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Joint Institute for High Temperatures
Russian Academy of Sciences, Moscow

Investigation of the dynamics of rear side spallation in metallic films by PHELIX ultra short laser pulses

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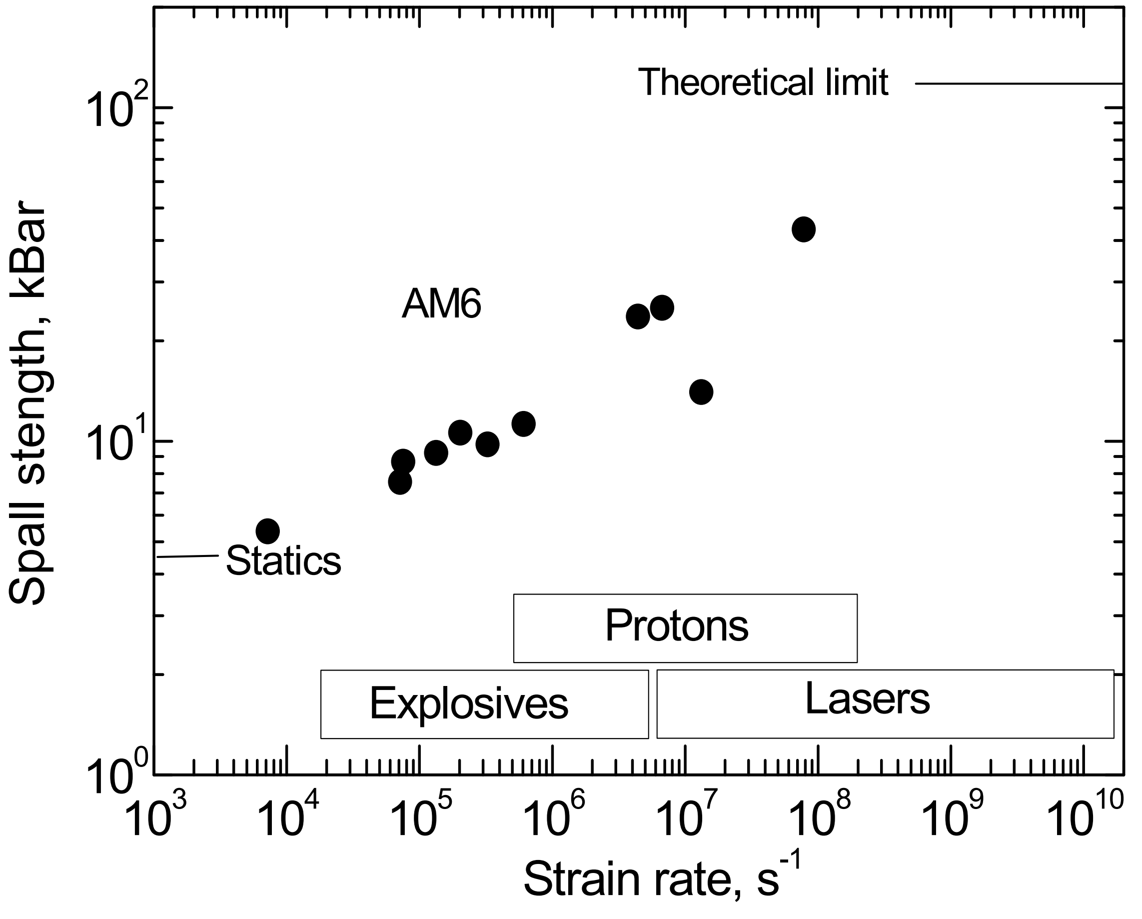
Petawatt High-Energy Laser for Heavy Ion Experiments

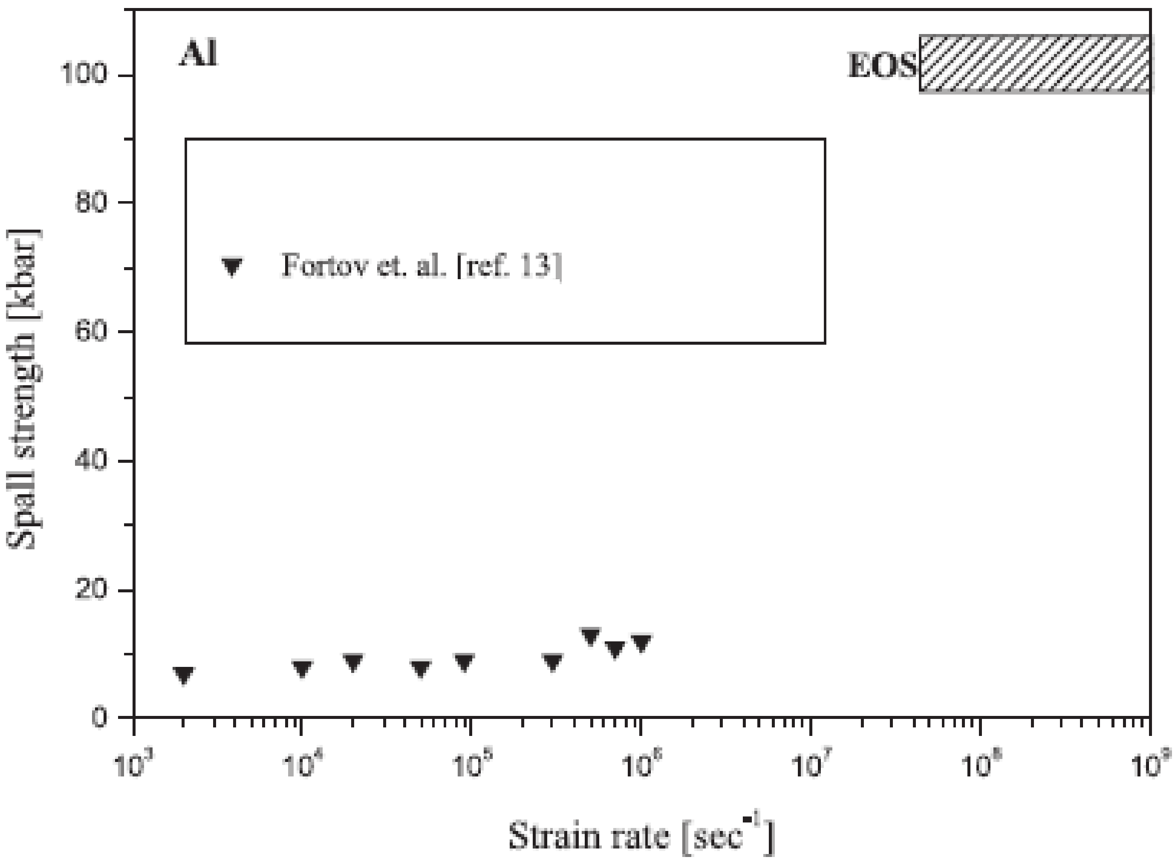
Outline

1. **Lasers in spall strength measurements**
2. **Modern state of problem**
3. **Ultrafast processes in metals induced by femtosecond laser pulses and laser shockwave excitation: theory**
4. **Experimental setup: Femtosecond shock waves laser excitation**
5. **Proposal: Experiments at PHELIX**
6. **Experimental setup**
7. **Requirements on the PHELIX-laser beam**

1. Lasers in spall strength measurements



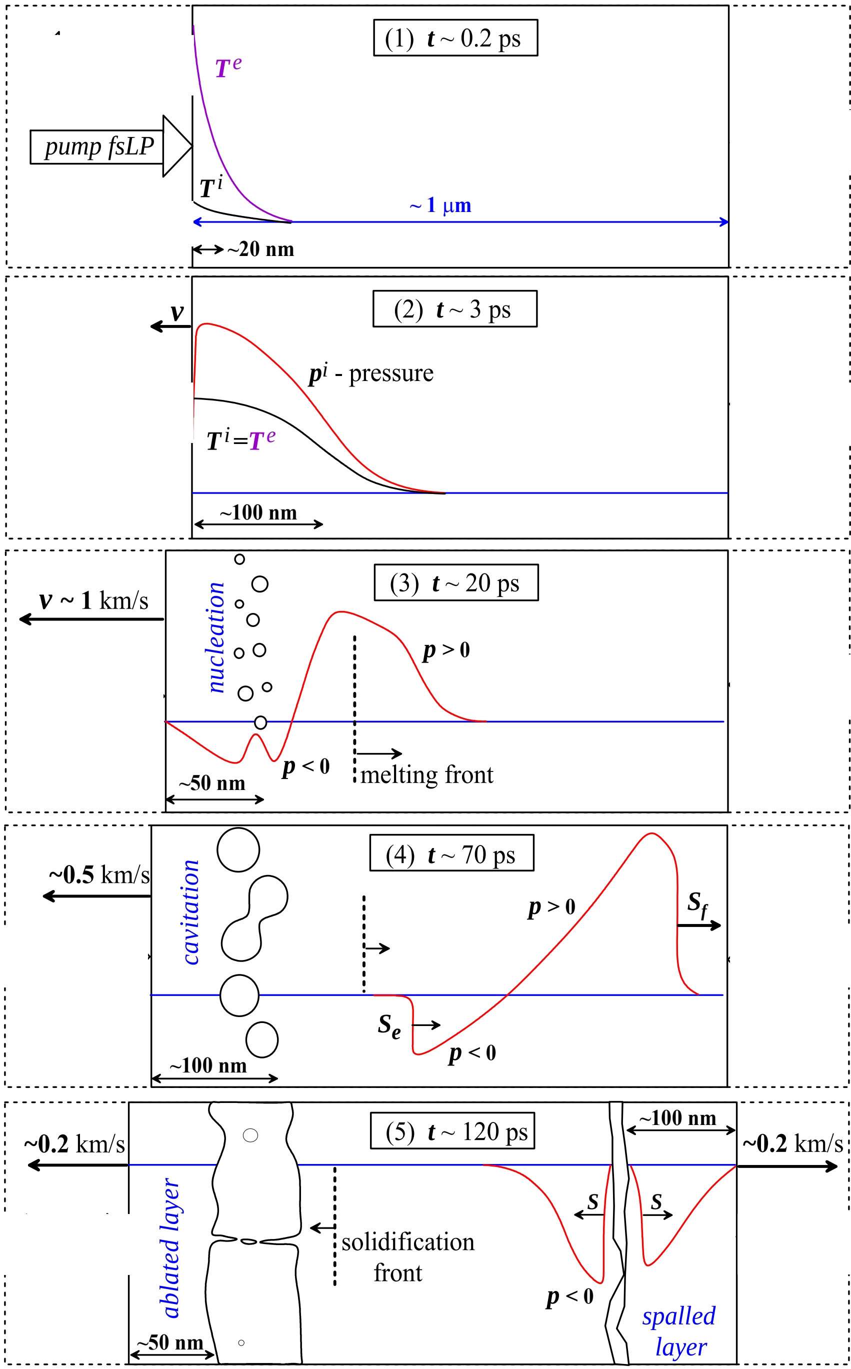
2. Modern state of problem



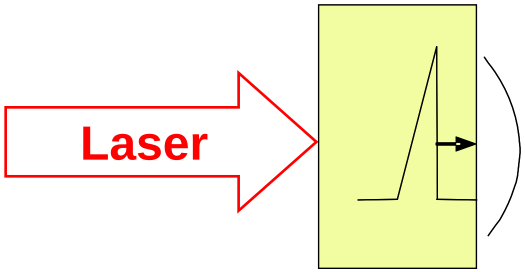
- Fortov V.E., Kostin V.V. & Eliezer S. (1991). Spallation of metals under laser irradiation. *J. Appl. Phys*. **70**, 4524– 4531.
- Moshe E., Eliezer S., Dekel E., Ludmirsky A., Henis Z., Werdiger M., Goldberg I.B., Eliaz N. & Eliezer D. (1998). An increase of the spall strength in aluminum, copper and Metglas at strain rates larger than 10^7 s^{-1}. *J. Appl. Phys*. **83**, 4004–4011
- Eliezer S., Moshe E. & Eliezer S. (2002), Laser-induced tension to measure the ultimate strength of metals related to the equation of state. *Laser & Particle Beams*, **20**, 87-92

3. Ultrafast processes in metals induced by femtosecond laser pulses of moderate intensities I<10^{14}W/cm^2

- Laser energy absorption, non-equilibrium electron and lattice heating
- Electron-phonon relaxation, warmed up layer and pressure profile formation.
- Pressure profile acoustic decay – pressure and rarefaction wave formation, cavitation in a stretched melt and beginning of a shock wave formation.
- Cavitation bubbles growth. Shock wave movement toward rear side of target.
- Ablation at a heated surface. Rear side spallation



3. Laser excitation of shock waves in Al

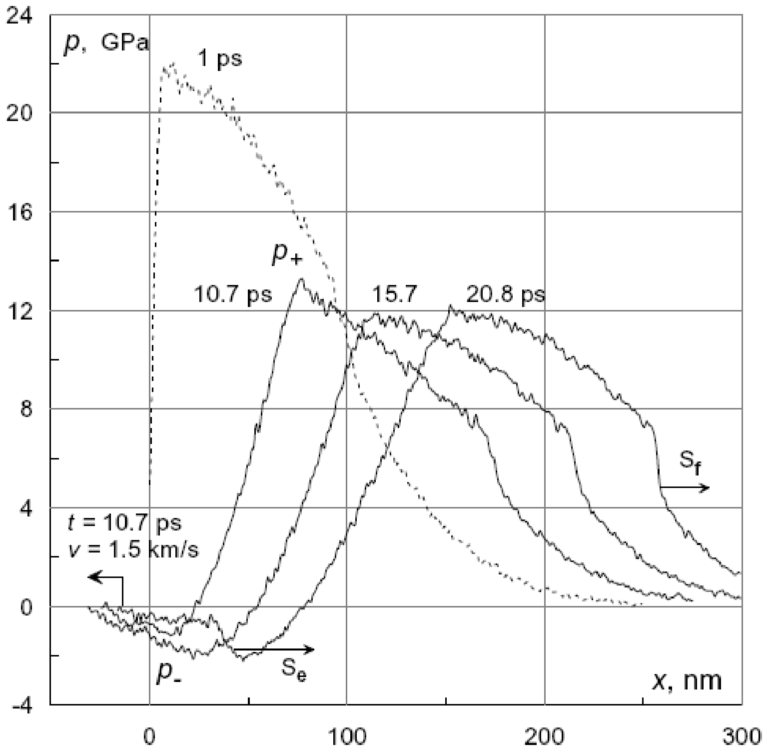


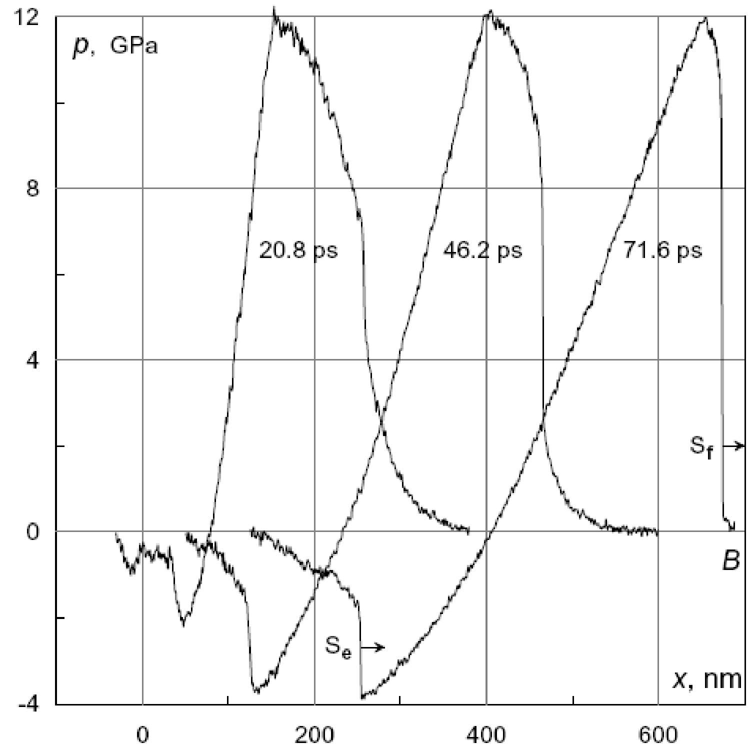
Target

Laser driven shock wave profile:

2T-hydrodynamical model +MD simulations

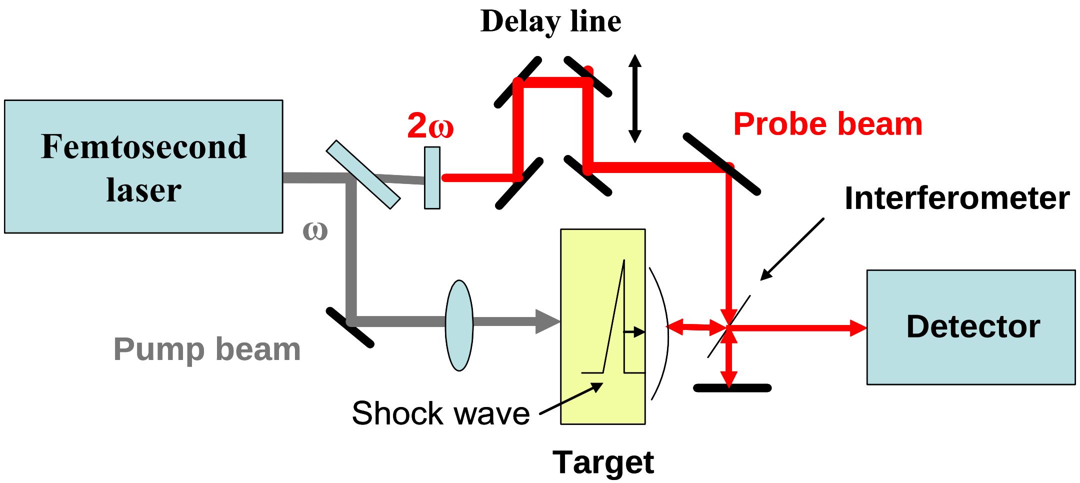
Al target; τ_L=100fs; I= $2\cdot10^{13}$ W/cm^2



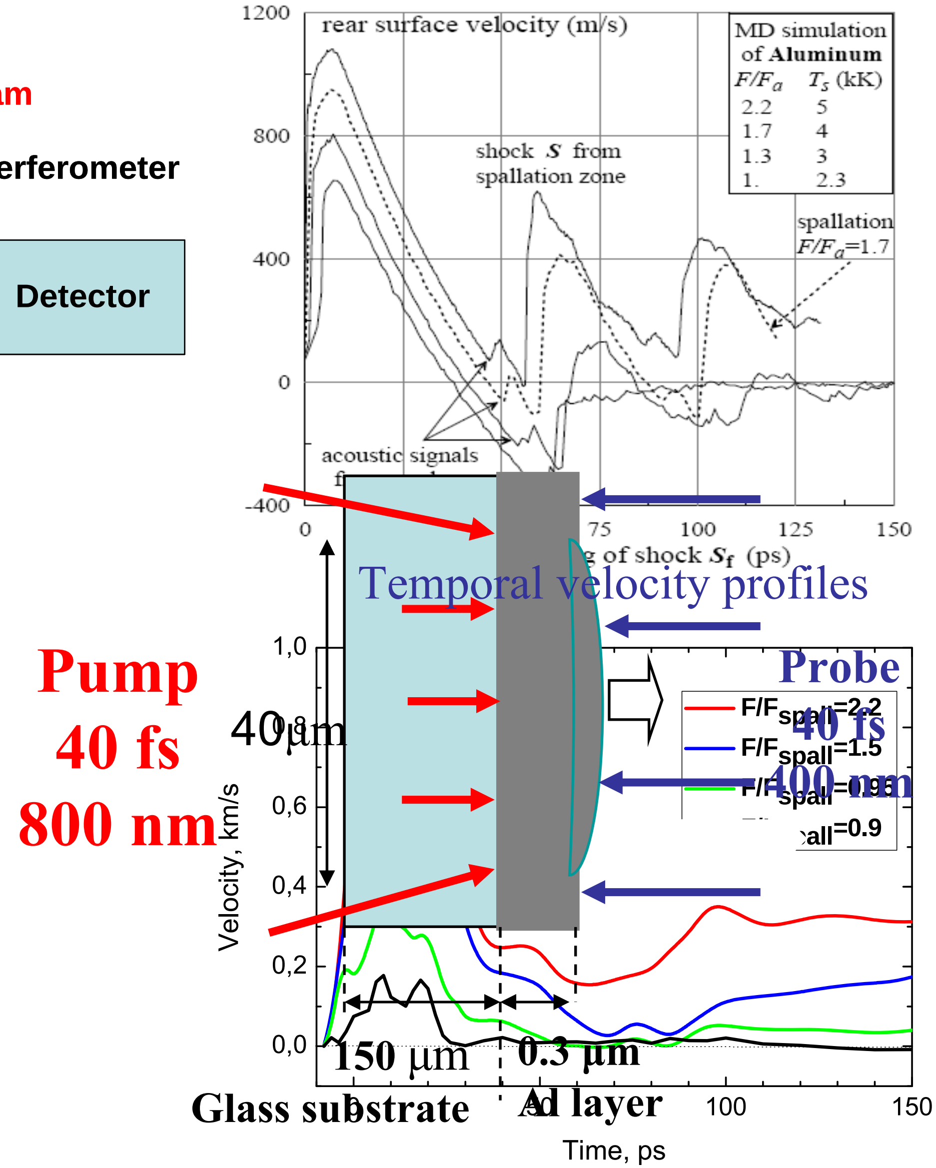


S.Anisimov, N.Inogamov et al, Appl.Ph.A 2008

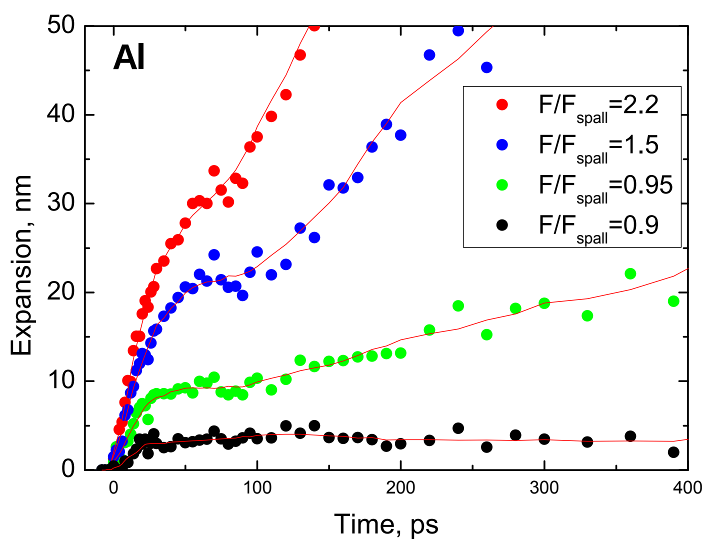
4. Experimental diagnostic of shock waves formed by femtosecond laser pulses



MD-simulations



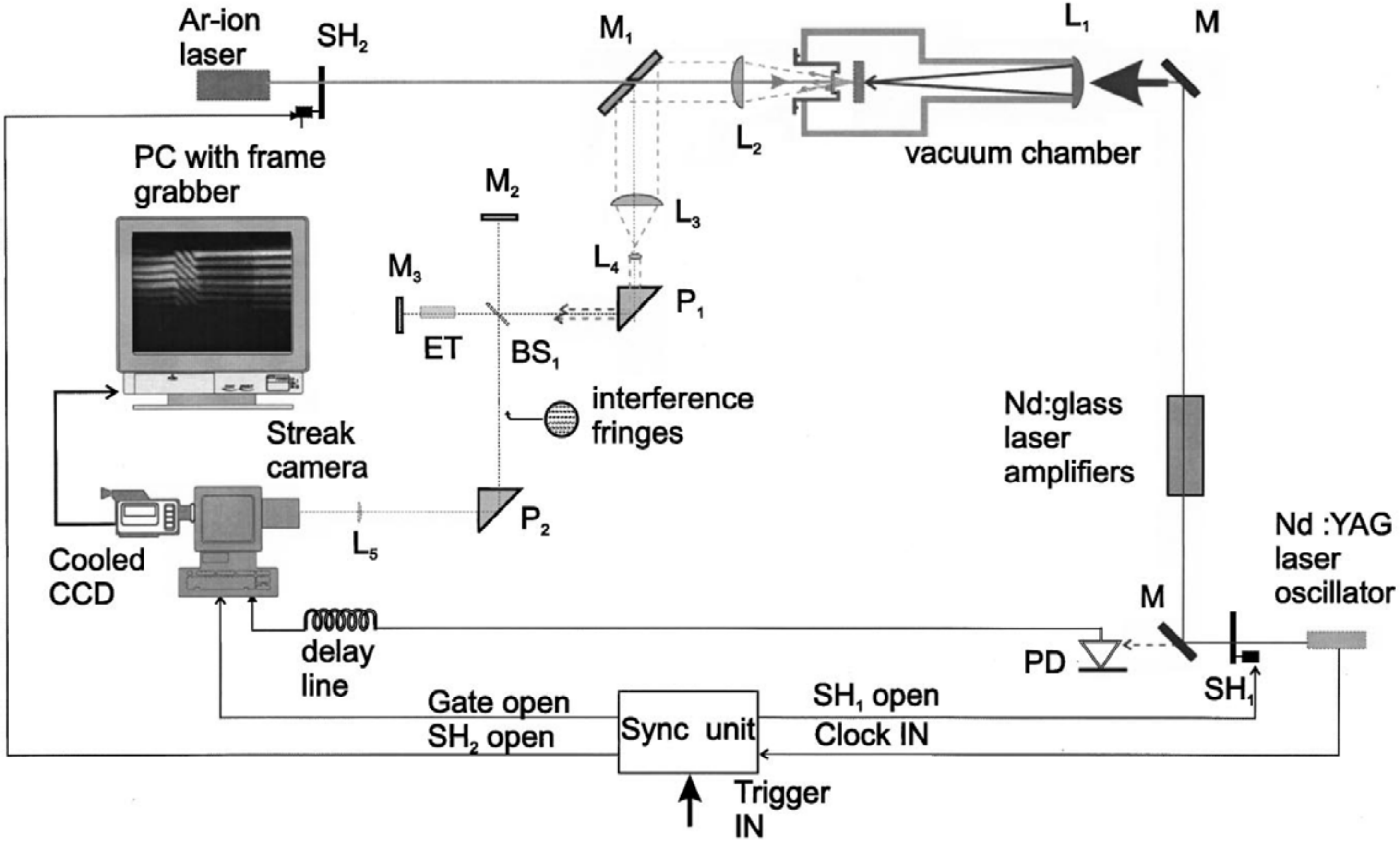
Temporal displacement profiles



5. Proposal: experiments at PHELIX

- **Goal: study of mechanical behavior of materials under ultrafast-rate loading conditions and measurements of the dynamic spall strength in thin metallic films using subpicosecond laser pulses**
- **Technique: interferometric single shot pump-probe technique**
- **Measurements: The strength of the materials and the strain rate may be determined from the free surface velocity time history, measured by optically recording velocity interferometer system (ORVIS)**

6. Experimental setup



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Moshe E., Eliezer S., Dekel E., Ludmirsky A., Henis Z., Werdiger M., Goldberg I.B., Eliaz N. & Eliezer D. An increase of the spall strength in aluminum, copper and Metglas at strain rates larger than 10^7 s^{-1}// *J. Appl. Phys*. **83**, 4004–4011 (1998)

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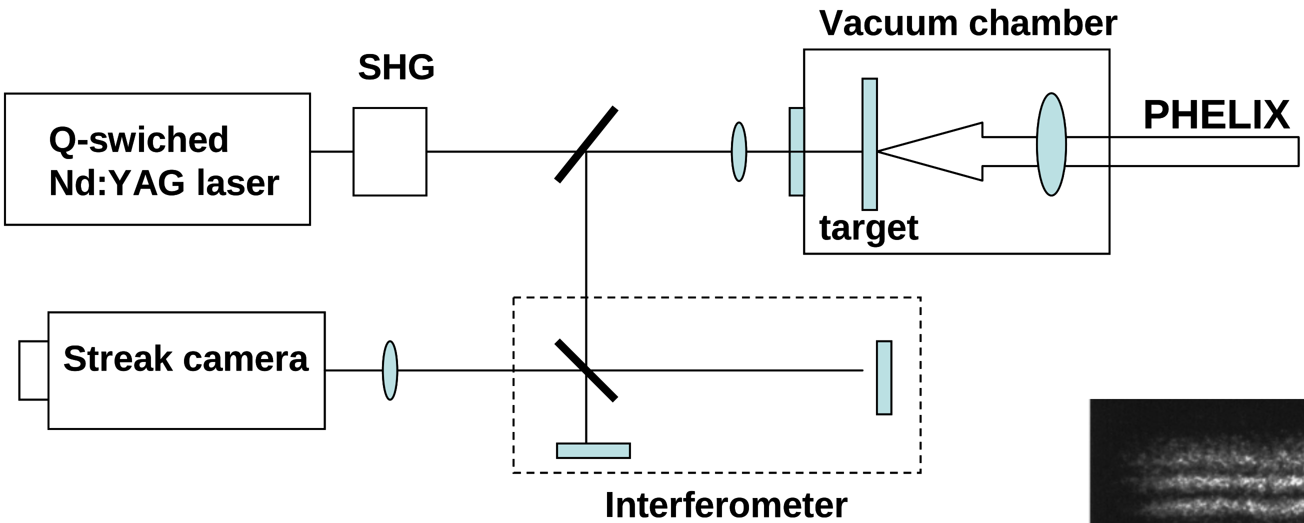

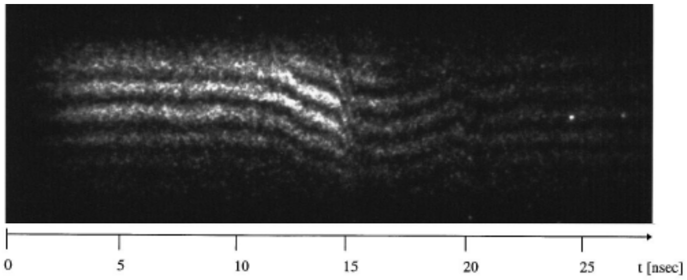

1. Q-switched Nd:YAG laser with SHG module (10 ns, 532 nm, 10^6 W)
2. Michelson interferometer (ORVIS)
3. Streak camera (temporal resolution - ≤5 ps; sweep range – 0.25; 0.5; 1 ns)

7. Requirements on the PHELIX-laser beam

- Energy ~ 0.1 - 1 J
- Focal spot size at the target: 100 - 1000 μm
- Laser pulse duration – less 1 ps
- Laser contrast ~ 10^{-6}
- PHELIX laser intensity should be higher than 10^{13} W/cm^2

Thank you for attention