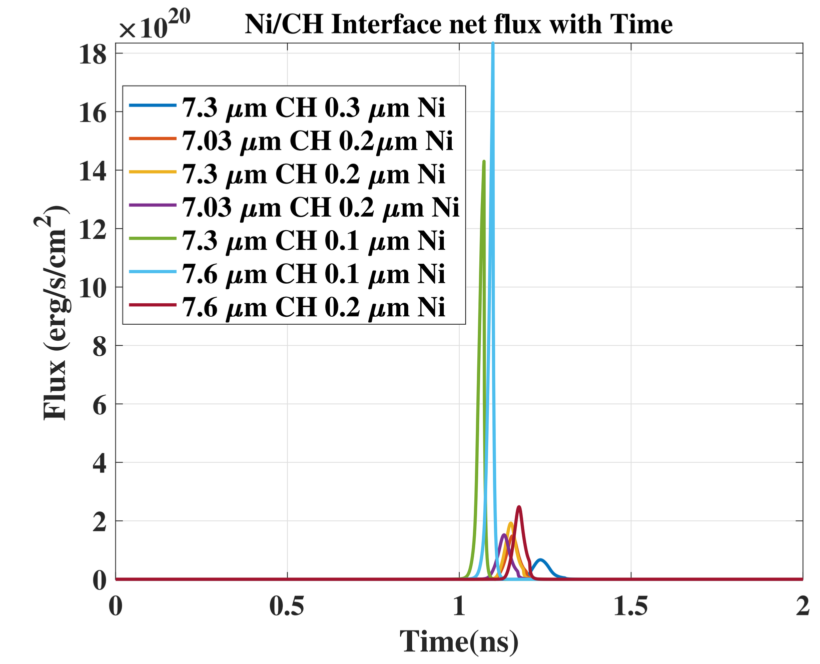




- 20 laser with 1 ns, square pulses and 800 μm spot diameter drive the capsule implosion
- Low energy spectra are similar between CH and Ni capsules

Plans to enhance the line emission





Pancake implosion

- Adjusting the layer thicknesses suggest moderate changes to diameter and stagnation time
- Lower mass leads to significant increase in total flux leaving Ni
- Pancake implosion should enhance emission in optically thick dimension[5]

Future Work

- Consider effects of photoionization in Ni layer near stagnation
- Additional experiments in 2021 to test line enhancement techniques

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References

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