UCRL-CONF-203095

Observation of a Laser-Driven Shock-Induced Phase Transition in KTP

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March 22, 2004

American Physical Society March Meeting 2004
March 22-26, 2004

Palais des Congres de Montreal
Montreal, Quebec, Canada

This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

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1) Why KTP?
2) Shock Induced Phase Transitions.
3) Experiment.
4) Conclusions.

Laser-Driven Shocks

Drive Characteristics:

- Very high potential pressures
- Short time scales (several ns)
- Small sample sizes and thicknesses (<1 mm, ~50 μm)
- Planarity and shock steadiness issues.
- Visar measurements of velocities

Sample Requirements:

- Fast dynamics
- Large volume discontinuities
- Transparent samples
- Steady drives

Why KTP?

KTP (Potassium Titanyl Phosphate) may be an appropriate material for high quality phase transition study using laser shocks

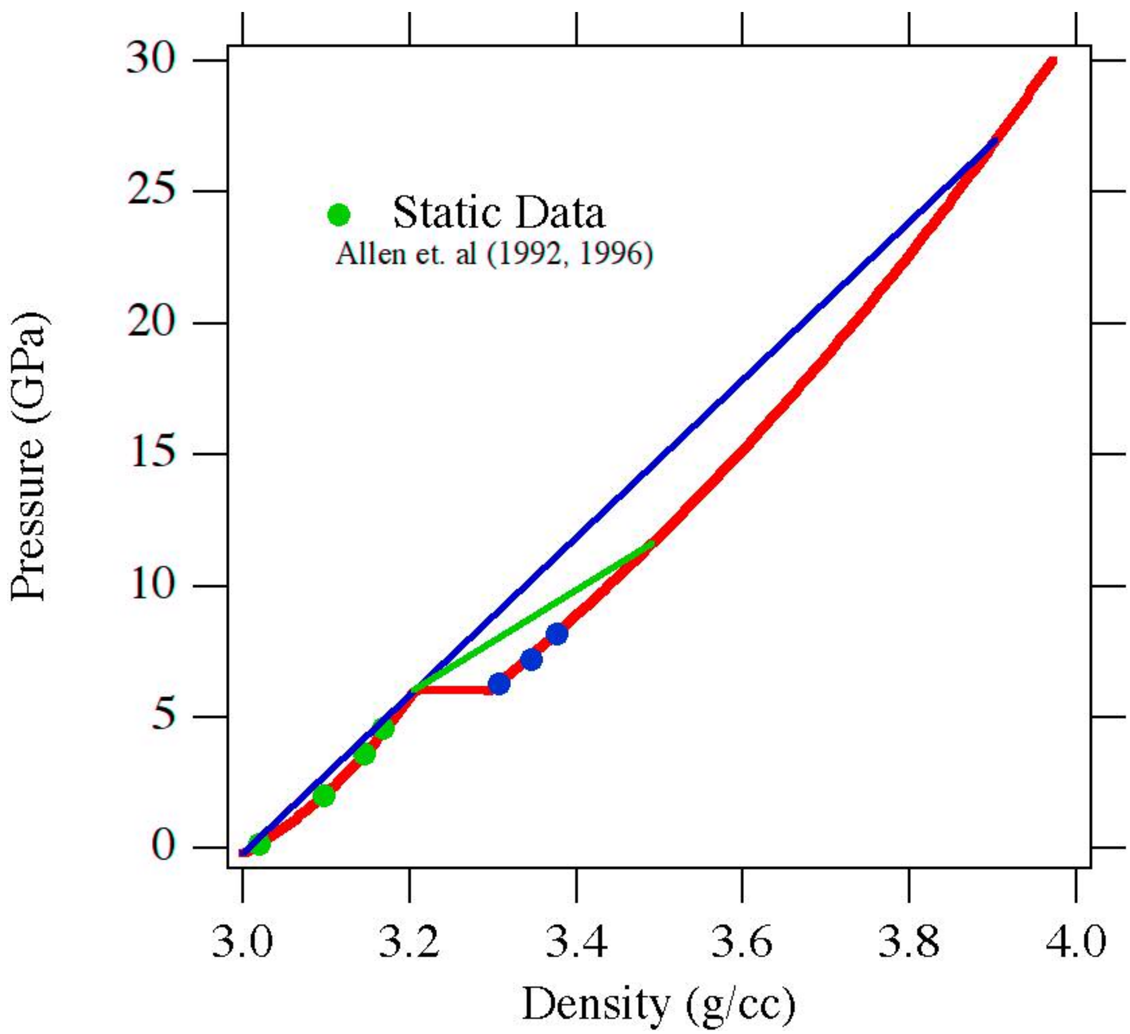
- Phase transition at 5.8 GPa is isosymmetric (no change in space group).
- Phase transition volume discontinuity (2.8%) is nearly one-dimensional (0.3%, -0.1%, 3.5% in *a*, *b*, *c* respectively).
- Orthorhombic ($Pna2_1$), biaxial crystal with large non-linear suseptibility.

- Transition should be very fast
- Mechanism may depend on orientation.
- Transparent sample allows Visar measurements of shock and particle speeds.

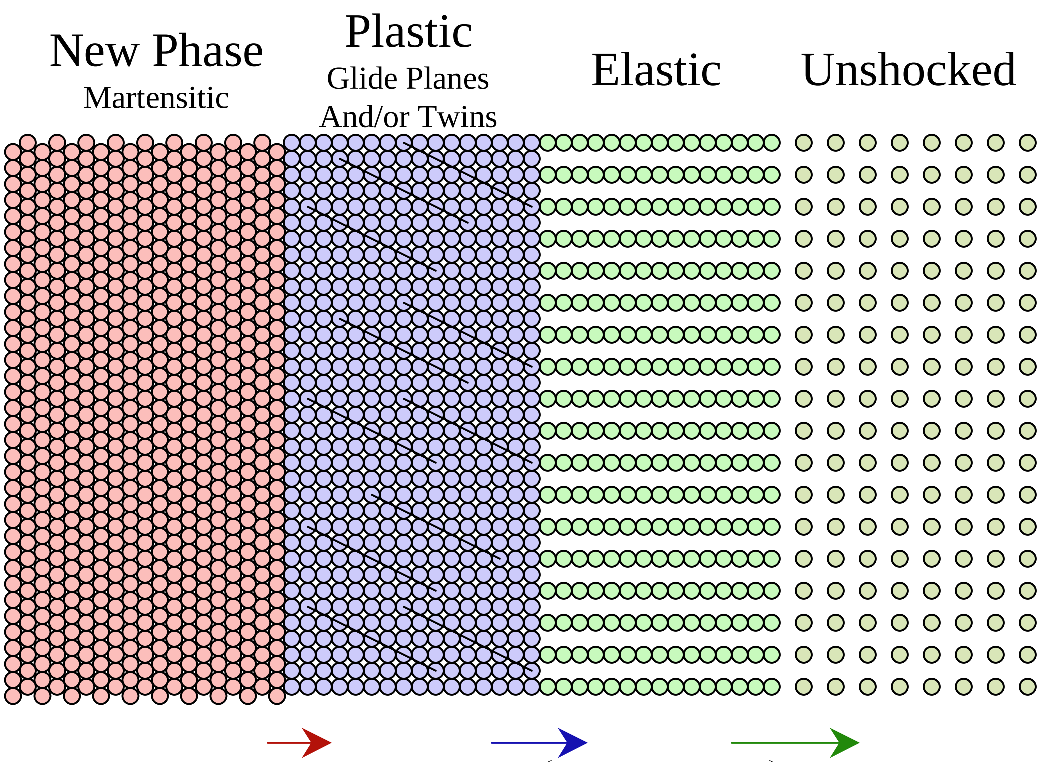
Phase Transitions => Multiple Shocks

$$C(P,\rho) = \left[\frac{\partial P}{\partial \rho}\right]^{\frac{1}{2}}$$

$$U_s(P,\rho) = \left[\frac{\rho(P - P_0)}{\rho_0(\rho - \rho_0)}\right]^{\frac{1}{2}}$$



Multiple Shocks



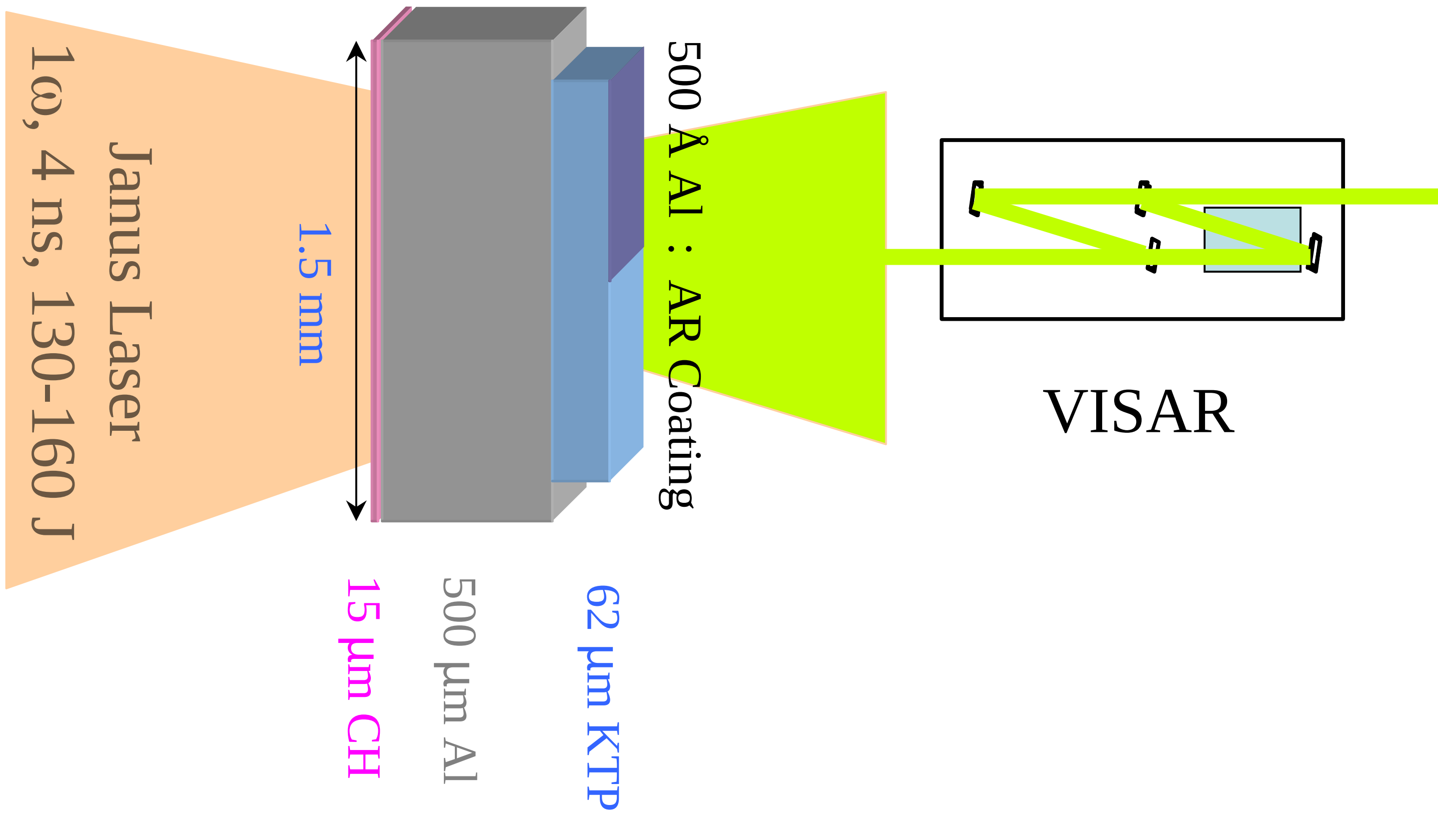
$$\begin{Bmatrix} P_x & 0 & 0 \\ 0 & P_x - P_{cr}^* & 0 \\ 0 & 0 & P_x - P_{cr}^* \end{Bmatrix} \begin{Bmatrix} P_x & 0 & 0 \\ 0 & P_x - P_{cr} & 0 \\ 0 & 0 & P_x - P_{cr} \end{Bmatrix} \begin{Bmatrix} P_x & 0 & 0 \\ 0 & \frac{\sigma}{1-\sigma} P_x & 0 \\ 0 & 0 & \frac{\sigma}{1-\sigma} P_x \end{Bmatrix} \quad \begin{Bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{Bmatrix}$$

Three-wave structure: eg. Iron

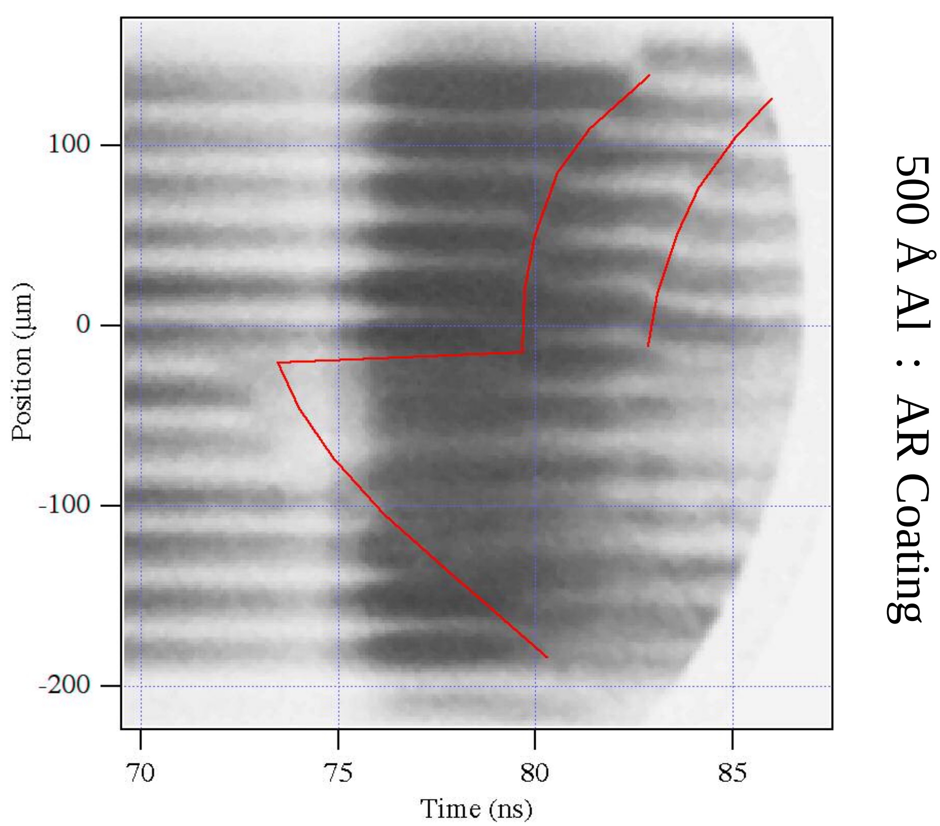
Or two-wave structure: eg. CdS, InSb

Free-Surface Velocity:

Experiment

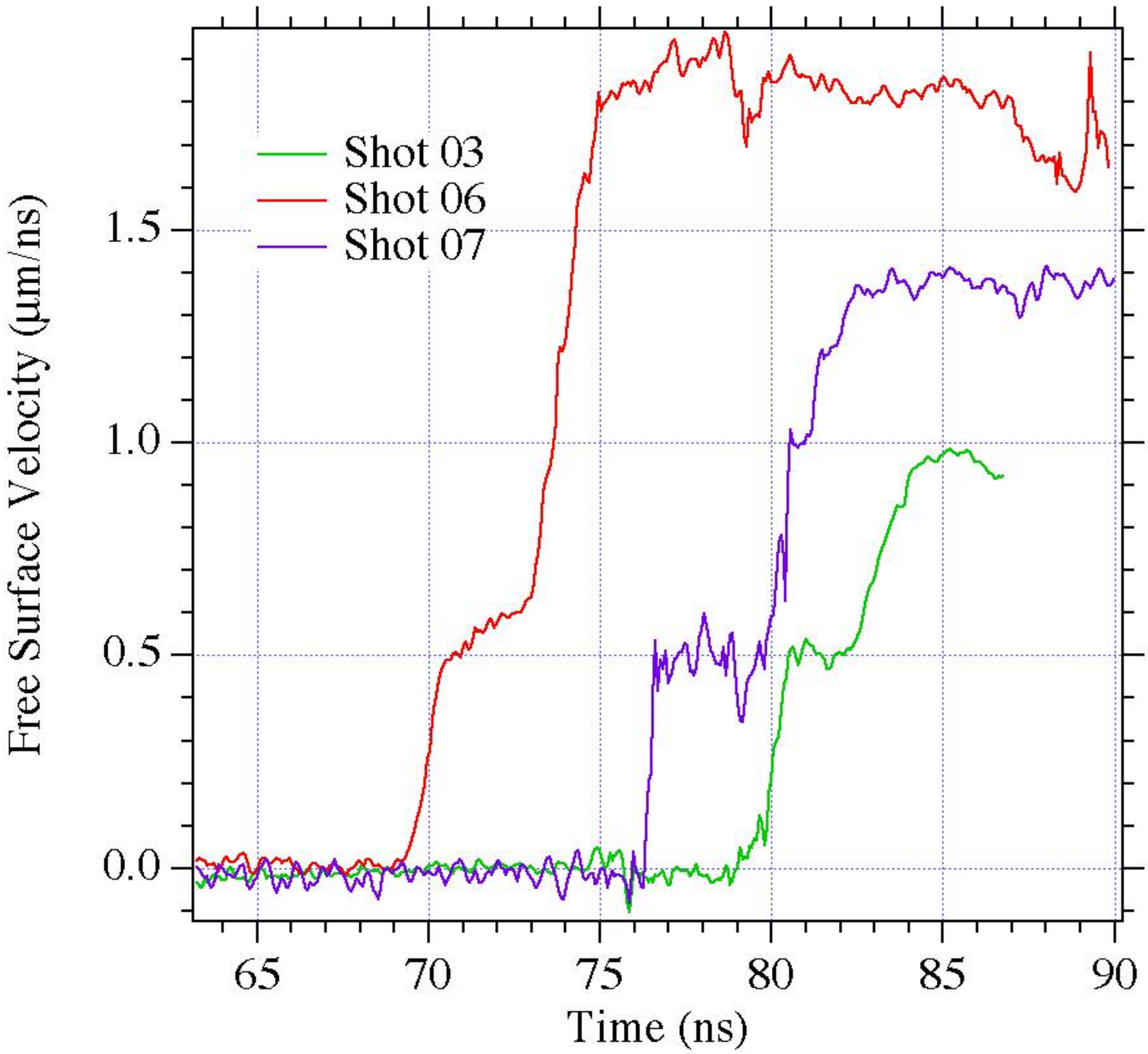


1ω, 4 ns, 130-160 J
Janus Laser
1.5 mm
500 Å Al : AR Coating
15 µm CH
500 µm Al
62 µm KTP
VISAR



100
0
-100
-200
Position (µm)
70
75
80
85
Time (ns)
500 Å Al : AR Coating

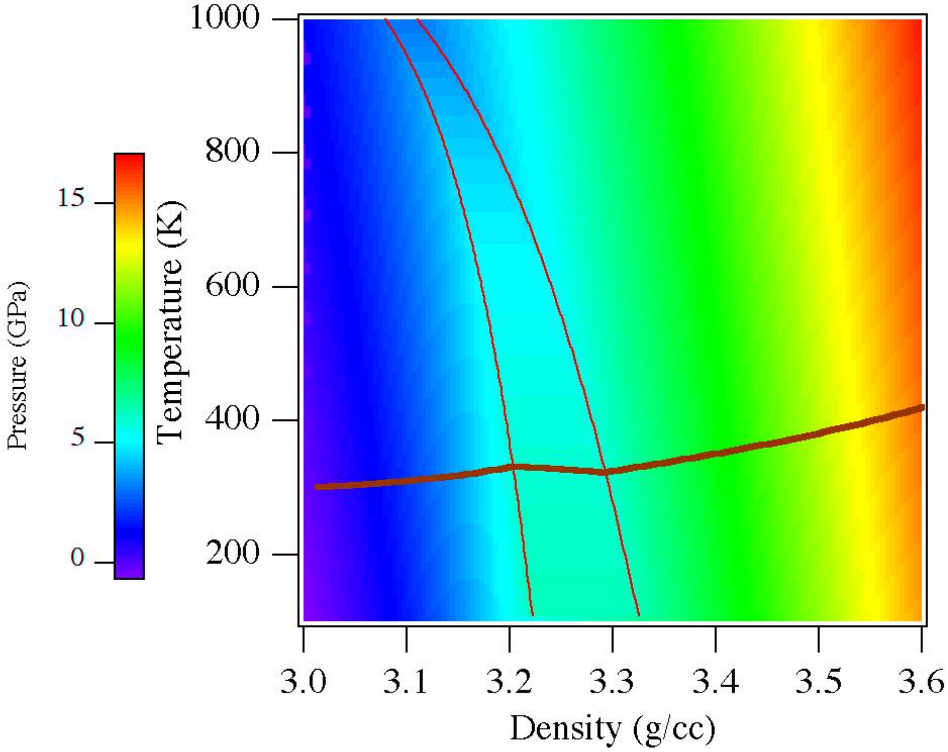
Free-Surface Velocities

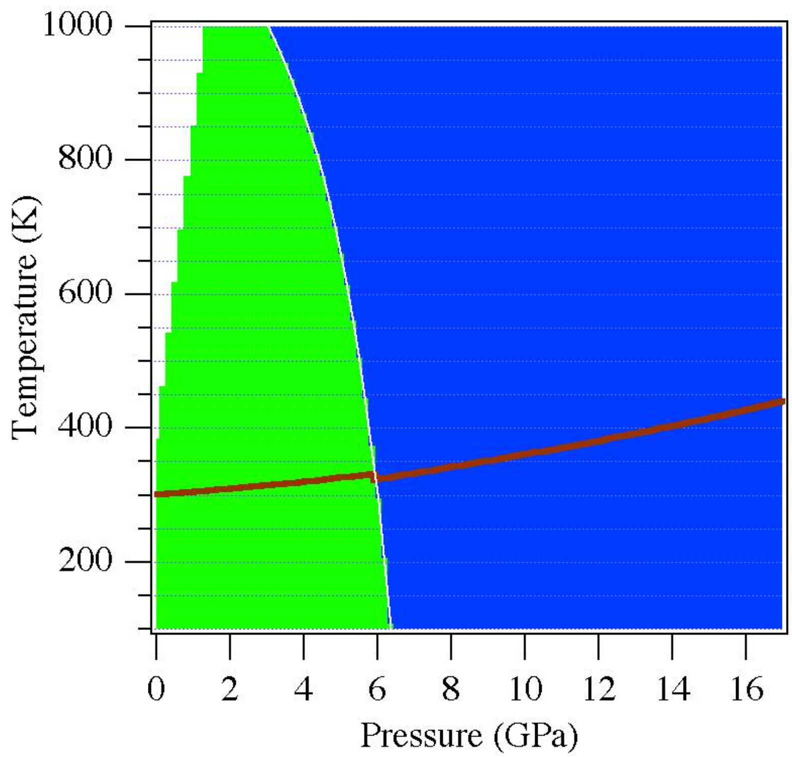


Double shock represents Phase Transition or Elastic-Plastic Transition.

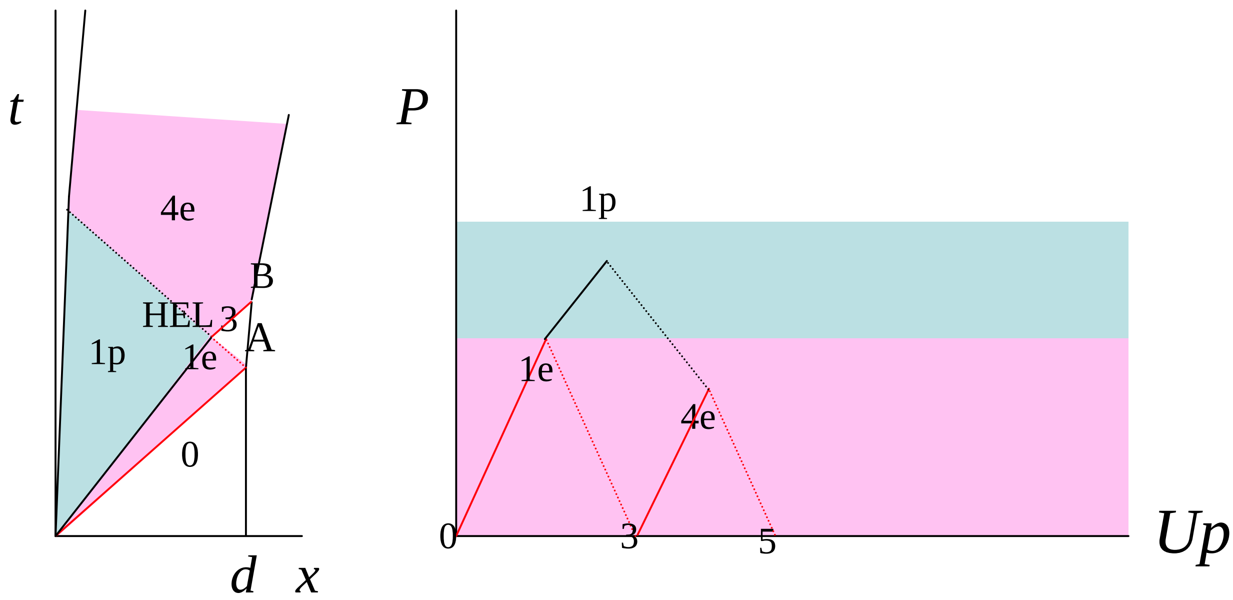
Multi-Phase EOS

Analytic Helmhotz free energy fit to cold curve and thermal expansion.



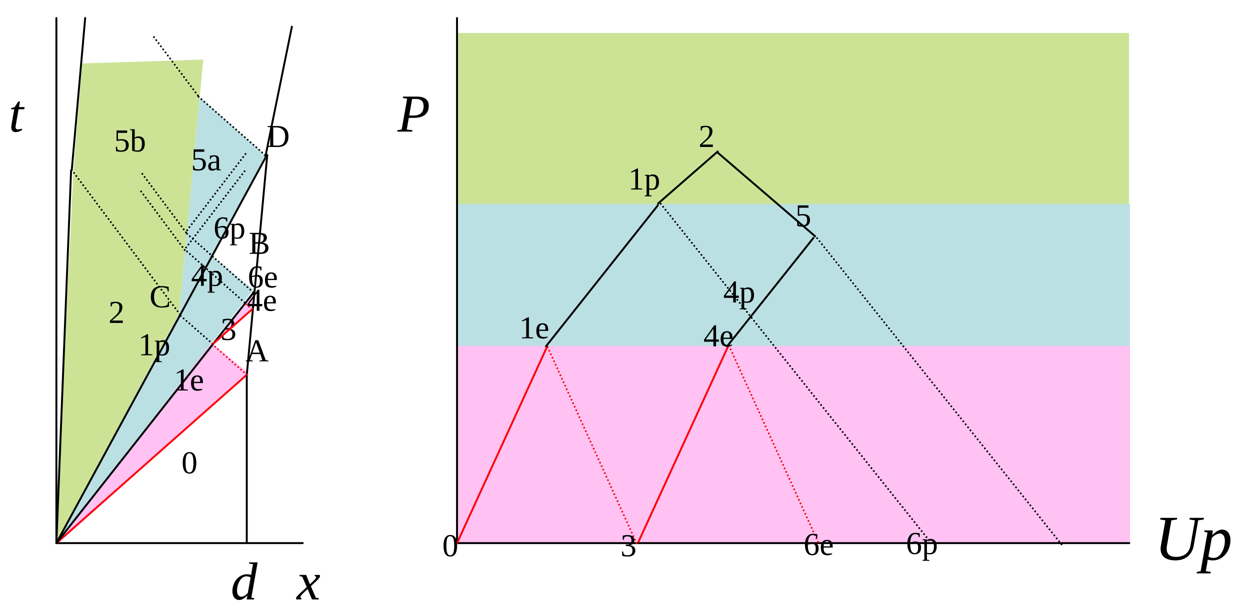


Phase Transition vs. Elastic-Plastic



Solid -- Shocks Dashed -- Release

Red -- Elastic Black -- Plastic



Solid -- Shocks Dashed -- Release

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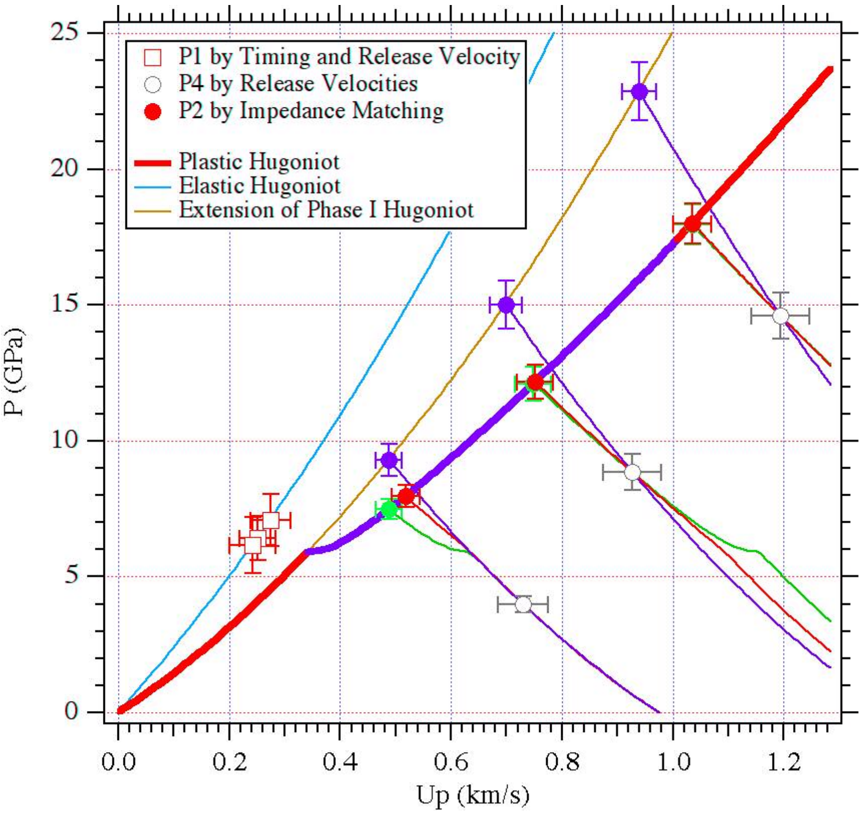
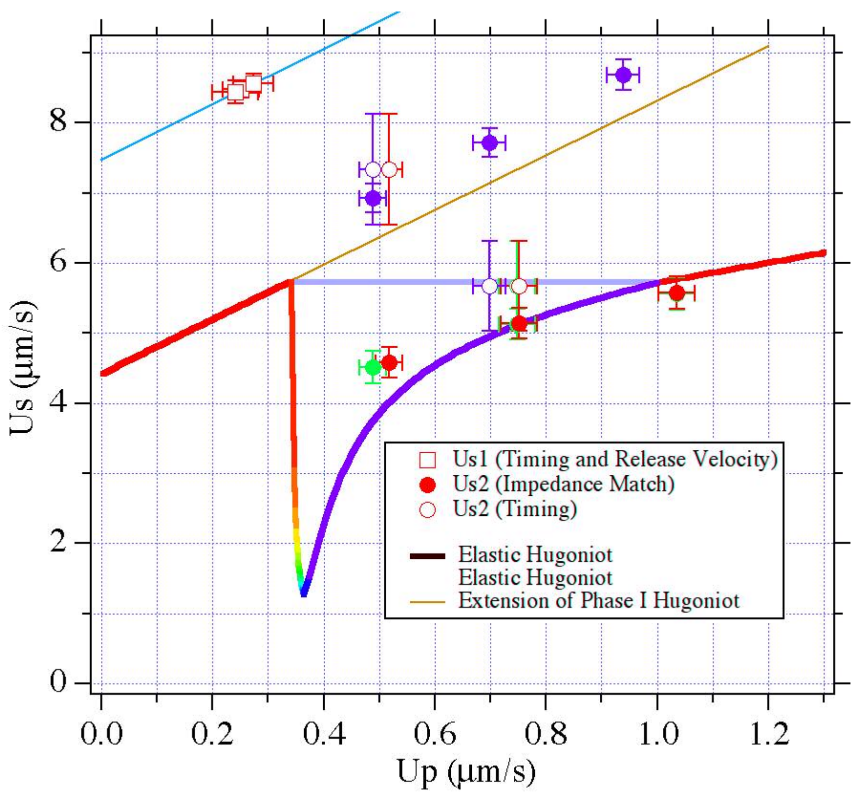
Pressure and Us





Conclusions

- We see definite two-wave structure in KTP between 6 and 7 GPa. Static phase transition at 5.8 GPa.

- Future experiments to exclude possibility of plastic-elastic transition.

- Future experiments to look at transition dynamics.

- Future experiments to study orientation dependence of transition.