Study and Application of Laser Driven Shock Wave

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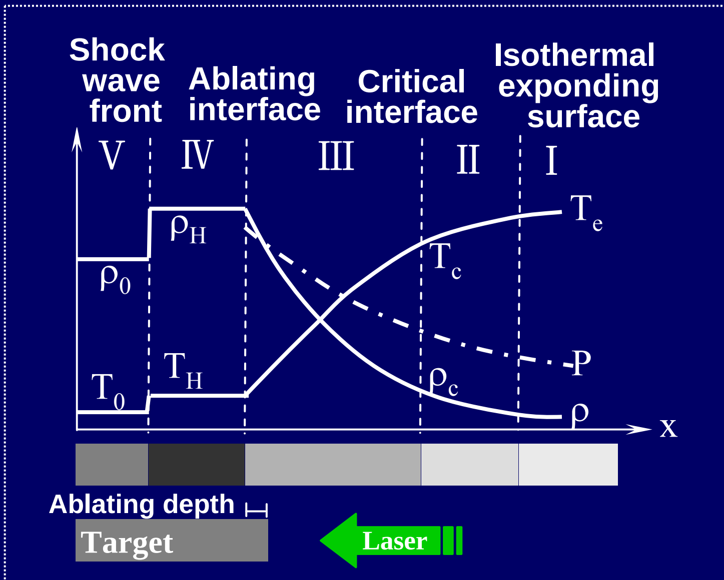
Outline For Shock Wave



	Features
I	Free spread
II	Laser absorption
III	Conduction of electron & radiation
IV	Compression
V	undisturbed

Properties' study:

* Shock planarity
* Shock stability
* Shock cleanness
* ……

Application:

* Shock adiabatic data
* Isentropic release after intense shock
* Off-Hugoniot compression with multi-shocks
* Isentropic compression with shocked flyer (as plasma energy reserve with density distribution)
* Radiation temperature measurement by shock wave
* Shock-timing for ignition
* …….

Shock Wave

Source

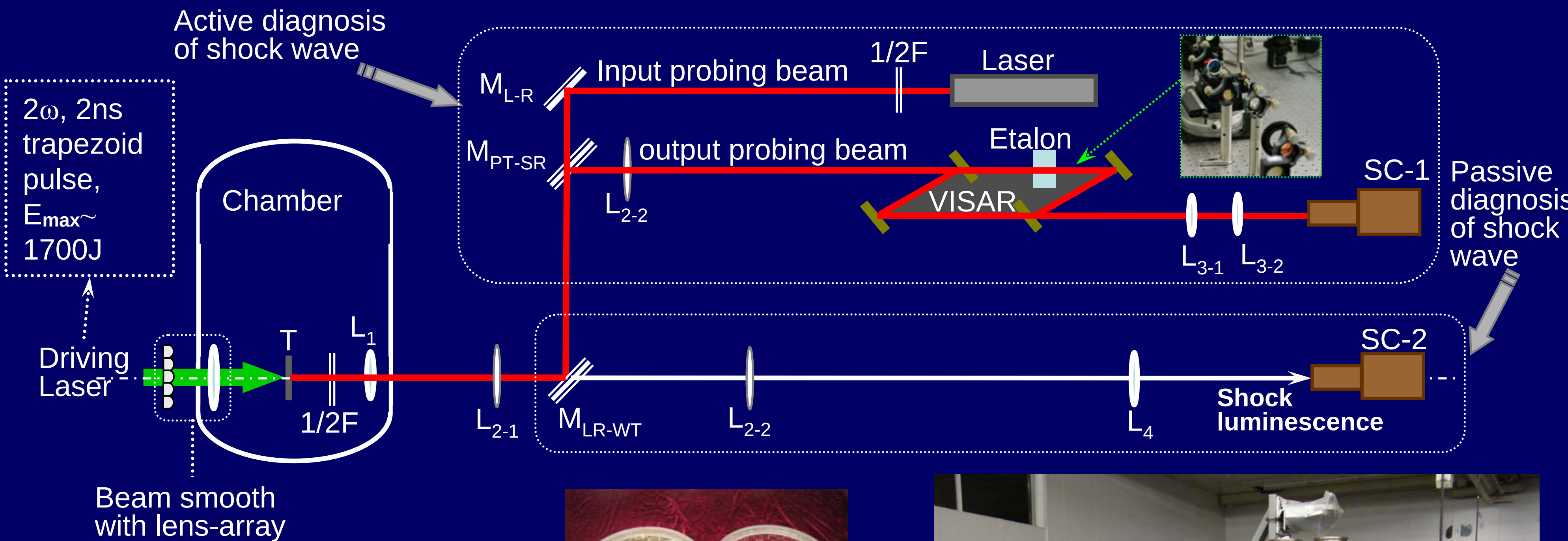
High power laser

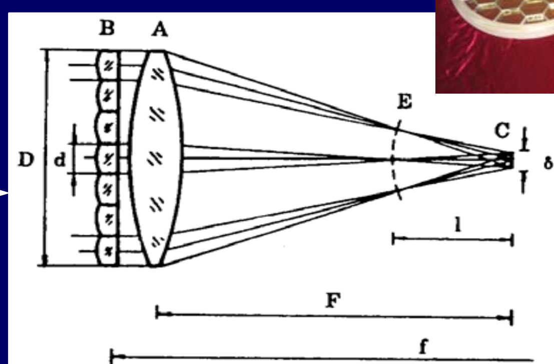
Interaction

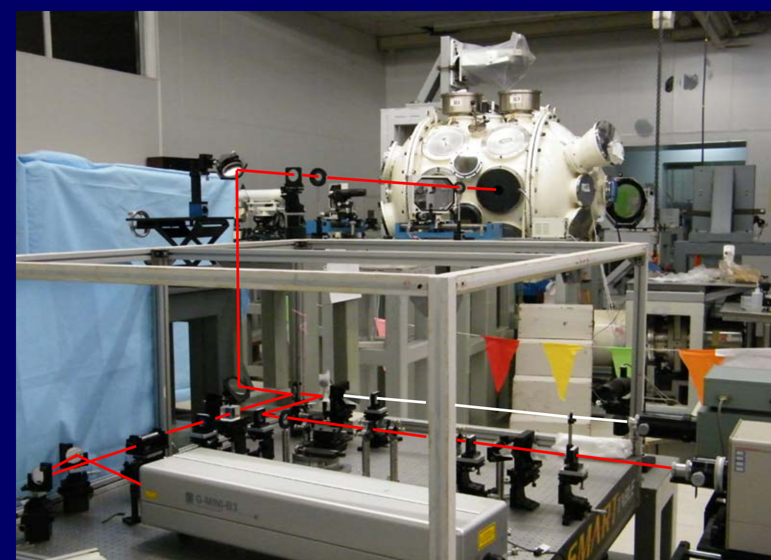
Material

Ablating Pressure

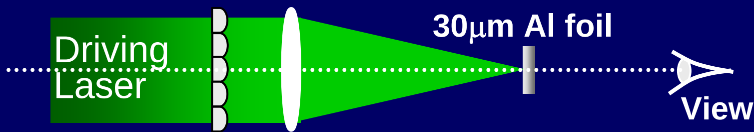
Set up Of Shock Wave Experiment On Shenguang-II

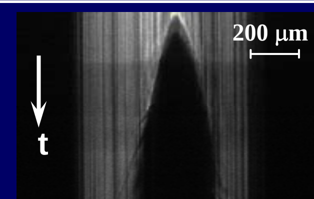
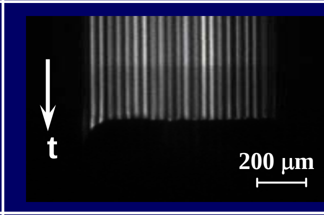
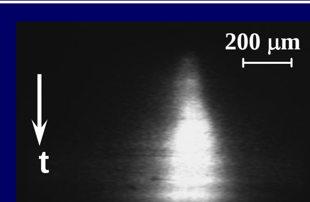
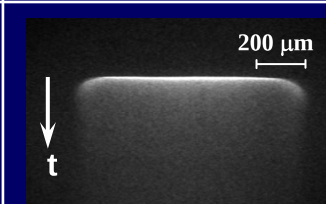


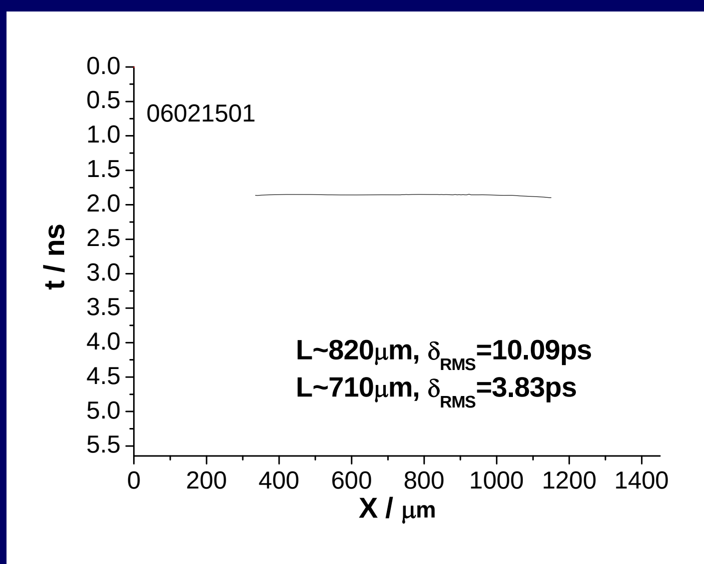




Shock Planarity With Spatial Beam Smooth Of Lens-Array

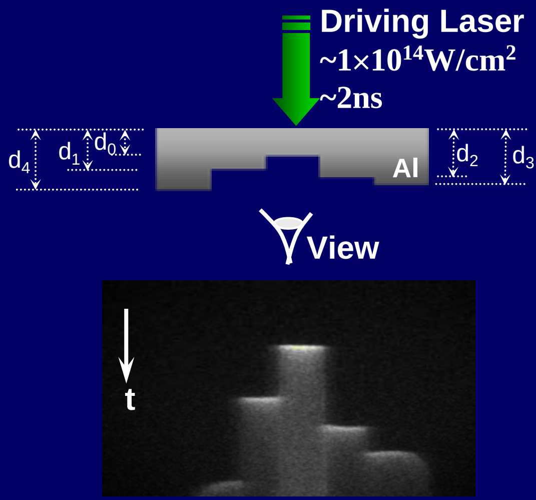


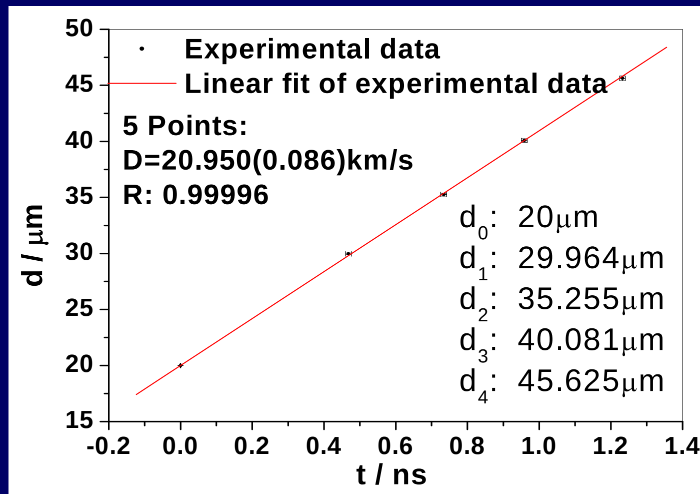
	Without lens-array	With lens-array
Active diagnosis: Probing beam reflected from back-surface of target		
Passive diagnosis: Shock luminescence from back-surface of target		

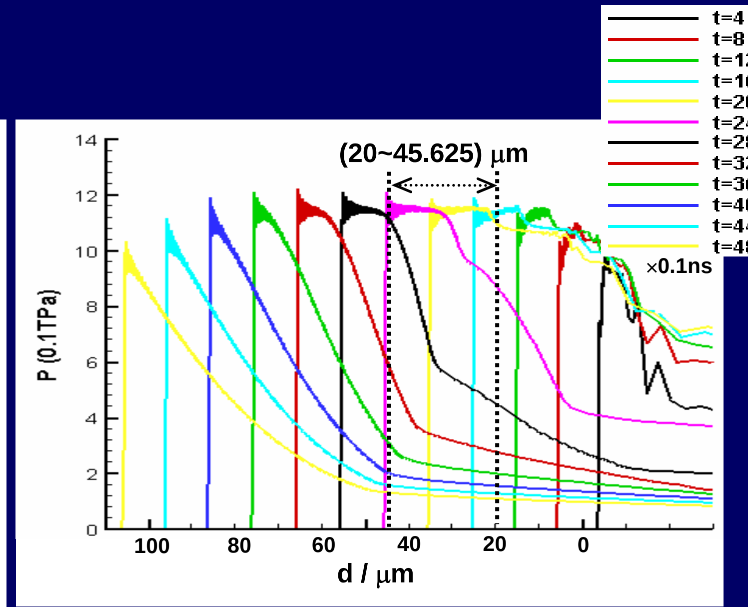


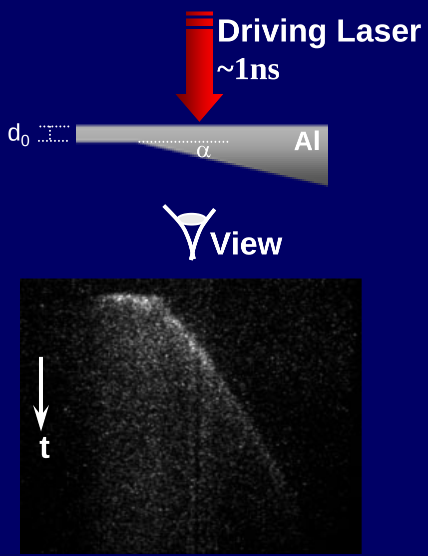
One kind of sources induced measuring error of EOS data

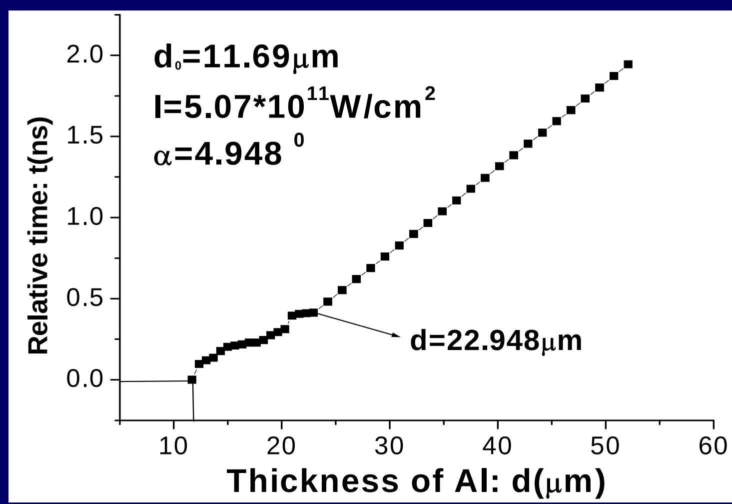
Shock Stability In Al

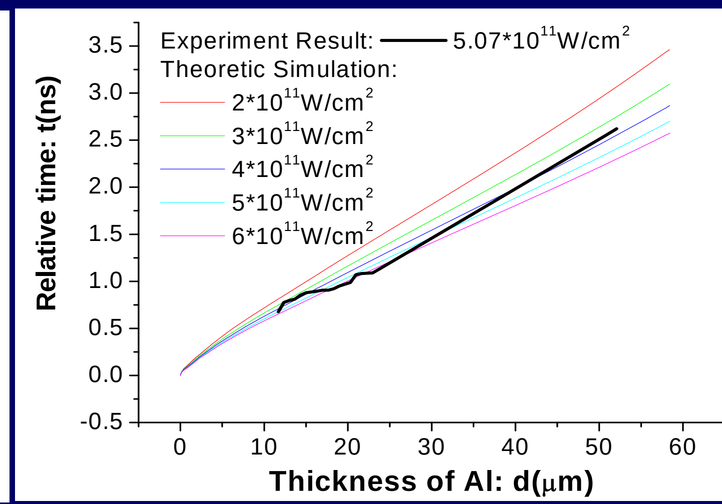




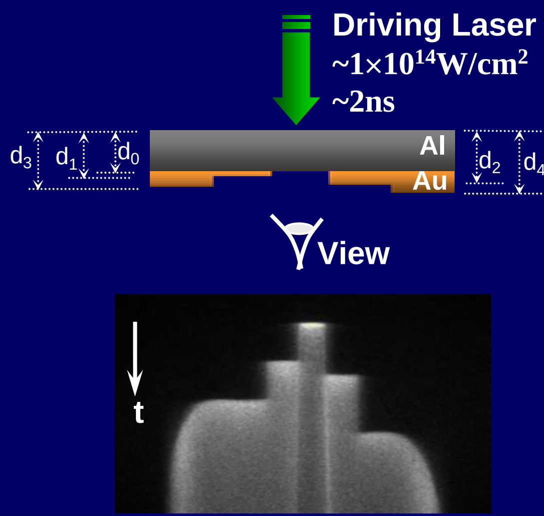


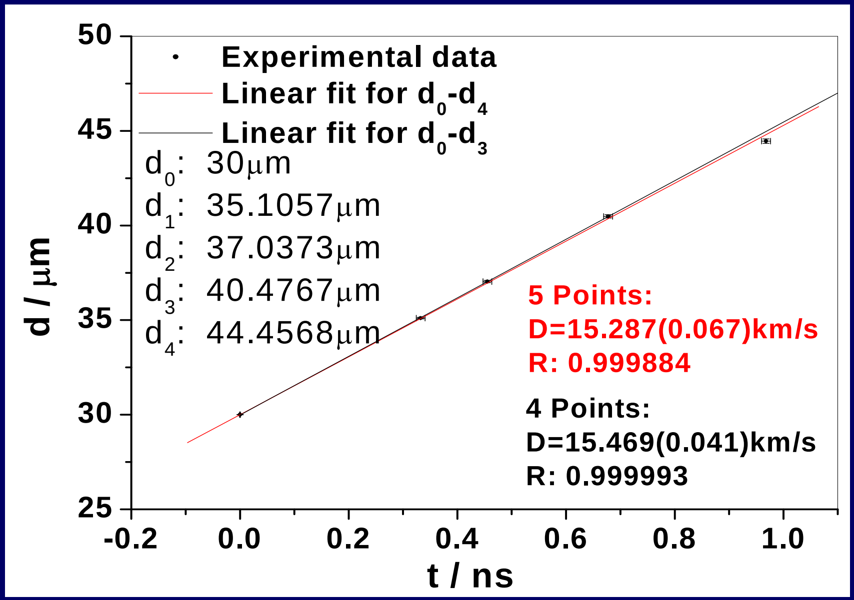


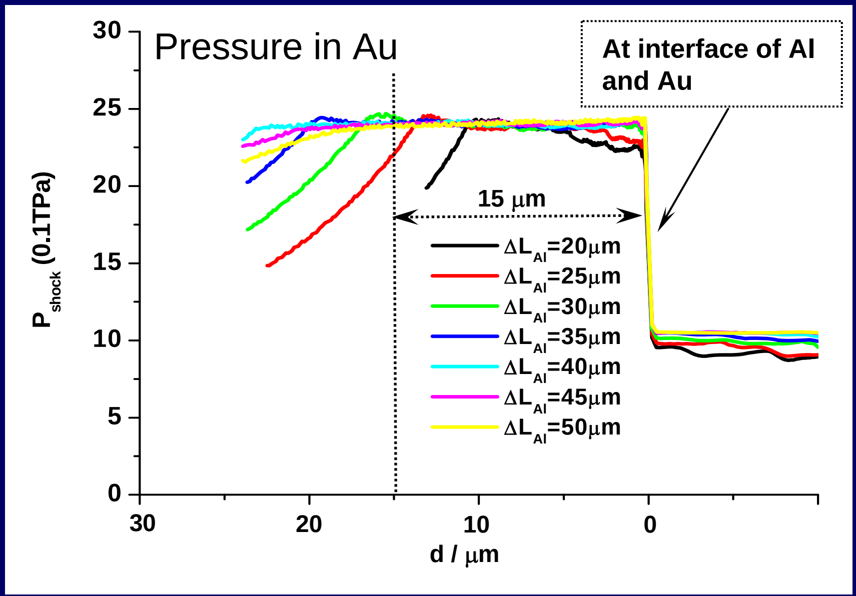




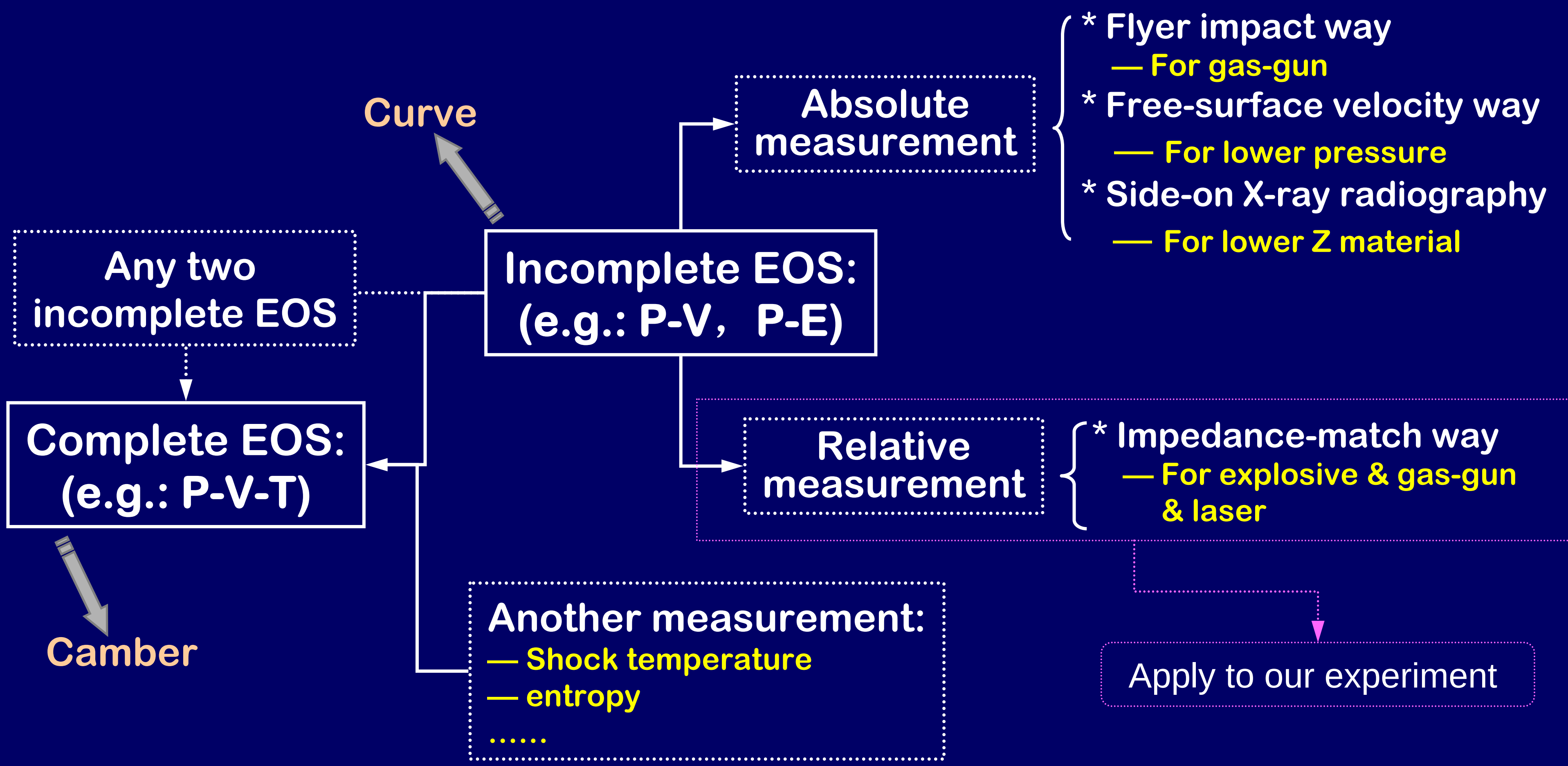
Shock Stability In Al-Au



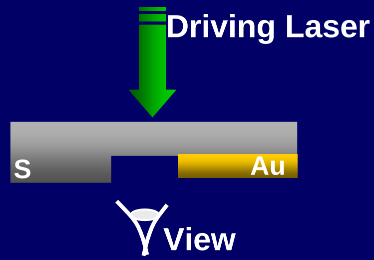


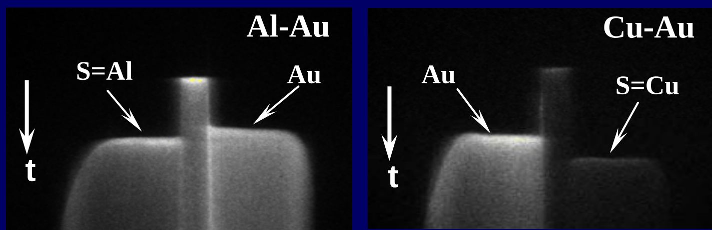


Brief About The Method Of EOS Measurement On Experiment



Shock Adiabat (Hugoniot Data) Of Au



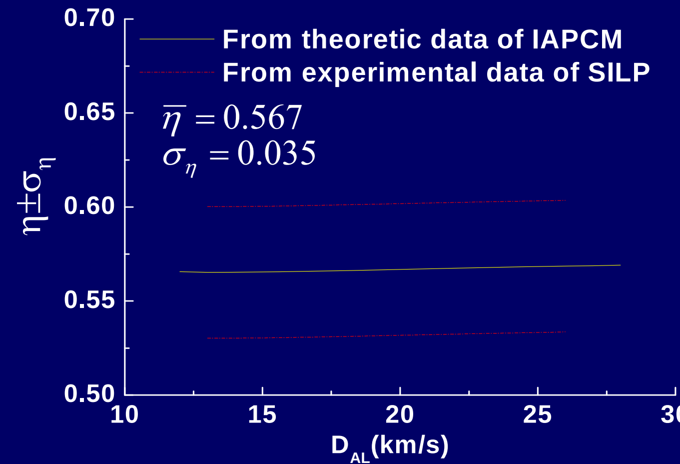


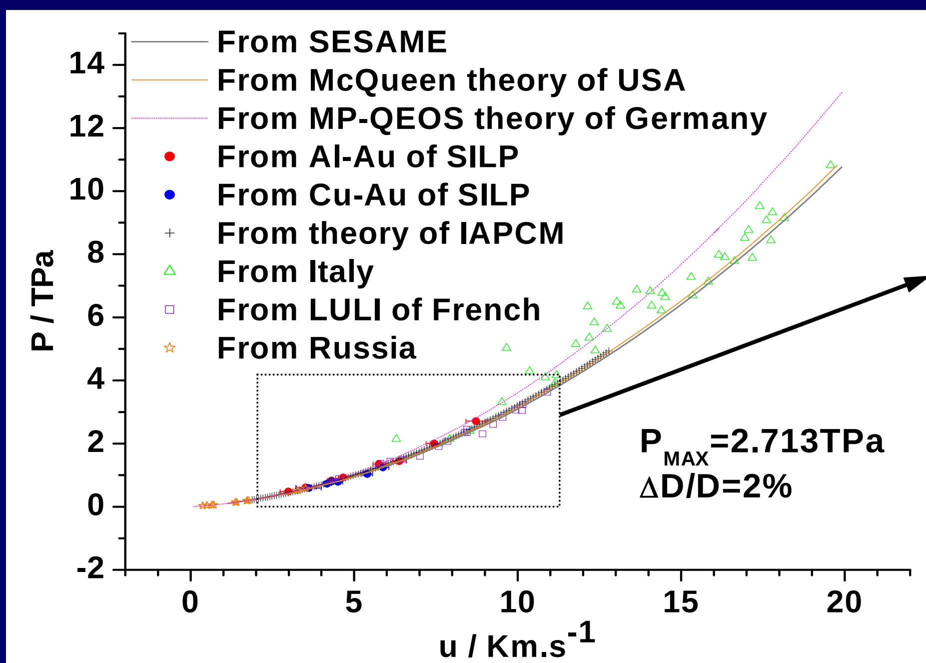
** Data dispersion

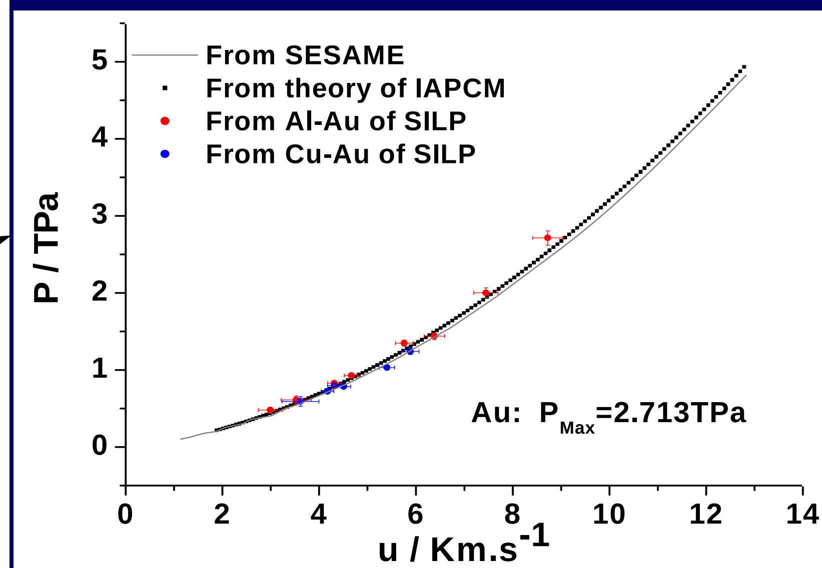
$$\eta_i = \left(\frac{D_T}{D_{Al}}\right)_i$$

$$\eta_i^S = \left(\frac{D_T}{D_{Al}}\right)_i^S = f(D_{Al})$$

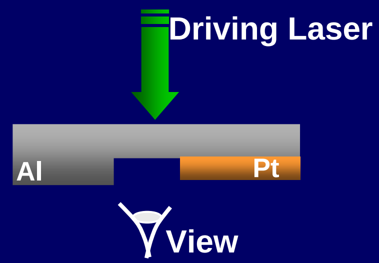
$$\sigma_\eta = \sqrt{\frac{\sum_{i=1}^{n}(\eta_i - \eta_i^S)^2}{(n-1)}}$$



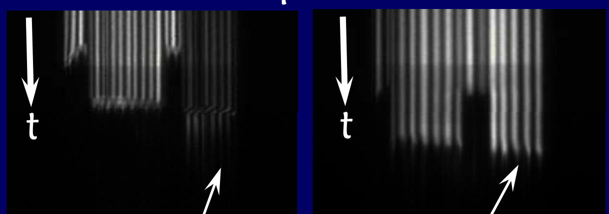




Shock Adiabat (Hugoniot Data) Of Pt

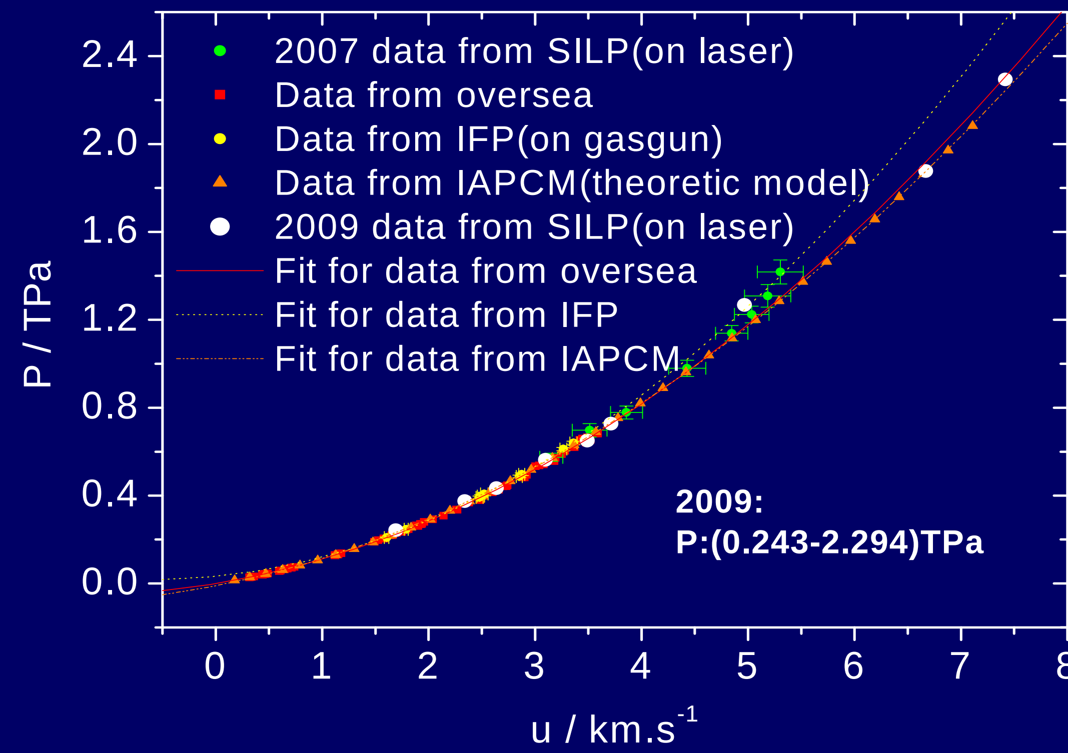


Low pressure



Shock breaks out of Pt step (empennage)

Shock breaks out of Pt step coating 0.2μm Al

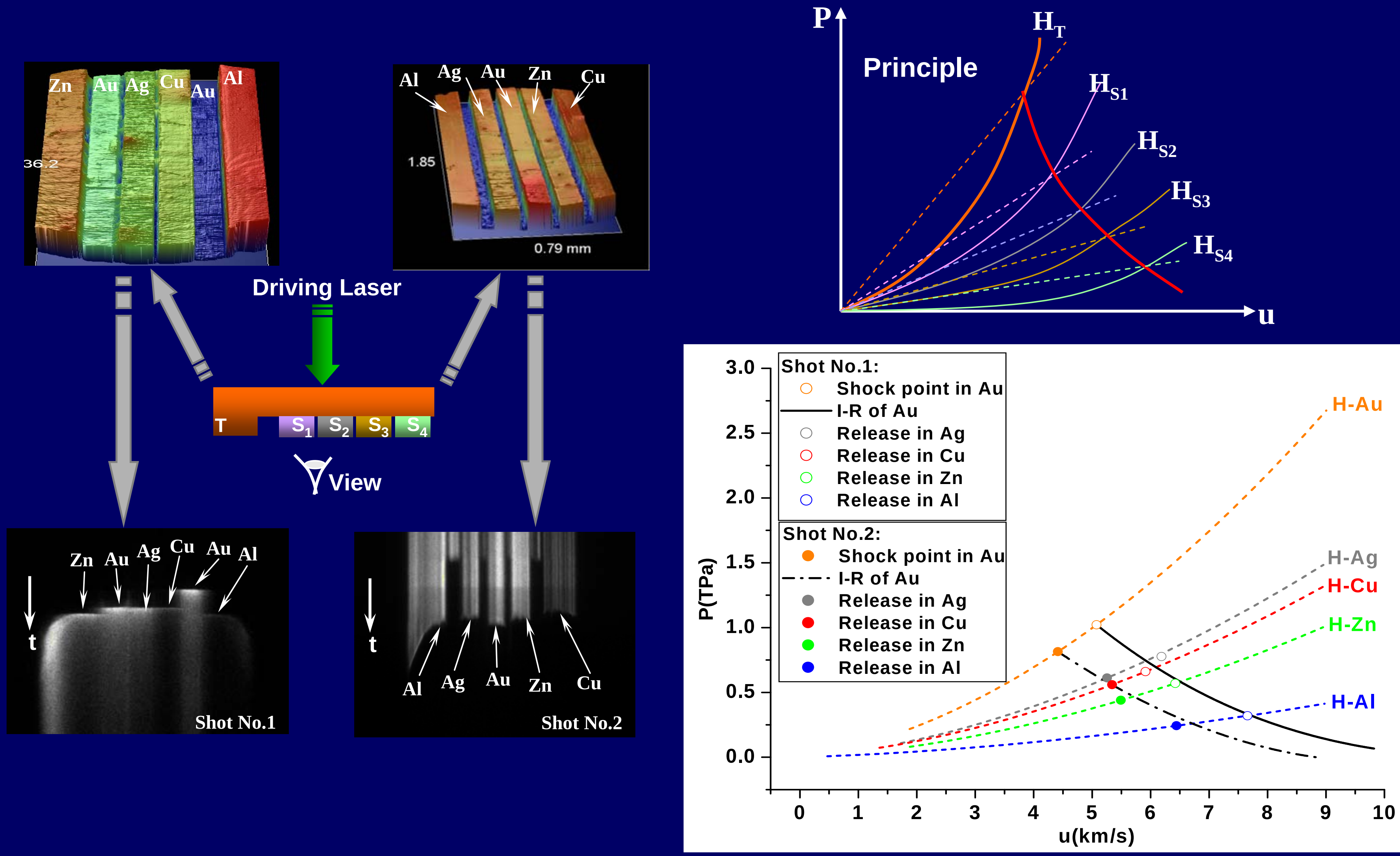


High pressure

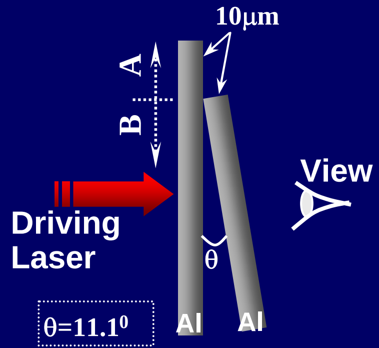
	Al	Pt
Melting T(^{0}C)	658	1769

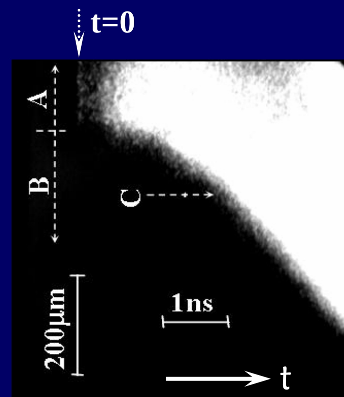
With active diagnosis of VISAR, measured pressure can be extended to lower regions, and compared to those from another loading facility (e.g. gasgun)

Isentropic Release Of Au After Intense Shock

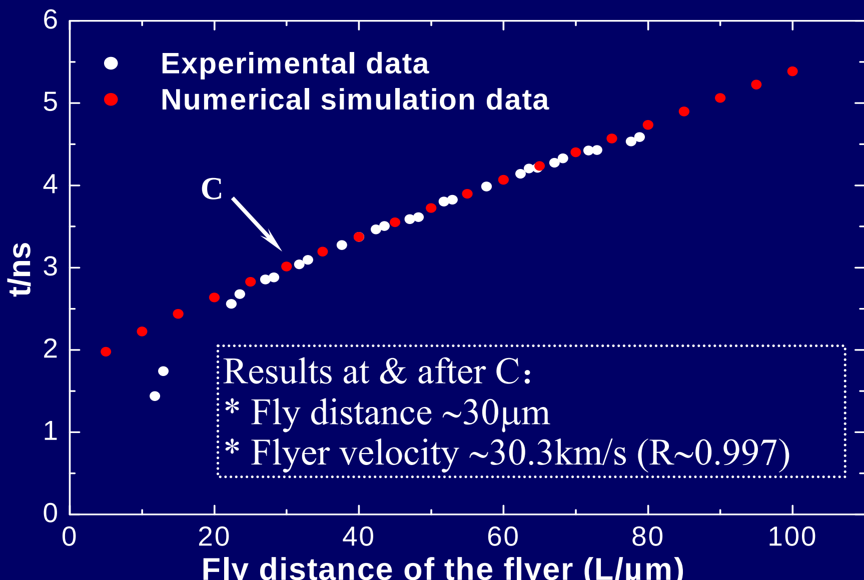


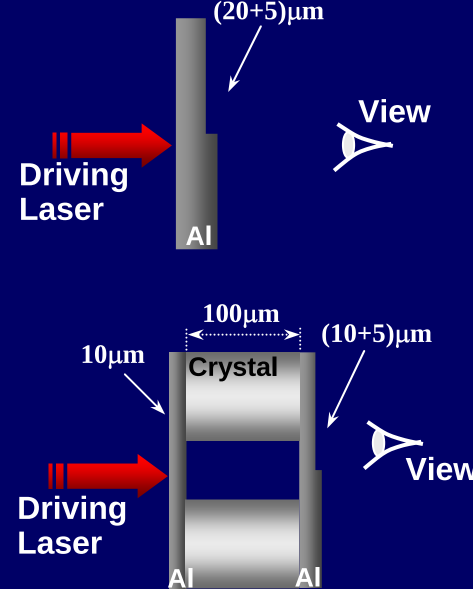
Flyer's Character And Its Application For Pressure Increase

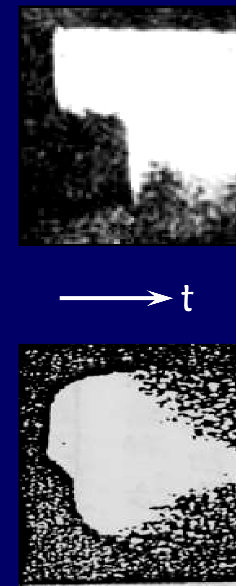


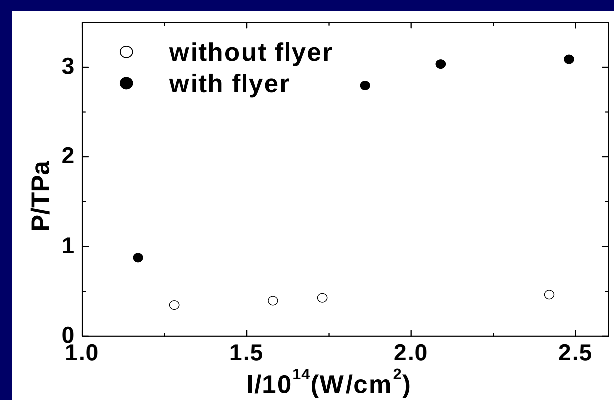


$t = t_1(\sim ns) + t_2(\sim 100ps)$



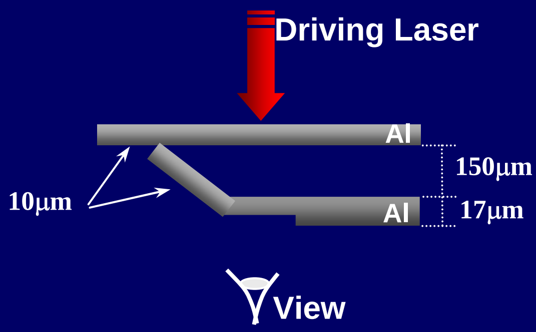




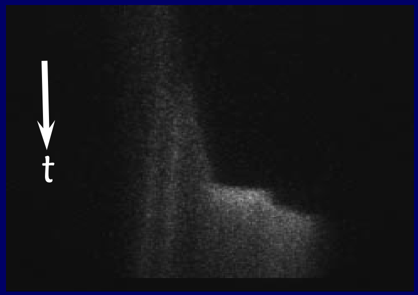


	$P = \alpha I^{\beta}$	
	α	β
Without flyer	0.34	0.45
With flyer	0.79	1.80

Exploring For Absolute Measurement With Flyer Impact



Flyer velocity D_F	~30km/s
Skock velocity D_S	~18km/s
Calculated particle velocity u from D_S	~10km/s
??: D_F=2u	

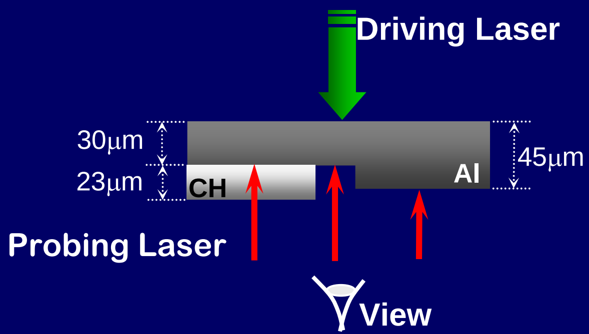


** In laser driving condition, The symmetrical impact is more difficult

** The impact is close to ablative style, not rigid press style

** A special designed flyer impact can be used to realize a ramp compression (Shocked flyer is as a plasma energy reserve with density distribution)

Preheating Ahead Shock Wave In Lower Z Material

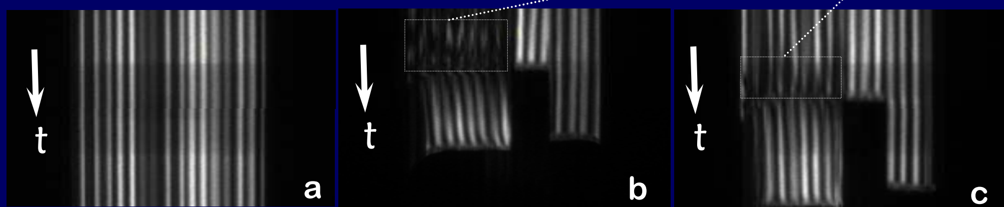


Disturbed stripes:

*** Reflected on interface between Al & CH**

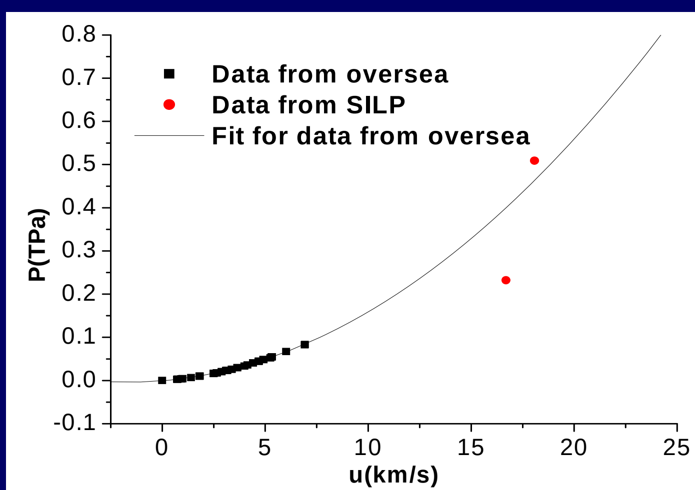
*** Ahead shock wave arriving at the interface**

*** Caused by preheated CH**



Static state E=1546(J) E=722(J)

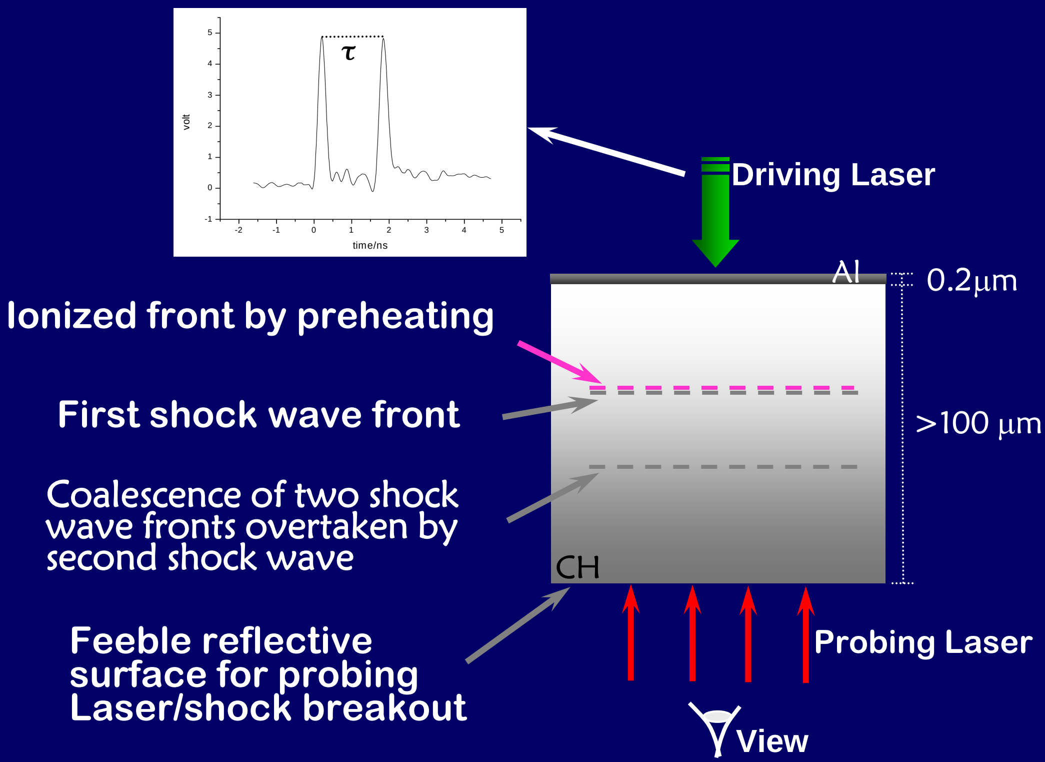
?: Al substrate had already been preheated before CH step was preheated



	Al	CH	Au	Pt
Melting T(^{0}C)	658	240	1063	1769

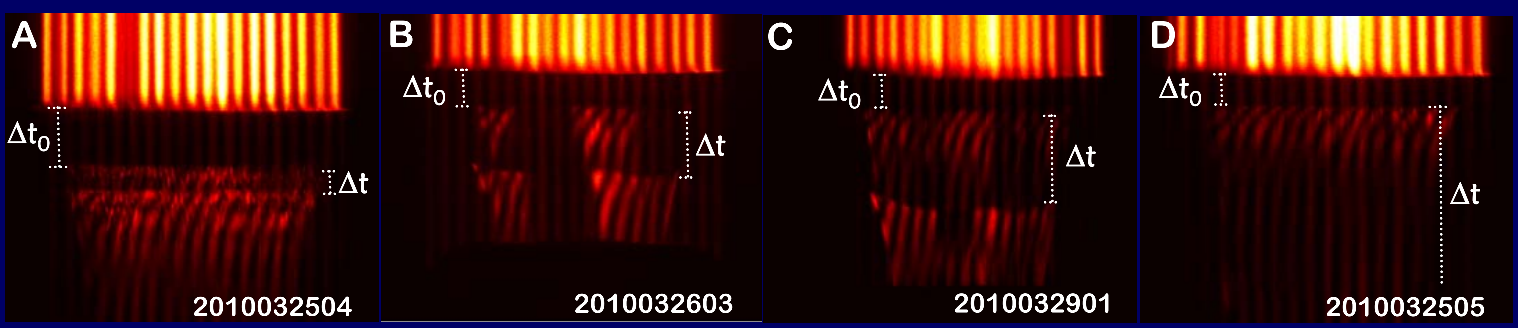
**** Preheating effects are very different in different materials!**

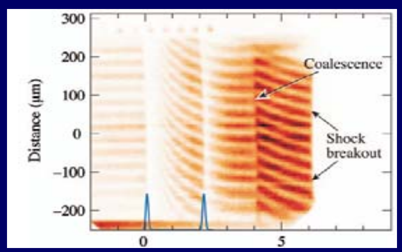
Exploring Of Shock-Timing In Double Shocked CH



* Blind reflective region, shocks velocity and overtaking time are more sensitive with driving lasers' energy and duration

	E(J)	τ(ns)	Δt_0(ns)	Δt(ns)
A	165.07	1.15	4.2	1.6
B	255.6	1.64	2.5	4.29
C	299.98	2.03	2.3	6.24
D	189.93	2.34	2	—





Result from Ω experiment

The End

Appendix

About the theoretical simulation code of JB-2

- The JB-2 is a one-dimensional and three-temperature hydrodynamic code coupling with superthermal electron transportation and a self-consistent electric field.
- The main physical processes in the JB-2 code include:
  * Inverse bremsstrahlung and anomalous laser absorption
  * Coulomb interaction of electron–ion
  * Free–free and free–bond processes of electron photon,
  * Average atomic model and local thermodynamic equilibrium in the ionization process
  * Free–free, free–bond, and bond–bond processes for photon’s opacity
  * Coulomb collisions between superthermal electrons and thermal ions for the scattering mean-free-path
- Theoretic equation of state given by the Thomas–Fermi model and experimental data from the high explosive loading facility in the respective ranges of ultrahigh and low pressure, etc.

Al Step as an example				5ns	2ns
d	Measured	$d_S = \left| \overline{h_S} - \overline{h_0} \right|$		11.7580	14.5668
	Type A	$\Delta d_S^A = \sqrt{(\Delta h_0^A)^2 + (\Delta h_S^A)^2}$		0.06823	0.01194
	Type B	$\Delta d_S^B = \gamma d_S$		0.04769	0.05908
	Combined	$\delta d_S = \sqrt{(\Delta d_S^A)^2 + (\Delta d_S^B)^2}$		0.08324	0.06028
	Relative	$\delta d_S / d_S$		0.708 %	0.414%
t	Measured	$t_S = \Delta Ch_S \times t_c$		0.5271	0.55309
	Type A	$\Delta t_S^A = \sqrt{(\Delta Ch_0^A)^2 + (\Delta Ch_S^A)^2} \times t_c$		0.00172 (0.326 %)	0.00246(0.445%)
	Type B	$\Delta t_S^B = \sqrt{(\Delta Ch_S \times \Delta t_c)^2 + (\Delta t_q)^2}$		0.0117(2.22 %) (2.16 %)	0.00441(0.797%) (0.723 %)
	Combined	$\delta t_S = \sqrt{(\Delta t_S^A)^2 + (\Delta t_S^B)^2}$		0.0118	0.00505
	Relative	$\delta t_S / t_S$		2.24 %	0.913%
D	Measured	$D_S = \frac{d_S}{t_S}$		22.308	26.337
	Relative	$\frac{\delta D_S}{D_S} = \sqrt{\left(\frac{\delta d_S}{d_S}\right)^2 + \left(\frac{\delta t_S}{t_S}\right)^2}$	K=1	2.35 %	1.0025 %
			K=2	4.70 %	2.005 %