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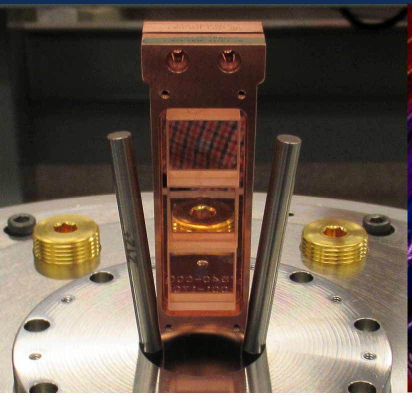

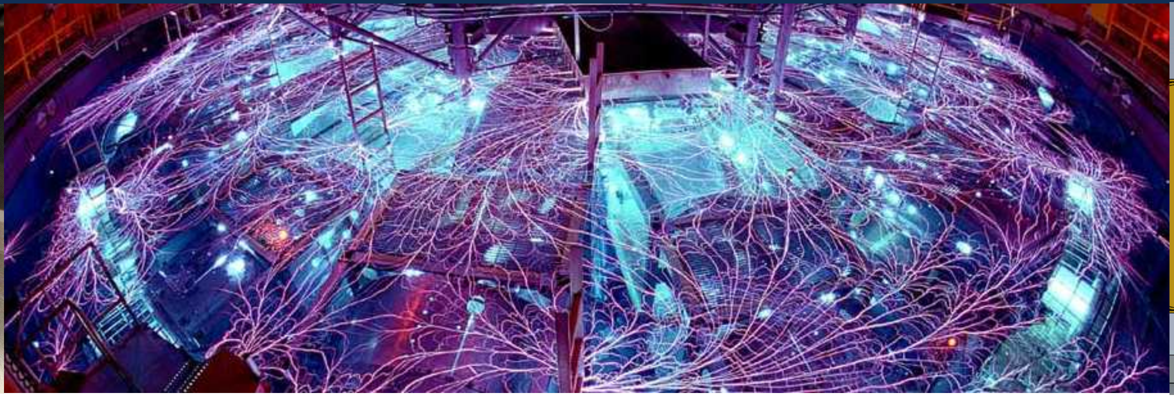

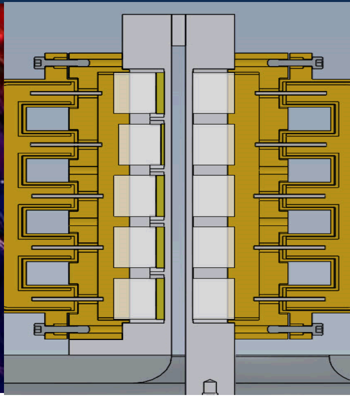

Ramp Compression of Polymer Binded Explosives Using Sandia's Z Machine

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Experimental Goals

- Ramp compression can provide unreacted equation of state (EOS) measurements on energetic materials
  - Reach higher pressures than with shock compression
- Quasi-isentropes obtained from ramp compression experiments can help in refining computational models
  - Explosive and reaction products EOS
- Previous ramp compression experiments in 2009 measured the quasi-isentrope of PBX 9502 to 32 GPa [1]
- The goal of this work was to measure the quasi-isentrope of PBX 9502 to 50 GPa

[1] M. Baer et al. AIP Conf. Proc. **1195,** 699 (2009).

Experimental Method

- Magnetic ramp compression enables a continuous measurement of a material's quasi-isentrope
  - Quasi-isentrope because its not completely reversible

- Current flow between the anode and cathode generate a strong magnetic field
  - The resulting Lorenz force, **P** = **J** x **B**, compresses the sample

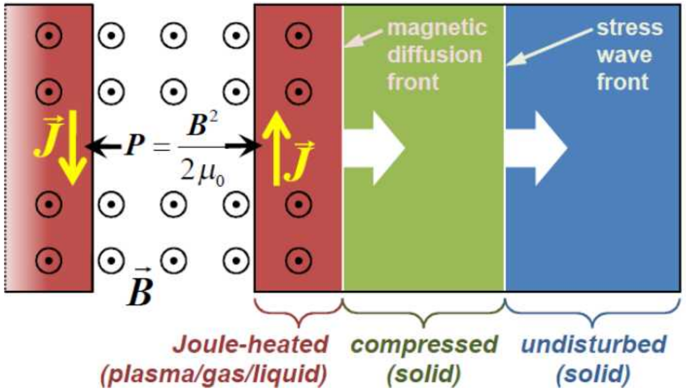
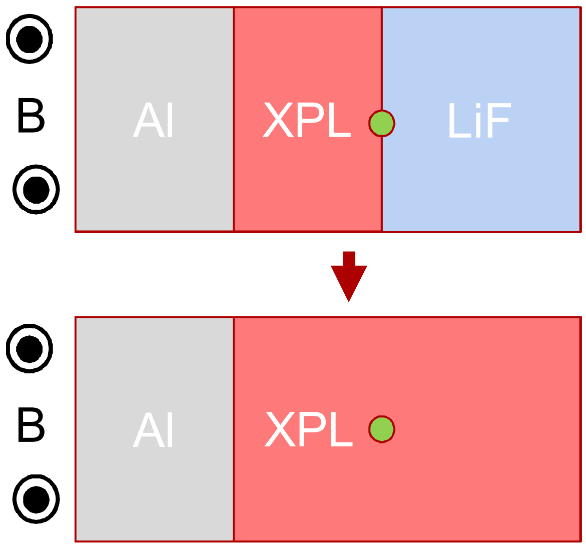
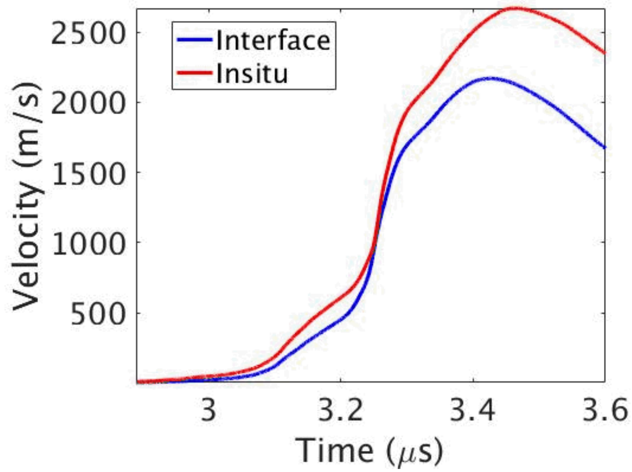


Image from Glover et al. IEEE Trans. Plasma Sci. **40** (2012).

Quasi-Isentrope Determination

- Usually velocimetry measurements are at window interfaces
  - Need to be related to Lagrangian, or insitu, velocities
- There are two mapping methods
  - Inverse Lagrangian analysis (ILA) [2]
    - Iterative method of characteristics approach
  - Transfer function method [3]
    - Iterative approach using MHD simulations and Fourier transforms
- In this work we used the transfer function method

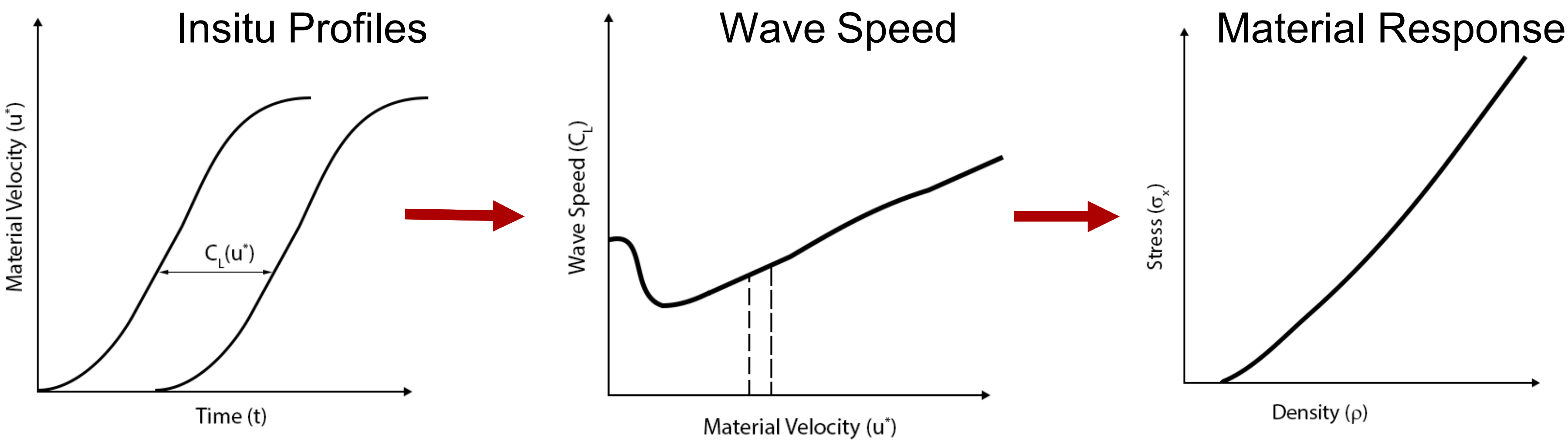




[2] J.P. Davis et al. J. Appl. Phys. **116**, 204903 (2014). [3] Brown et al., J. Appl. Phys. **114**, 223518 (2013)

Quasi-Isentrope Determination

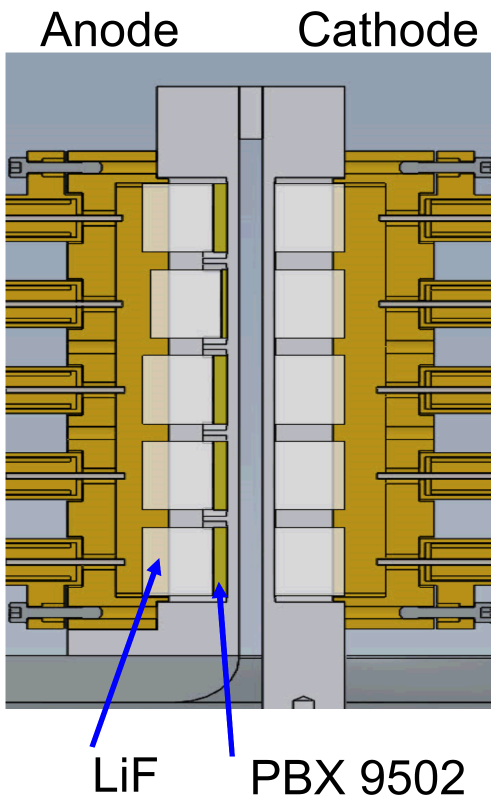
- Quasi-isentrope is determined with Lagrangian, or *insitu*, material velocities at two locations in the sample [2]
  - Direct Lagrangian analysis
    - $dv = -\frac{-du^*}{\rho_0 C_L(u^*)}$ $\quad d\sigma_x = \rho_0 C_L(u^*)du^*$
  - Assumes simple, steady waves

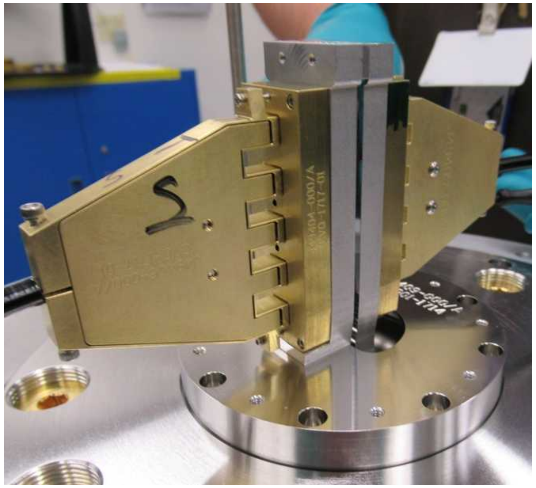


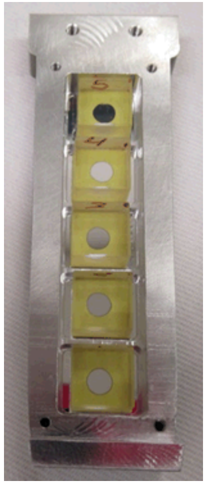
[2] J.P. Davis et al. J. Appl. Phys. **116**, 204903 (2014).

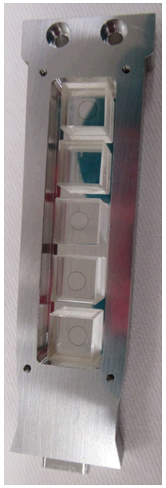
Experimental Parameters

- 5 PBX 9502 Samples
  - Ranging from 0.4 to 1.0 mm thick
- Stripline geometry
  - Aluminum panels with 1.0 mm floor thickness
  - 2mm AK gap
  - LiF windows with Al deposited mirrors
  - Interface velocities recorded with VISAR
  - Drive measurements for each sample



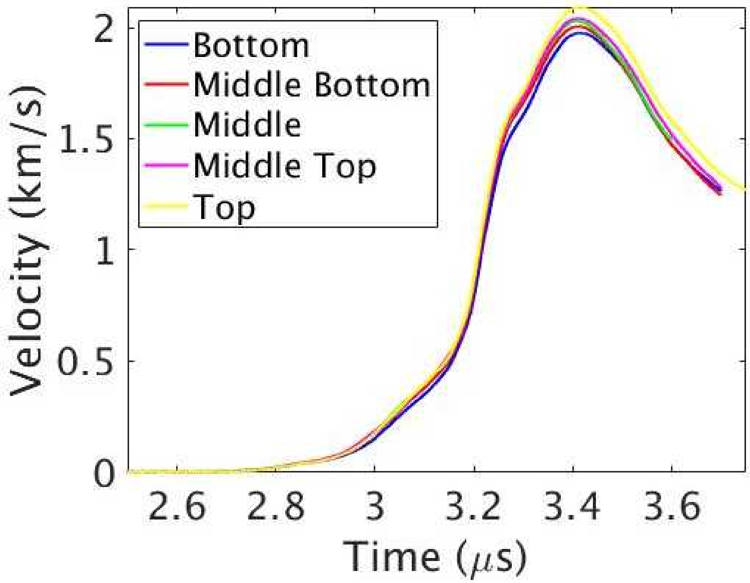


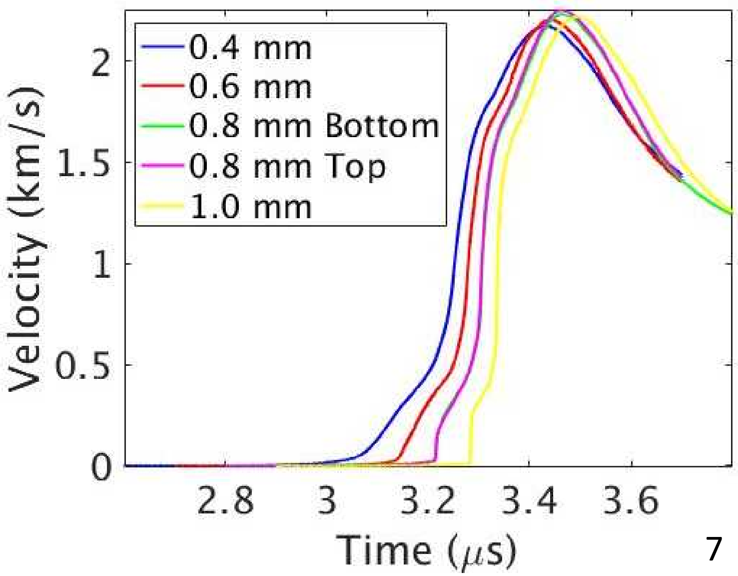




Experimental Results

- The VISAR records for both the drive and sample measurements were corrected using the method developed by Davis [3]
  - Iterative technique utilizing 1D hydrocode simulations to numerically determine the window correction
    - Accounts for temperature effects

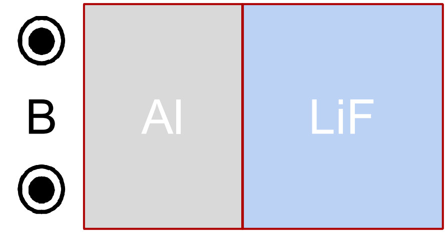


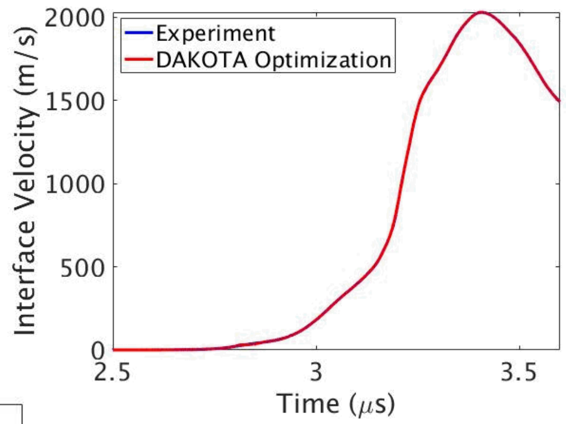


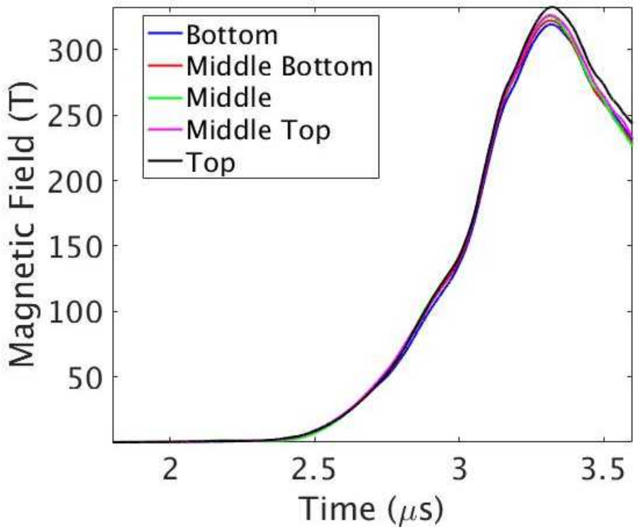
[3] J. Davis et al., J. Appl. Phys. **120**, 165901 (2016)   [4] Brown et al., J. Appl. Phys. **114**, 223518 (2013).

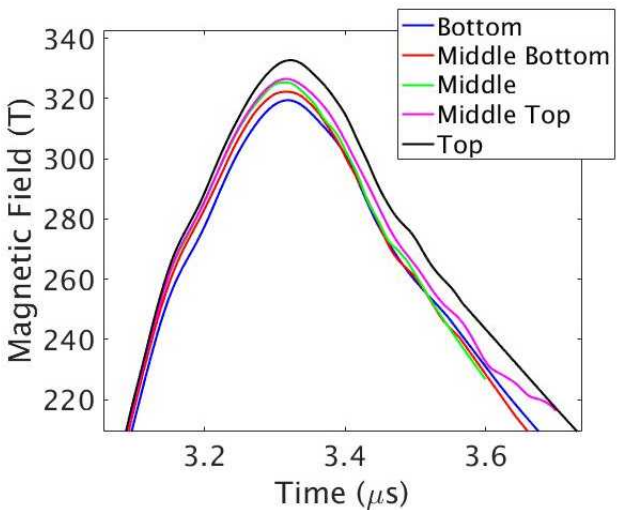
Magnetic Drive Determination

- The magnetic drive opposite each sample was determined with a DAKOTA optimization
  - Utilized 1D LASLO simulations to match the measured drive
    - Assumes properties of the Al and LiF standards are well known
  - Enables correction for variations in drive over the height of the panel



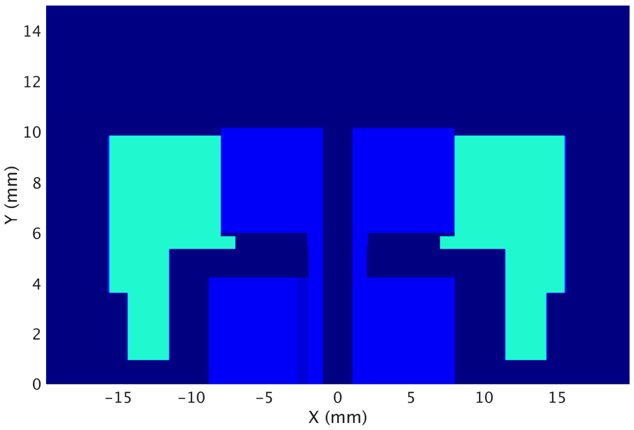




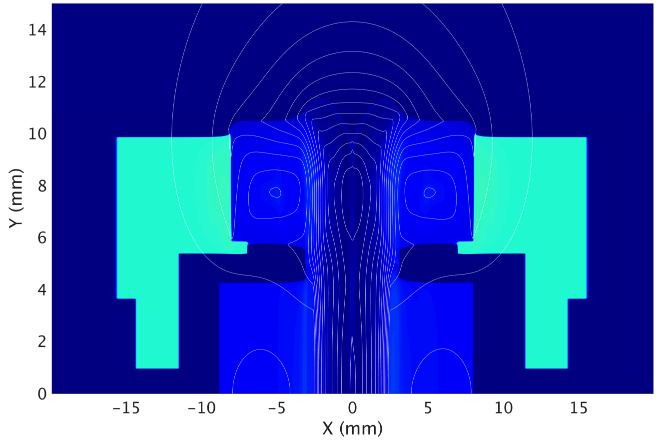


Symmetry Determination

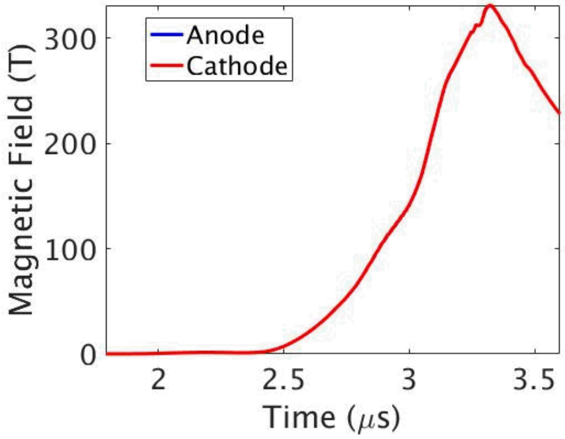
- Deformation during the experiment can invalidate assumption of symmetry
  - Drive determined from cathode may not match that experience by anode
    - Due to geometric changes resulting from deformation
- 2D ALEGRA simulations were performed to ensure both anode and cathode see identical drives over the entire experiment



t = 0

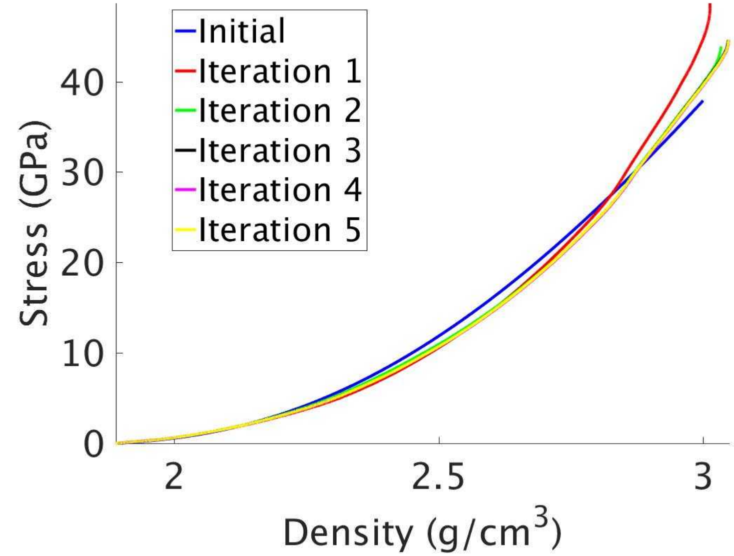


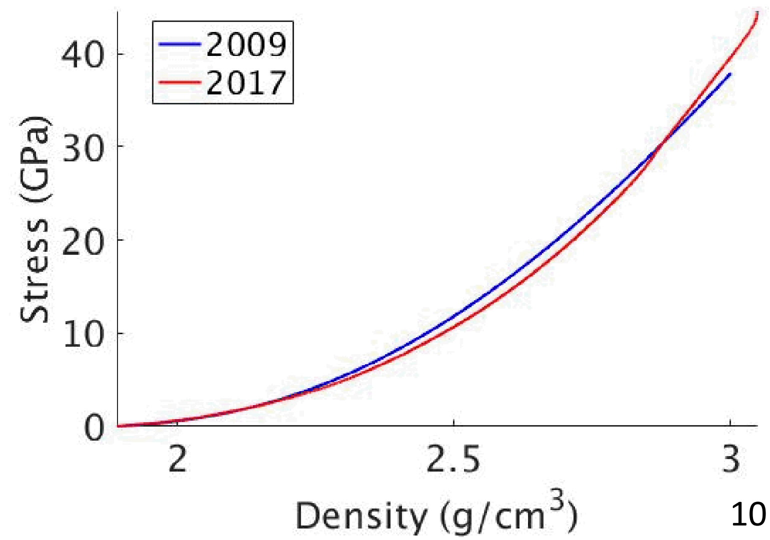
t = Peak Current



Quasi-Isentrope Determination

- Iteratively applied the transfer function technique to determine the quasi-isentrope of PBX 9502
- The quasi-isentrope obtained was to 45 GPa
  - Jitter in the discharging of the Marx generators lead to slightly lower pressure than desired
- The measured quasi-isentrope is softer at lower pressures and stiffer at higher pressures





Conclusions and Future Work

- Successfully measured the quasi-isentrope of PBX 9502 to 45 GPa
  - Higher than previous experiments
  - Utilized a stripline geometry for more accurate results
  - Provides valuable information for model validation and calibration

- Future work
  - Employ a Bayesian error estimation technique to quantify the uncertainty in these measurements
  - Another Z experiment is planned for 2018 on PBX 9501
  - Interest in ramp compression work at lower pressures on THOR with additively manufactured (AM) explosives