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Absorption Spectroscopy of Aluminum and Magnesium Tracers in Low-Density CH_2 Foam Heated by Z-pinch Radiation

High-Temperature Plasma Diagnostics Conference

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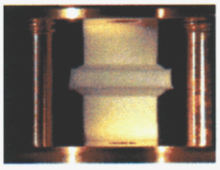
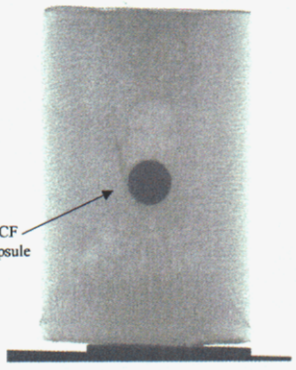
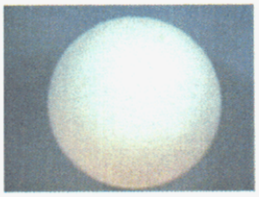
Low-density CH and CH_2 foams have become an important fixture in ICF and HEDP technology

Dynamic Hohraums

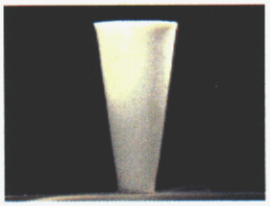




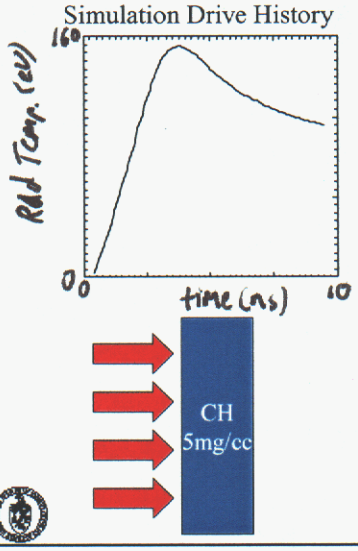
Capsules

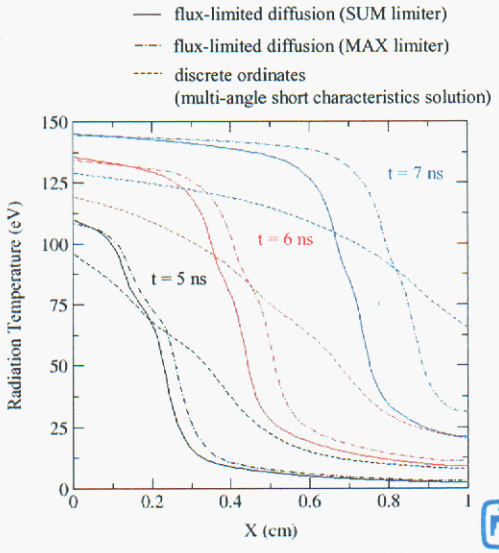


Shaped Implosions

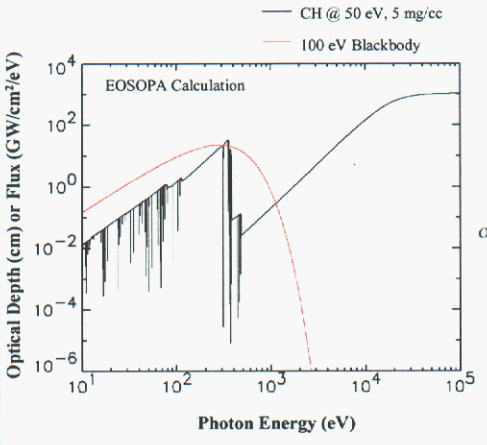


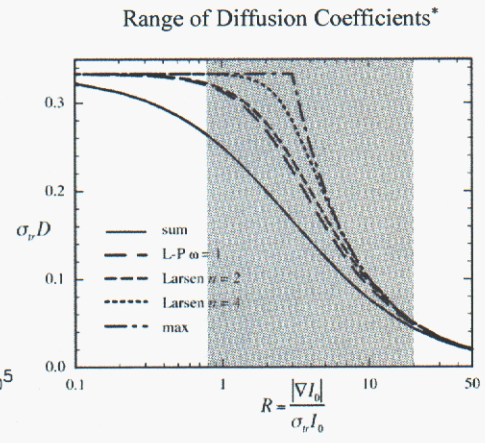
Different radiation transport approximations predict different propagation speeds in 5 mg/cc CH.





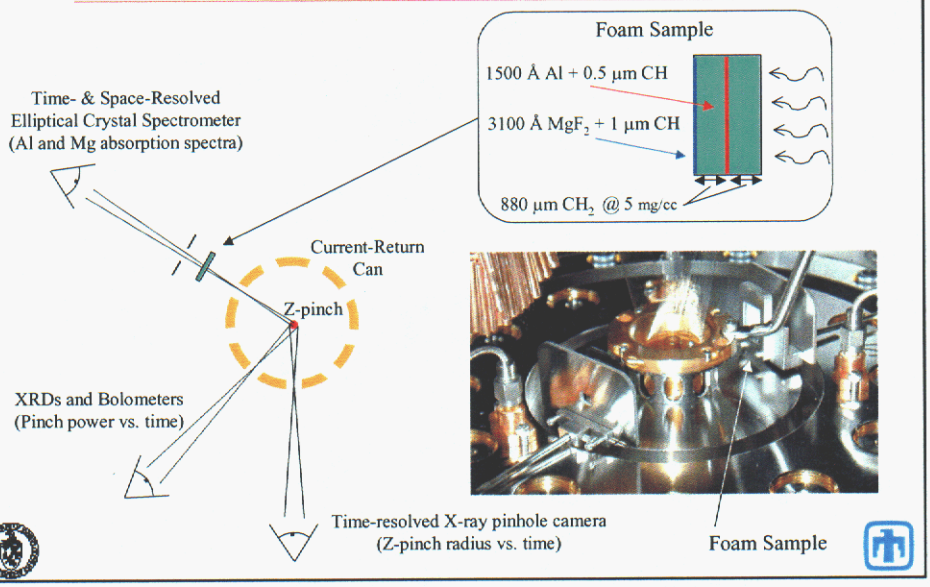
The scaled radiation energy gradient, R, in the CH foam is in a regime where the diffusion flux limiter is unphysical



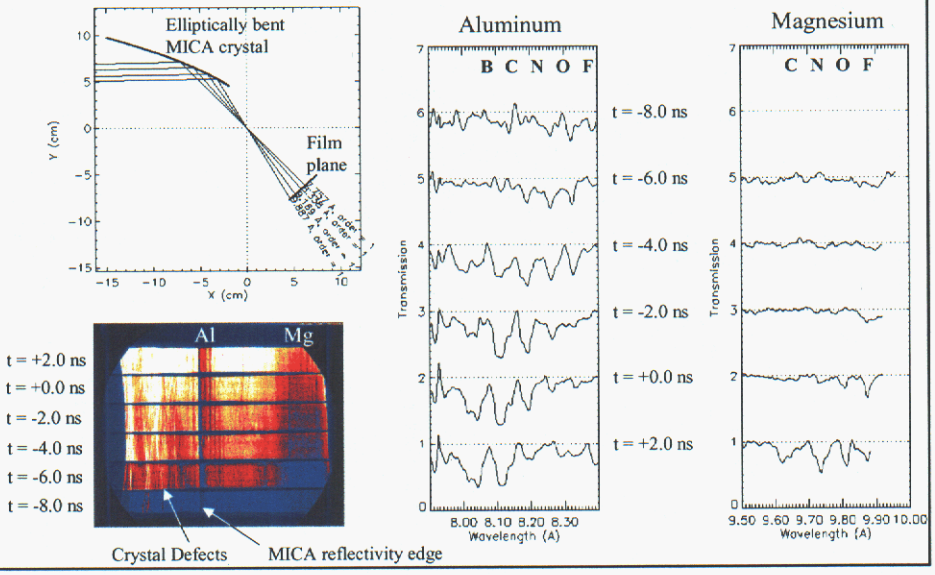


*G. L. Olson,et. al., J. Quant. Spectrosc. Radiat. Transfer, **64**, p. 619 (2000).

A 5 mg/cc CH_2 foam was fielded on Z shot #874 with Al and MgF_2 tracers to measure the relative heating at two different locations.



A time-resolved elliptical crystal spectrometer measured shifting charge states in the Al and MgF_2 tracers on Z shot #874.



Calculating the plasma conditions in the Al and MgF_2 tracers requires coupling together a number of simulations

Z-pinch Power vs. Time Data

Z-pinch Radius vs. Time Data

Simulation: Hardware Albedo vs. Time

Simulation: View Factors

Time and Frequency Dependent Radiation Boundary Condition

Simulation: Radiation-Hydrodynamics

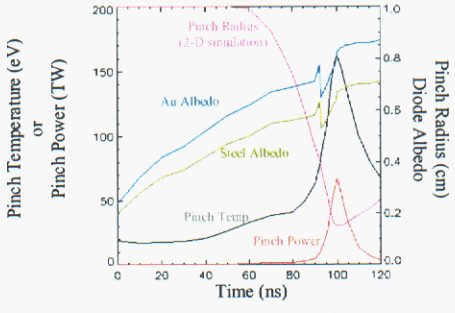
Plasma Density and Temperature Profiles

Simulation: Detailed Line Emission and Absorption

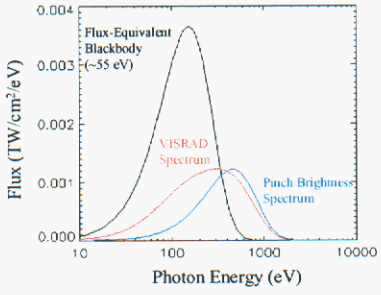
Time-Dependent Absorption Spectra

3-D simulations using the VISRAD view-factor code are utilized to calculate time-dependent, non-thermal drive spectra on the sample surface.

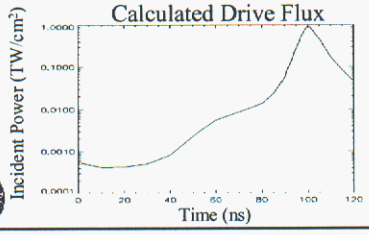
View-Factor Inputs



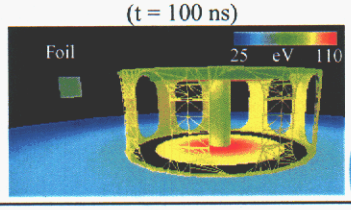
Incident Spectra at t = 100 ns



Calculated Drive Flux



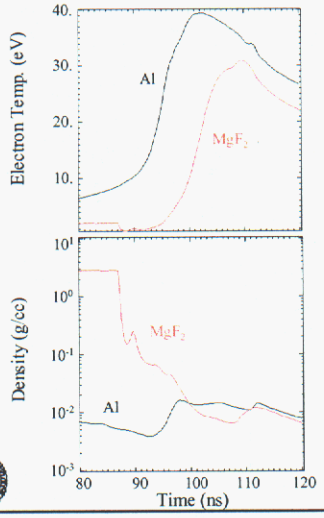
Incident Radiation Temperatures (t = 100 ns)



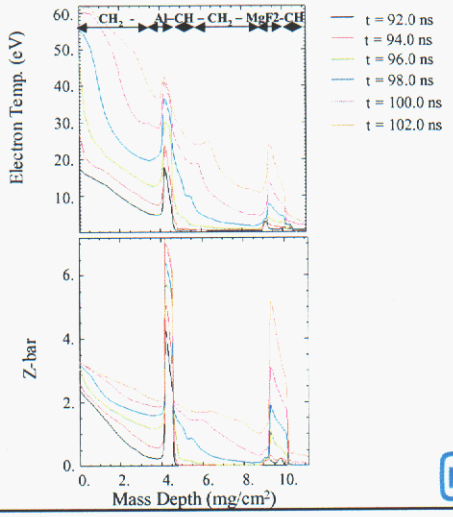
The plasma temperature and density evolution is calculated by the BUCKY 1-D radiation-hydrodynamics code.

(Radiation transport modeled with discrete ordinates assuming a 15% increase in measured z-pinch power)

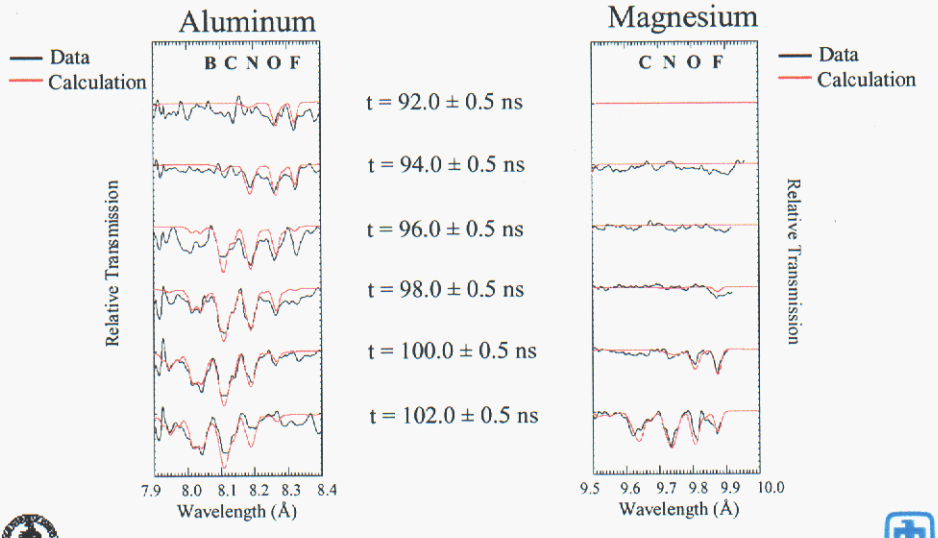
Average Conditions In the Al and MgF_2 Plasmas



Spatial Profiles of the Calculated Plasma Conditions



SPECT3D calculations of the atomic level populations under the calculated plasma conditions yields good agreement between the computations and the experimental data*.



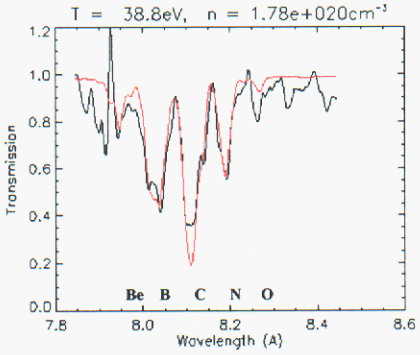
*Radiation transport modeled using discrete ordinates assuming a 15% increase in measured z-pinch power.

Each time-frame can be analyzed by an automatic chi-squared fitting program called SPECTROFIT.

SPECTROFIT

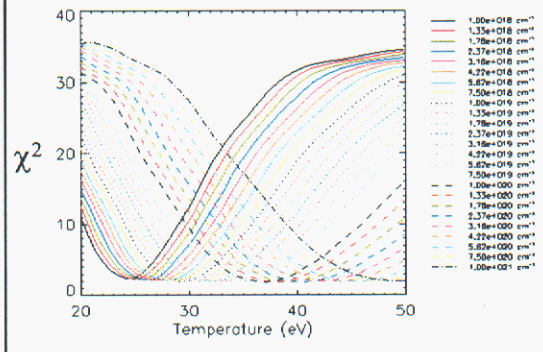
- Reads detailed line-opacity tables generated by the JATBASE/EOSOPA code
  - LTE and Non-LTE opacities
  - Arbitrary plasma mixtures
- Compares two relative transmission absorption spectra (i.e. experiment vs. calculation) at discrete temperatures and densities.
- Computes chi-squared fit parameter for a user-defined grid resolution over a specified temperature and density range.
- Reports fit-variance, χ^2, and $+1\sigma$

Comparison between Al K-α spectra at t = 100 ns, and a SPECTROFIT best fit (χ^2 = 1.91)

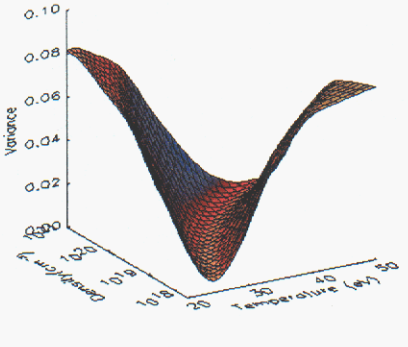


The SPECTROFIT χ^2 and fit-variance curves show the contour in temperature-density phase space where the calculated spectra best match the data.

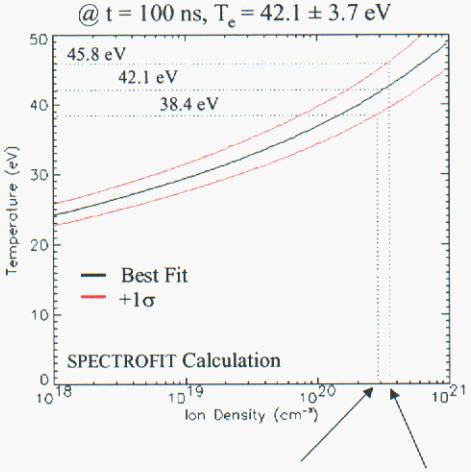
χ^2 plots at discrete densities for the comparison between the Al data at t = 100 ns, and the calculated spectra.

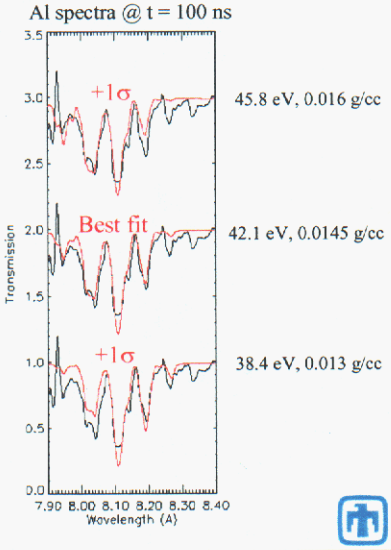


Fit variance over the searched T-ρ phase space for the Al spectrum at t = 100 ns.



The average density in the Al and MgF_2 layers under the ± 25% uncertainty level in the measured z-pinch power can be used to place error-bars on the inferred temperature at each time frame.

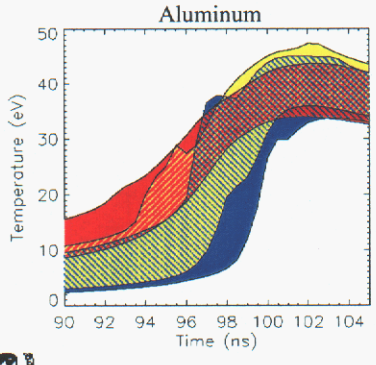


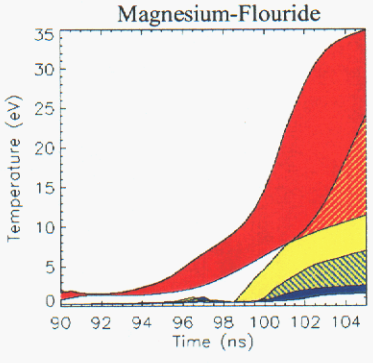


Using discrete ordinates radiation transport, the calculated average Al densities at +- 25% measured power are: 0.013 g/cc and 0.016 g/cc

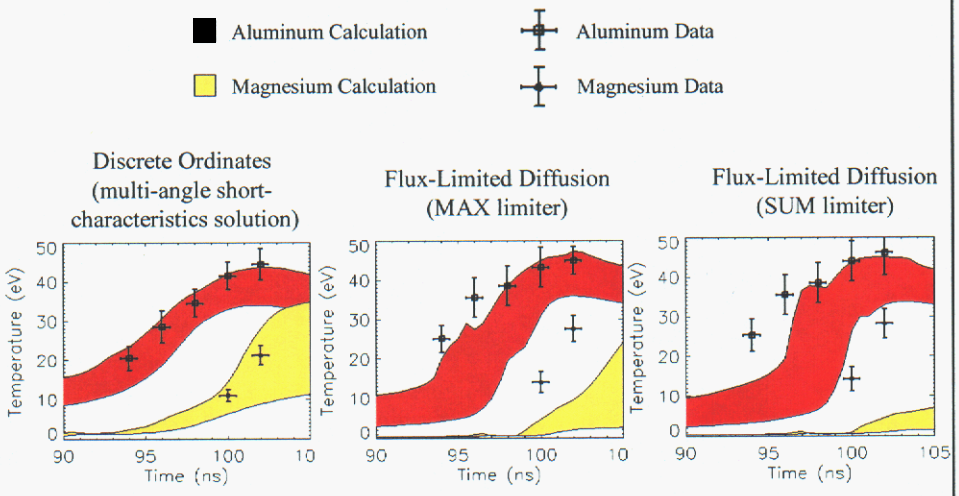
Including the ± 25% uncertainty in measured z-pinch power, different radiation transport methods predict a wide-range of temperature conditions in the Al and MgF_2 tracers.

- Discrete Ordinates
- Flux-Limited Diffusion (MAX limiter)
- Flux-Limited Diffusion (SUM limiter)
- Discrete Ordinates or Flux-Limited Diffusion (MAX limiter)
- Flux-Limited Diffusion (MAX or SUM limiter)
- Discrete Ordinates or Flux-Limited Diffusion (SUM limiter)
- All





Despite this uncertainty, the data from the experiment clearly indicates that flux-limited diffusion is too restrictive, suggesting that discrete ordinates is a much more accurate transport method.



Summary and Hypothesis

- Calculations indicate that 5 mg/cc CH_2 foams have an optical depth in a regime where flux-limited diffusion may not provide an accurate predication of the radiation transfer speed.
- A 5 mg/cc CH_2 (TPX) foam was fielded on the Z machine for shot #874 with Aluminum and Magnesium-Fluoride tracers buried at different depths.
- Z-pinch backlit K-shell absorption spectra of the shifting Aluminum and Magnesium charge states provide information on the time-dependent heating of the tracers under the z-pinch x-ray emission.
- The SPECTROFIT chi-squared fitting code was utilized in conjunction with radiation-hydrodynamics calculations of the time-dependent density conditions in the Aluminum and Magnesium-Fluoride layers to infer the time-dependent temperature profile in the two tracers.
- Direct comparison between the inferred heating profiles and radiation-hydrodynamics calculations using different radiation transport approximations suggests that Discrete Ordinates provides a much more accurate solution to the radiative transfer speeds in 5 mg/cc CH_2 foam than the standard Flux-Limited Diffusion approximation.